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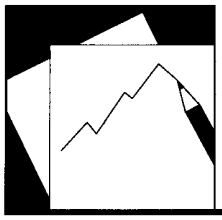

# IMF Working Paper

# Next Generation System-Wide Liquidity Stress Testing

*Christian Schmieder, Heiko Hesse, Benjamin Neudorfer, Claus Puhr, Stefan W. Schmitz*

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# Next Generation System-Wide Liquidity Stress Testing[1]

Prepared by Christian Schmieder, Heiko Hesse, Benjamin Neudorfer, Claus Puhr, and Stefan W. Schmitz

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## Abstract



A framework to run system-wide, balance sheet data-based liquidity stress tests is presented. The liquidity framework includes three elements: (a) a module to simulate the impact of bank run scenarios; (b) a module to assess risks arising from maturity transformation and rollover risks, implemented either in a simplified manner or as a fully-fledged cash flow-based approach; and (c) a framework to link liquidity and solvency risks. The framework also allows the simulation of how banks cope with upcoming regulatory changes (Basel III), and accommodates differences in data availability. A case study shows the impact of a "Lehman" type event for stylized banks.

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Authors' E-Mail Addresses: cschmieder@imf.org, hhesse2@imf.org, benjamin.neudorfer@oenb.at, claus.puhr@oenb.at, stefan.schmitz@oenb.at

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## I. INTRODUCTION

Bank liquidity was traditionally viewed as of equal importance to their solvency. Liquidity risks are inherent in maturity transformation, i.e., the usual long-term maturity profile of banks' assets and short-term maturities of liabilities.[2] Banks have commonly relied on retail deposits, and, to some degree, long-term wholesale funding as supposedly stable sources of funding. Yet, attention to liquidity risk diminished in recent decades, was symbolized by the absence of consideration of liquidity risk in the 1988 Basel I framework (Goodhart, 2008).

The global financial crisis has clearly shown that neglecting liquidity risk comes at a substantial price. Over the last decade, large banks d became increasingly reliant on short-term wholesale funding (especially in interbanking markets) to finance their rapid asset growth. At the same time, funding from non-deposit sources (such as commercial paper placed with money market mutual funds) soared. With the unfolding of the global financial crisis, when uncertainties about the solvency of certain banks emerged, various types of wholesale funding market segments froze, resulting in funding or liquidity challenges for many banks.[3] In the light of this experience, there is now a widespread consensus that banks' extensive reliance on deep and broad unsecured money markets pre-crisis is to be avoided (and in current market conditions there is no appetite for that anyway). Creating substantial liquidity buffers across the board is the explicit aim of a number of regulatory responses to the crisis, such as the CEBS Guidelines on liquidity buffers (CEBS 2009b) as well as the forthcoming Basel III liquidity standards, the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR).

The liquidity stress testing framework presented herein was developed in the context of recent Financial Sector Assessment Programs (FSAPs)[4] and IMF technical assistance especially in Eastern Europe, extending the seminal work of Čihák (2007), and drawing upon work at the Austrian National Bank (OeNB). While developing the framework, five key facts were accounted for: (i) the availability of data varies widely; (ii) liquidity risk has several dimensions and assessing banks' resilience vis-à-vis funding risks requires multi-dimensional analysis; (iii) designing and calibrating scenarios is more challenging than for solvency risks, mainly as liquidity crises are relatively rare and originate from different sources; (iv) there is a close link between solvency and liquidity risks; and (v) while the paper and tool present some economic benchmark scenarios, but these scenarios and economic and behavioral assumptions used for the tests should depend on bank- and country-specific circumstances, and current circumstances (i.e., the level of stress), among others. More generally speaking, the presented liquidity stress testing framework herein does not substitute for sound economics in designing the tests.

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[2] Appendix II provides an overview of the typical distribution of banks' assets and liabilities.

[3] See Appendix I for the evolution of liquidity evaporation during the crisis.

[4] Examples include Chile, Germany, India, Turkey and the UK.

The answer to these multiple dimensions is a framework that is an Excel-based, easy-to-use balance sheet type liquidity stress testing tool that allows running bottom-up tests for hundreds of banks: First, the tool can be used to run some basic tests in circumstances where data is very limited to broad asset and liability items. Likewise, a cash flow based module allows running detailed liquidity analysis like those carried out by banks for the internal purposes but again can be adapted to a more limited data environment. Second, the framework includes three broad dimensions (based on four modules) that allow for complementary views on liquidity risks, including the link to solvency risks. Third, the paper provides benchmark scenarios based on historical evidence on the one hand and common scenarios used by FSAP missions on the other. Fourth, the framework allows assessing the link between liquidity and solvency, albeit additional effort is needed in this context, including work that captures dynamic aspects of this relationship and spillover effects such as dynamically examining the link from liquidity to solvency concerns.[5] As such, the framework is meant to provide users with the possibility to run a meaningful system-wide liquidity stress test within a relatively short period of time, but can also be used for monitoring purposes.

It is vital to bear in mind that the key benefit of system-wide stress tests is to benchmark banks against one another, i.e. to run peer comparisons and thereby assess their relative vulnerability to different shocks. Whether and how a shock materializes depends on the various factors, with behavioral aspects increasingly playing an essential role.[6] Hence, it is also acknowledged that regular liquidity stress testing is not a panacea for a qualitative judgment by policy-makers in order to complement findings even from well-designed liquidity stress tests.

While cash flow data reporting, for instance, will become mandatory in the European Capital Requirements Directive (CRD) IV regulation, it is (for now) still rarely available at regulatory/ supervisory institutions so we follow a two-pronged approach, distinguishing between implied cash flow tests and a "real" cash flow approach[7], thereby seeking to lift liquidity tests to a next generation level.[8]

The framework consists of three elements:

(i) Stress testing funding liquidity based on an *implied cash flow approach*, with two different components: (a) a tool to simulate bank-run type scenarios while accounting for fire sales of liquid assets and/ or central bank liquidity provision subject to eligible

[5] See IMF (2011) and Barnhill and Schumacher (forthcoming) in that context.

[6] In an environment of unstable short-term funding, the reaction of counterparties to anything from an actual liquidity squeeze to unjustified rumors can have a highly devastating impact.

[7] The idea is that supervisors and regulators can move towards cash flow approaches once data becomes available. Moreover, the input template could be used as a benchmark for the data collection exercise.

[8] While accommodating for such a flexible design it is up to the stress tester to understand the limitations of sacrificing granularity of data input and the impact on the quality of the results.

collateral and haircuts;[9] and (b) a liquidity gap analysis module that matches assets and liabilities for different maturity buckets under different stress assumptions, including rollover risk; the tool also allows for calculating (simplified)[10] Basel III liquidity ratios.

(ii) *Cash flow-based liquidity tests*—running this module ideally requires detailed data on contractual cash flows for different maturity buckets and behavioral data based on banks' financial/funding plans. If the latter are not available, the tool can be run on contractual cash-flows only and behavioral flows can be modeled based on the stress test assumptions. The calibrated scenarios then denote roll-over assumptions for contractual cash-outflows and cash-inflows. The former focus on funding risk and the latter take into account the banks' objective to maintain its franchise value even under stress.[11] In addition, market funding risk can be captured through haircuts. Accordingly, the module allows for an intuitive view of each banks' liquidity risk bearing capacity in the form of the cumulated counterbalancing capacity at the end of each maturity bucket. In addition to stress testing, the module is also meant to be used for liquidity monitoring purposes, for which behavioral cash-flows are particularly informative.

(iii) *Tests linking solvency and liquidity risk*—the tool allows linking liquidity and solvency risk from three complementary perspectives. The assumptions are crucial for these tests and require sound judgment by the stress tester. First, the module allows simulating the increase in funding costs from a change in solvency, indicated by a change in a bank's (implied) rating.[12] Second, the tool enables simulating the partial or full closure of funding markets (both long and short-term) depending on the level of capitalization with or without considering solvency stress. Third, it allows examining the potential impact of concentration in funding and a name crisis (e.g., from parent banks) on banks' liquidity positions**.**

The output of the tests provides failure and pass rates (in terms of the number of banks and total assets, respectively), and the estimated funding shortfalls for each bank as well as at the system level (or group of banks tested). For instance for the fully-fledged cash flow test, (cumulative) funding gaps and the corresponding (cumulative) counterbalancing capacity for each maturity bucket are provided after haircuts and roll over rates for each bank and the

[9] Market liquidity is thereby captured through haircuts.

[10] It is taken into account that full granularity needed to calculate the Basel III liquidity ratios is often not available.

[11] If behavioral cash-flows are available, the stress test assumptions can be applied to these. While behavioral cash-flows are more challenging to collect, they allow the stress tester to take into account individual bank strategies explicitly (e.g. regarding its future funding mix).

[12] If available, market implied ratings and liquidity measures (e.g. bid-ask spreads, trading volume in cash and repo markets) should be used. Alternatively, letter ratings can be used. Calibrating adequate models is a pre-condition to run such tests.

aggregate banking system. For the LCR and the NSFR the tests show which banks are likely to be below the regulatory threshold.

The paper is organized as follows: Section II first provides some generic considerations on concepts and methods to assess liquidity risks. Section III presents the newly developed methodological framework. Section IV is devoted to designing "extreme yet plausible" scenarios by focusing on run-off assumptions for different funding sources, issues pertaining to asset fire sales, collateral and haircuts, as well as on illustrating some benchmark scenarios. Section V presents an illustrative case study and section VI concludes.

## II. Review of General Concepts to Assess Liquidity Risks

### A. General Considerations and Motivation

Compared to solvency stress tests, particularly market risk, liquidity stress tests are less developed, for several reasons: (a) liquidity risk management appeared to be "*less of an issue*" until the current crisis, hence stress tests have a shorter development history making use of IT systems (which greatly facilitate this purpose); (b) liquidity crises are very *low frequency-high impact* events, which greatly reduces historical cases to calibrate models[13]; and (c) all liquidity crises are somehow different, at least if one seeks to analyze how triggers become manifest in a shortfall of liquidity, reducing the meaningfulness of "standard" stress assumptions.

What makes liquidity crisis highly challenging is that they usually occur very suddenly, spread by a mix of facts and rumors, giving banks very little time to react[14]. This warrants that liquidity buffers are based on highly conservative principles—an important consideration for the design of scenarios (section IV). A key principle by the U.S. authorities during the height of the financial crisis late 2008 was to ensure that ailing (investment) banks make it through a business week, in order to find a viable solution during the weekend. With the regulatory framework to be established by Basel III, the aim is to assure banks' resilience against a "significant stress scenario lasting 30 days" (BCBS 2010b), i.e., to survive a month of (medium to severe) stress.

[13] In some cases, central bank support via liquidity provisions has masked the extent of an explicit liquidity squeeze, with many banks hoarding liquidity and banks faced with funding liquidity challenges merely substituting their loss of market wholesale and/or retail funding with central bank funding.

[14] During a recent market turmoil, fuelled by rumors on potential risks, French banks lost about $60bn of funding in U.S. short-term markets, especially from U.S. money market mutual funds, within a few days—which is equal to one third of their U.S. Dollar liabilities and 6 percent of their foreign deposit liabilities, but "merely" 1.3 percent of their total deposit holdings (J.P. Morgan, Global Asset Allocation Report from 12 August 2011: "Flows & Liquidity: Fears about French banks overdone"). Overall, due to their strong liquidity position for now (i.e., solid liquidity buffers) banks managed to digest the withdrawal, but the example clearly shows how sensitive short-term wholesale funding markets can be.

Idiosyncratic liquidity crises can be triggered by various events, most notably solvency problems, but also political instability and fraud for example. Contagion can escalate idiosyncratic shocks into market-wide shocks, as seen during the recent crisis period.

Appendix II provides an overview of the evolution of liquidity conditions during the financial crisis, together with more information on liquidity risks and regulatory action during since the onset of the great recession.

In conceptual terms, the framework seeks to reflect the following, stylized nature of liquidity crisis, distinguishing between three stages:[15]

(i) *Stage 1*—Liquidity crises originate from a sudden dry-out of funding sources. Initially, the dry-out could be associated with higher costs (and thus lower income[16]). Unsecured wholesale funding is the most "vulnerable" (i.e., sensitive) to changes in the business climate and/or a name crisis, notably due to the fact that usually considerable funds are at stake, tenors are often short, and counterparties tend to be more sensitive to bank reputation and market rumors. In the first step, funding costs will rise (visible both in spreads and, for secured funding, collateral requirements).

(ii) *Stage 2*—As the situation worsens further, some wholesale funding markets start closing for single names and/or the whole system, first the long-term markets and then short-term ones. Unsecured funding is the first source to drain, while secured funding might remain available, but at higher costs (i.e., higher prices and/or collateral). At the same time banks start hoarding liquid assets which they can use as collateral, such as government debt and central bank reserves.

(iii) *Stage 3*—As a crisis unfolds, bank runs start, which are often subject to contagion and thus develop into a banking crisis unless this is prevented by policy intervention. Silent bank runs (e.g. Greece, Ireland in 2010) are by far more common than the text-book bank run during which retail customer start queuing outside the banks' branches. In a silent bank run, large corporate and retail depositors start withdrawing their deposits and move them either to competitors within the banking system or abroad if the whole banking sector suffers from a systemic crisis. However, despite the wide-spread availability of deposit insurance systems, "even nowadays" retail funding considered *stable* can be subject to a run, as Northern Rock has vividly demonstrated.[17,18] More informed retail depositors (often with higher amounts at stake)

[15] This stylized process corresponds to empirical evidence, see De Haan and Van den End (2011).

[16] It is assumed that only part of the increase in costs can be passed on to customers.

[17] The UK deposit insurance scheme entailed a co-insurance component which implied a substantial reward for depositors who withdrew early, thus thwarting the very rationale for deposit insurance.

[18] In fact, the deterioration of fiscal conditions of many sovereigns can undermine deposit insurance systems, particularly if they are meant to provide unlimited guarantees. An unlimited deposit guarantee—yet informal—was given by Angela Merkel for retail deposits in Germany at the beginning of the financial crisis, which appears to have calmed down the general public.

are likely to be the first ones to react to potential crisis indicators of certain institutions or the system in general.[19] Likewise, with competition for retail deposits having increased significantly as has the transparency of deposit rates, deposits have become more volatile in recent years, particularly for the ones driven by yield, which is further spurred by regulatory evolutions (Basel III, see Appendix I).[20] Another important reason for the withdrawal of deposits is that typically the amount covered by deposit insurance is limited, so holdings above a certain limit are subject to potential losses for the depositors.

The obvious solution to counterbalance bank-run type outflows is liquidating assets through fire sales. The dilemma for banks is the cost of holding high quality liquid assets, particularly cash and "prime" government bonds. More illiquid securities are less costly (i.e., qualify as some substitute for traditional bank business) but subject to higher haircuts, at best, or cannot be sold at all (i.e., become illiquid) and/or do not qualify as eligible collateral any more.

In case of longer lasting liquidity disturbances, the maturity profile of assets and liabilities plays an important role, as inflowing assets can then be used to deleverage, provided that (at least partly) maturing (longer-term) debt can be rolled over. In fact, the analysis of rollover risks has become an important aspect of liquidity risk analysis as many large banks are facing a "wall of funding" over the coming years.[21] For instance, with cheap funding in advanced economies due to the low interest rate policy of central banks, capital flows have swelled into emerging market countries (EC) countries with their domestic banks increasing their reliance on cheap foreign and short-term funding. It is especially this type funding that can dry up in (external) shock scenarios, and banks suddenly face rollover problems.

A natural counter-balancing role is played by central bank funding. In case of a severe crisis, central banks can act as a lender of last resort. For instance, a number of central banks entered swap agreements with the Fed during the financial crisis so they could supply their domestic banks with much needed dollar funding. In fact, the Fed became the world's USD lender of last resort during the crisis providing liquidity to also large international banks such as Barclays and UBS besides domestic U.S. financial institutions.[22] Parent banks can also step in to increase or maintain credit lines to subsidiaries if a subsidiary or branch looses access to

[19] Moreover, the recovery of deposits is, at best, subject to administrative burden and usually takes some weeks despite the fact that the pay-out schedule has been shortened in many countries recently, or could still face a loss should the deposit insurance scheme not be sufficient to cover all losses

[20] Recently referred to as a "deposit war".

[21] Banks' debt maturity profiles are monitored in the GFSR, for example.

[22] Moreover, in May 2010, the Bank of Canada, the Bank of England, the European Central Bank, the Federal Reserve, and the Swiss National Bank announced the re-establishment of temporary U.S. dollar liquidity swap facilities in response to the re-emergence of strains in U.S. dollar short-term funding markets in Europe. Since then, these were extended twice in terms of time and as recently as mid September 2011 in terms of scope with especially the ECB providing unlimited 3-month U.S. dollar funding after the re-intensification of funding strains in Europe.

funding sources while the parent retains access to funding (ideally in the required currency). Yet, the crisis gave rise to episodes of ring-fencing which restricted the transferability of capital and liquidity during stress times (see Cerutti et al., 2010, for example). Nevertheless, parent funding (predominantly in Euro for, both, Euro area and non-Euro area subsidiaries) turned out to be more stable than alternative funding sources (i.e. non-Euro area subsidiaries' access to Euro wholesale markets)[23], in Central and Eastern Europe supported by the Vienna initiative.[24] CEBS (2009a) suggests that the majority of instances in which parent institutions did not provide additional liquidity for subsidiaries were due to idiosyncratic liquidity shocks hitting the parent as a consequence of severe (perceived) solvency problems of the banking group, i.e. in circumstances where they could not provide support.

The "typical" balance sheet structure of banks based in OECD countries, ECs and low income countries (LICs) is displayed in Appendix II. It is shown that the key difference on the asset side is that banks in OECD countries exhibit a lower level of cash and government securities in favor for a higher portion of other securities than in ECs and LICs. The total portion of securities that can be used for fire sales is approximately the same. On the liability side, banks' portion of wholesale funding is substantially higher in OECD countries (both short-term and long-term) than in ECs and LICs (where banks predominantly use customer[25] deposits to fund their business), and has grown rapidly during the buildup of the financial crisis. The data do, however, not confirm the belief that the portion of short-term wholesale funding is positively correlated with size. Rather, the largest banks (with assets more than $1 trillion) exhibit a slightly lower portion of short-term wholesale funding (14 percent vs. 17 percent on average). Reducing their dependency on (unsecured) short-term wholesale funding will take time and is costly for the banks that have sizeable portions. The stylized balance sheets of "average" banks will be used to illustrate the framework in section V and some additional liquidity patterns.

## B. Methodological Aspects

### Overview of Recent Methods to Assess Liquidity Risks

A natural starting point to assess liquidity risks is through financial soundness indicators (FSIs), which provide relevant information on the liquidity position of banks, both vis-à-vis peers (banks and/or countries) and over time.

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[23] Parent bank funding is important in two cases: first, the subsidiary is the same currency area, but liquidity management and (parts of) funding are centralized; second, the subsidiary is in another currency area, but features a multi-currency balance-sheet (e.g. the subsidiary provides FX-loans). In the latter case non-Euro area subsidiaries hardly have direct access to long-term stable Euro funding.

[24] Within the European Union, transfers of capital and liquidity can, in principle, not be restricted (European passport). The Vienna initiative sought to prevent the withdrawal of Euro funding from Western European parent banks in Central and Eastern Europe—to safeguard financial stability, which proved quite successful.

[25] i.e., retail and non-bank SME/corporate deposits.

One of the early adopters of cash flow based liquidity stress testing (both top-down and bottom-up) in recent years has been the Austrian National Bank (for instance OeNB, 2008[26]), or more recently Schmitz (2009 and 2010), whose work has heavily influenced the European approach as well (see, e.g., ECB, 2008).

Van den End (2008) at the Dutch Central Bank developed a stress testing model that tries to endogenize market and funding liquidity risk by including feedback effects that capture both behavioral and reputational effects. Using Monte Carlo approach he applied the framework to the Dutch banks and showed that second round effects have a more substantial impact than first round effects (i.e., that liquidity risks are highly non-linear), resulting from collective behavior and suggesting that banks hold substantial liquidity buffers. Wong and Hui (2009) from the Hong Kong Monetary Authority sought to explicitly capture (i.e., endogenize) the link between default risk and deposit outflows. As such, their framework allows simulating the impact of mark-to-market losses on banks' solvency position leading to deposit outflows; asset fire sales by banks is evaporating and contingent liquidity risk sharply increases.

An attempt to (fully) integrate (funding) liquidity risks and solvency risk is the Risk Assessment Model for Systemic Institutions (RAMSI), developed by the Bank of England (Aikman et al., 2009). The framework simulates banks' liquidity positions conditional on their capitalization under stress, and other relevant dimensions, such as a decrease in confidence among market participants under stress. By now, the framework can be regarded as the most comprehensive approach to endogenize liquidity risk stress tests in a modeling framework.

At the IMF, in the context of FSAP stress tests, liquidity tests were originally centered on Čihák (2007) using bank balance sheet data to perform bank-run type stress tests on a bank-by-bank level. Besides, a recent chapter of the GFSR (April 2011) focused on systemic liquidity, based on a Merton-type approach using market data and balance sheet information to estimate banks' individual liquidity risk and to calculate the joint probability of all institutions experiencing a systemic liquidity event accordingly, which can be captured by means of a systemic liquidity risk index, for example.[27] Barnhill and Schumacher (forthcoming) develop an empirical model that seeks to link solvency risk and liquidity risks, similar to Van den End (2008) and Wong and Hui (2009). The framework attempts to be more comprehensive in terms of the source of the solvency shocks, and tries to compute the (longer term) impact of funding shocks, i.e., deleveraging beyond fire sales.

On the regulatory side, substantial micro-prudential efforts were undertaken to contain liquidity risks on a bank-by-bank level: In 2008, the Basel Committee of Banking Supervision (BCBS) published guiding principles for sound liquidity risk management (BCBS 2008) and an overhaul of the regulatory framework followed in December 2010 (BCBS 2010b), when

[26] In the liquidity stress tests conducted for the IMF FSAP in 2007, highly adverse scenarios were adopted to test the resilience of Austrian banks. See section IV.E for further information.
[27] The framework can also be used to compute each institution's contribution to systemic risk and systemic risk shortfalls, respectively, which could trigger an insurance premium.

the Committee introduced two measures to contain short-term vulnerabilities on the one hand and excessive maturity mismatch on the other. To this end, the minimum liquidity standard will incorporate a 30-day Liquidity Coverage Ratio (LCR), essentially a pre-specified substantial bank-run type stress test lasting a month that banks have to pass in order to be considered rather safe in the short-term, and a longer-term structural liquidity ratio, the so-called net stable funding ratio (NSFR) that aims at limiting maturity mismatch, with a focus on the next 12 months. Both ratios are subject to a transition phase, during which the ratios will ultimately be calibrated and are scheduled to be fully implemented by 2015 (LCR) and 2018 (NSFR), respectively.

In addition, several macro-prudential approaches to manage systemic liquidity risk have been brought forward during the last two years (which have, at least partially, been used in emerging markets for many years). All approaches aim at introducing incentives to limit systemic liquidity risks, including through levies, capital charges and introducing minimum liquidity ratios and haircuts, but implementation seems unlikely at this stage, mainly due to the complexity of measuring systemic risk. See IMF (2011) for further information.

Finally, in the industry bank level tests are centered on maturity mismatch approaches, sometimes complemented by stochastic Value-at-Risk components for those funding sources for which sufficient histories of high frequency data is available. The ultimate goal of liquidity tests is to determine a banks' risk tolerance for liquidity risk, i.e. the maximum level of risk that the bank is willing to accept under stress conditions. Most large European banks compute their maximum risk tolerance (ECB 2008), for example. The stochastic approach aims at determining Liquidity at Risk[28] (maximum liquidity gap within a certain time horizon and for a given confidence level) or Liquidity Value at Risk (maximum cost of liquidity under certain assumptions). While instructive under business as usual and mild stress scenarios, these models face limitations in stress testing under more severe liquidity shocks. Given that liquidity risk is a low frequency, high impact risk, historic volatilities and correlations tend to underestimate funding risk under severe stress, which is highly non-linear (see ECB 2008, for example).

**Top-Down or Bottom-Up?**

The most intuitive way to stress test liquidity risks is to use cash flow level data, usually available only within banks.[29] Provided that the cash flow structure and maturity of all cash flows is monitored through IT systems, the challenge is how to deal with:

[28] Liquidity at Risk denotes computing a 99.9 percent event based on the cumulative probability distribution (as is done for market risk and credit risk).

[29] Deutsche Bank, for example, has information on the expected daily cash flows for the next 18 months; both on-balance and off-balance, by currency, product and organizational division (see Deutsche Bank, 2009, p.95).

(i) The volatility, i.e., cash flows with non-predefined cash flow structures, such as contingent liabilities (e.g., credit lines) on the asset side and demand deposits or short-term interbank market access on the liability side as well as

(ii) The strategy of managing maturity mismatch.

For system-wide liquidity stress tests, the subject matter of this framework, there are two ways to stress test liquidity risk:

(i) Defining common scenarios that are run by banks themselves, so-called bottom-up (BU) tests, making use of granular data, or

(ii) Collecting data by broader liability and asset types, currency and maturity and applying scenarios accordingly in a top-down (TD) fashion.

The framework at hand mainly caters to the purpose of running TD stress tests. As such, the main advantage is to be able to run a set of consistent tests for all banks in the system (and relevant banks and non-banks outside of it). In principle, the tool could also be used to gather BU results and run additional sensitivity tests accordingly as outlined below. Table 1 summarizes the relative strengths and weaknesses of the two approaches for liquidity risk, omitting the hybrid case (TD, run by banks).

An interesting combination of BU and TD approaches are concerted rounds of common liquidity stress tests (e.g. ECB 2008) which also collect data on banks' measures taken in the face of the common scenarios and incorporate second-round effects in an additional TD round based on the results of the BU exercise. For example, if the majority of banks report asset sales of particular asset classes in their counterbalancing capacity, the TD analysis would increase haircuts on those assets; if banks report that they would discontinue reverse repos, the TD analysis would incorporate a (further) reduction in repo roll-overs.

**Table 1: Comparison of Pros and Cons of Balance Sheet Type TD and BU Liquidity Stress Tests**

| Type of Test | Pros | Cons |
|---|---|---|
| BU test (run by banks) | Cash flow level data, use of models developed by banks, P&L effects of liquidity shocks and cost of funding shocks can be incorporated more easily. | Less consistent than TD |
| TD tests (run by authorities) | Consistent approach, authority is flexible to run various scenarios, transparency of situation to authority | Less detailed data, bank-specific situation less recognized; data are outdated rapidly, which can be prevented by a high, but burdensome frequency of reporting |

Source: Authors.

### Outcome of Liquidity Stress Tests

The outcome of TD liquidity tests is three-fold:

(i) They show the counter-balancing ability of banks on the one hand (and their specific limit in case of reverse stress tests)[30] to remain liquid,

(ii) They reveal a peer comparison, i.e., the relative performance of banks under liquidity stress on the other hand, and

(iii) They can provide a link between the joint resistance to liquidity and solvency risks if the feedback between solvency and liquidity risks is modeled in the TD stress testing framework.

## III. Framework of Next Generation Liquidity Stress Tests

The framework originates from the balance sheet based liquidity stress tests based on Čihák (2007), and seeks to account for (a) lessons learnt from the crisis on the one hand; and (b) the evolution of conceptual and regulatory initiatives on the other, i.e., taking into account recent progress in terms of evidence and conceptual progress as discussed in section II. The framework is part of a larger project on next generation balance sheet stress testing at the IMF, a framework initiated by Schmieder, Puhr, and Hasan (2011).

As such, the tool provides extensions in five dimensions:

(i) A more granular balance sheet structure can be exploited.

(ii) Maturity mismatch is explicitly taken into account through separate tests.

(iii) The framework allows computing (simplified) Basel III liquidity ratios, both the LCR and NSFR (see also Box A1.1).

(iv) A fully-fledged cash flow test can reveal detailed information on banks' vulnerabilities provided that granular information is available.

(v) A framework to link liquidity risks and solvency risks addresses liquidity from complementary angles and allows examining the impact of changes of funding costs and a (partial) closure of funding sources on solvency and liquidity as well as funding concentration risks.

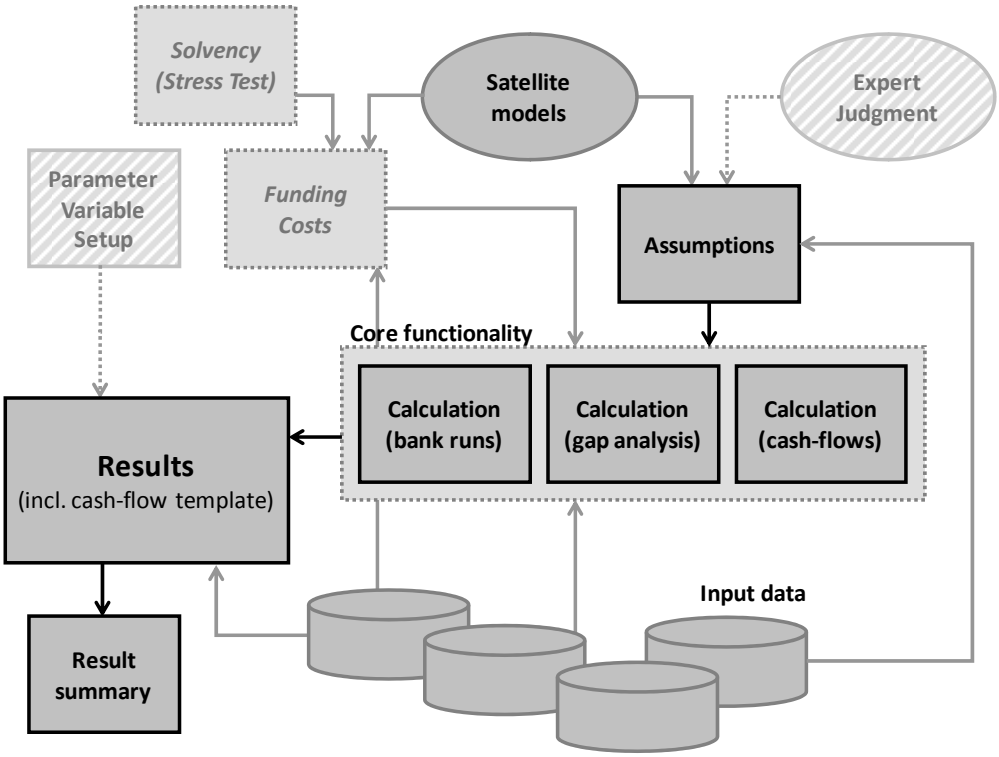
More specifically, the innovations of the tool can be summarized as follows: First, the tool allows for more flexibility and adds additional elements (such as the portion of encumbered assets or examining banks' overall interbank exposures) to the implied cash flow tests established by Čihák (2007). Second, maturity mismatch analyses are extended, with a fully

[30] Reverse stress test seek to identify maximum stress resistance of banks / the banking system by increasing the risk factors (e.g., haircuts, run-off rates, etc.) until a predefined threshold (e.g., positive counter-balancing capacity) is reached.

fledged cash flow test allowing for tests that are similar to the ones run by banks themselves based on granular contractual and behavioral cash flow data. Third, concentration risk analysis and the new Basel III ratios are added, which were not available in previous tools. Fourth and last, the link to solvency seeks to account for lessons learned in the recent past, and brings in a dynamic element. In the latter dimension, the tool seeks to bring forward straightforward ways to deal with the issues, while other frameworks (e.g., RAMSI) are more of a black box nature and need considerable technical effort to be set up. Lessons learned from the financial crisis were also taken into account for the above improvements.

The key elements of the framework on liquidity risk are displayed in Figure 1. Due to the lack of empirical cases as argued previously, the calculation of satellite models (i.e., econometric models) that link the outflow of deposits to macroeconomic conditions is not (yet) feasible. However, such models can be used to determine the haircuts for assets under stress (i.e., market liquidity risk). In addition, satellite models can be used to link banks' solvency under stress (e.g., capital ratios, or default probabilities) to funding costs. Accordingly, a multi-period solvency test can link the deterioration of liquidity conditions to the evolution of bank solvency and vice versa.

**Figure 1. Overview on Liquidity Risk Framework**




Source: Authors.

Table 2 displays the main features of the three modules that constitute the framework, namely (a) bank run type implied cash flow analysis (ICFA); (b) maturity gap/rollover tests based on ICFA and a fully-fledged cash flow approach; and (c) integrated solvency/liquidity tests.

**Table 2. Overview on the Main Elements of Three Liquidity Tests**

| Type of Test | Description | Outcome |
|---|---|---|
| Implied Cash Flow Analysis (ICFA) | Assesses banks' counter-balancing capacity in case of bank run type scenario, simulating a gradual outflow of funding for a time frame of (a) 5 periods (days, weeks, months); and (b) fixed period (30 days/3 months). Scenarios account for market liquidity of assets (in case of fire sales). The gradual test is usually run as a reverse test. | Which banks "fail" the test? (test enables peer comparison); Which portion of banks remains liquid under a specific scenario? How much liquidity shortfall occurs at the bank and system level, if applicable? |
| | (Proxy for) LCR, which assesses the counterbalancing capacity of banks for the next 30 days; The regulatory weights can be changed to assess sensitivities | Which portion of banks meets regulatory requirements? How much liquidity shortfall occurs, if applicable? |
| Maturity Mismatch/Rollover Stress Test | The liquidity gap simulation matches liability and asset maturities and identifies liquidity gaps for each maturity bucket and under different scenarios. The test is available (i) as a simplified version with limited data requirements and (ii) as a fully-fledged cash flow test. | Which portion of banks remains liquid up to a specific maturity bucket? How much is liquidity shortfall, if applicable? |
| | (Proxy for) NSFR assesses the stability of banks' funding sources in more structural terms. | Which portion of banks meets regulatory requirements? How much liquidity shortfall occurs, if applicable? |
| Integrated Liquidity and Solvency Tests | Simulates the impact of changes of solvency and concentration risk on liquidity conditions and vice versa (the first two modules require input from a solvency test and funding cost model, respectively). | Which portion of banks remains liquid/solvent under the specific assumptions? How much liquidity/capital shortfall, if applicable? |

Source: Authors.

The tests are meant to assess complementary dimensions relevant for liquidity risks, namely (a) the capacity to withstand a bank-run (*short-term counter-balancing capacity*); (b) the extent and capacity to deal with maturity mismatch; and (c) potential threats to liquidity arising from solvency risks.

The functioning of bank run test is illustrated by means of a case study in section V. Moreover, Appendix III provides more detailed information of each individual liquidity stress test and additional information is given in the tool itself.

Most of the tests are deterministic, but the framework can be extended to become more dynamic. In fact, the framework's link between funding costs and capitalization has been used in multi-period solvency stress tests based on Schmieder, Puhr and Hasan (2011), for example in the case of the Germany FSAP. Likewise, the five-period implied cash flow test could be made dynamic, for example, by gradually adding additional elements that hit banks that are performing badly under stress. The closing of funding markets conditional on bank solvency is another area that would invite such a dynamic analysis, shedding light on potential short- and medium-term deleveraging effects resulting accordingly.[31] As dynamic designs are highly challenging, they have not been implemented as part of the standard version of the tool, but future releases might see some of the elements being added.

## IV. Design of Stress Scenarios

### A. General Considerations

In line with the overarching principle for sound stress testing, scenarios should be "extreme yet plausible", which is even more important for liquidity risks than it is for solvency risk as only solid liquidity buffers can ultimately safeguard banks, unless there is a major systemic event when even those no longer suffice to mitigate a liquidity squeeze. Given that liquidity crises are infrequent (more so than solvency crises), evidence is scarce and stress levels vary widely. However, conditions tend to be very unfavorable once there is stress, i.e. stress is highly non-linear. As a consequence, the tool allows for a range of scenarios with varying degrees of severity to be run at low cost which we strongly recommend. The output across the scenarios then provides a clear view of the relative liquidity risk exposures and liquidity risk bearing capacities of the banks in the system. This allows supervisors to interpret the results on the basis of their own liquidity risk tolerance for the individual banks in the system and the aggregate system. Finally, scenarios can be interpreted as tools to condense a wealth of bank data and assumptions concerning the environment in which banks operate in a way that is consistent and intuitive. Based thereon supervisors can then scrutinize the funding structure of those banks that are flagged by the stress test to derive individual policy conclusions.

The classic alternative to point estimate based scenarios is to "stress it until it breaks" (Ong and Čihák, 2010) also referred to as *reverse stress tests*, where tests are used to determine a set of scenarios that would cause an increasing part of the system (or specific banks) to run short of liquidity. Reverse stress tests and tests simulating "extreme yet plausible" scenarios

[31] This dimension is highly relevant under the current circumstances in Europe, for example.

complement each other, and thus there is a good reason to run both, especially for liquidity risk.[32]

In general, three basic types of inputs can be useful in designing *extreme but plausible* scenarios: (a) past experience; (b) expert judgment; or (c) an individual, reverse test type assessment of the limit for each bank. Scenarios should take into account both market-wide shocks (a worsening of market conditions and investor confidence) that affect all banks in the system as well as an idiosyncratic shocks, e.g., due to deterioration of the solvency of single banks. Given that market confidence in individual banks is more fragile under market-wide stress, a combined scenario should be taken into account as well (e.g., the LCR is modeled around such a combined scenario).

If possible, scenarios should be accompanied by a consistent "story line" that underpin the assumptions on all relevant elements, namely (i) run-off rates for funding; (ii) haircuts for assets sold at fire sales prices and drawings of contingent liabilities; (iii) the impact of banks' rating downgrades, i.e. a deterioration of bank solvency. For the analysis of maturity mismatch, additional parameters (e.g., roll-over rates) need to be modeled in a consistent manner.

In the case of retail deposits, for example, guiding questions for the design of scenarios and the development of story lines could be: Which retail deposits are the most vulnerable (e.g., foreign currency denominated deposits, deposits held by foreigners abroad, demand deposits in case of an increase of policy rates from very low levels) and would go first? Would depositors hoard cash or shift deposits outside the national banking system in the event of a crisis? Under what conditions would a flight to quality initiate deposit inflows at a subset of banks in the system and an outflow at others?

### B. Run-Off Rates for Different Funding Sources

Table 3 provides an overview of the magnitude of a loss of funding based on empirical evidence as well as parameters used for stress testing in a broader context.

The financial crisis provided ample evidence for solvency and liquidity crises of banks. For liquidity, probably the most prominent victims were the U.S. investment banks, which suffered from interbank markets drying up in combination with solvency concerns given their continuing efforts to raise needed capital (e.g. from Sovereign Wealth Funds). Other banks became victims of their rapid and aggressive growth strategy and heavy reliance on wholesale funding, which applies to U.K.'s Northern Rock among others. The former even experienced a text-book retail bank run, with people queuing in front of the bank's branches to withdraw their money, after a silent wholesale run.

[32] A challenge is how to deal with the outcome of reverse stress tests in the context of authorities' stress tests. Given the sensitivity of liquidity risk an appropriate way to disseminate the results has to be found.

## Table 3. Magnitude of Runs on Funding—Empirical Evidence and Stress Test Assumptions

| | Loss of Customer Deposits | Loss of Wholesale Funding |
|---|---|---|
| **Empirical evidence**[33] | | |
| Banking System in Saudi Arabia (August 1990[34]) | 11 Percent (1 week) | |
| Banesto (ES, 1994) | 8 percent (1 week) | |
| Banking System in Argentina (2001) | Deposits in domestic currency: 30 percent (9 months) | |
| Northern Rock (UK, 2007) | 57 percent (12 months) | 57 percent (6 months) |
| Parex Bank (LV, 2008) | 25 percent (3 months) | |
| IndyMac (US, June 2008) | 7.5 percent (1 week) | |
| Washington Mutual (US, September 2008) | 8.5 percent (10 days) | |
| DSB Bank (NL, 2009) | 30 percent (12 days) | |
| **Regulatory Parameters** **LCR (30 days)** | Stable: min. 5<br>Less stable: min. 10 | (unsecured categories)<br>Stable SME: min. 5<br>Less stable SME: min. 10<br>Non-financial corporate, public sector: 75<br>All other deposits: 100<br>(secured)<br>Repos: 0-25 (quality collateral), 100 otherwise |
| **Regulatory Parameters** **NSFR** | Stable: 10<br>Less stable: 20 | (unsecured categories)<br>Short-term corporate & public sector (< 1 year): 50<br>Rest: 100 |
| **Recent FSAPs**[35] | 10-50 percent (up to 80 percent for non-resident deposits) | 10 to 50 percent for non-bank deposits<br>100 percent for bank funding<br>50 to 100 for parent funding |

Source: Authors based on publicly available data.

[33] Other bank runs include MBf Finance Berhad (Malaysia, 1999), Bear Stearns (US, 2008) and Landesbanki (IS, 2008), for example.

[34] Period after the invasion of Kuwait by Iraq.

[35] In many cases, the shocks were sensitivity analyses rather than scenario analysis, so the parameters are higher.

A third group of banks were those domiciled in countries with a major recession and/or banking crisis, such as in the Baltics and in Kazakhstan. Lately banks based in peripheral Europe have become highly dependent on funding by the ECB, testimony that they are shut out of the interbank market, debt capital markets, and a protracted outflow of funding, including retail deposits, in some cases. Selected examples of recent bank runs were summarized in Table 3 and further information is provided in Appendix IV.

In addition, the two prudential Basel III ratios provide benchmark parameters for run-off rates of funding sources, the LCR for a period of one month and the NSFR for 12 months (BCBS 2010b). For retail deposits, the LCR foresees minimum outflow ratios (run-off rates) are 5 percent for stable retail credit and funding provided by small- and medium-sized enterprises (SMEs), respectively, and 10 percent for less stable funding. For the NSFR, the level is twice as high (10 and 20 percent, respectively). Secured wholesale funding is subject to withdrawal between 0 and 25 percent, provided that it is secured with higher quality collateral, while unsecured wholesale funding is associated with run-off rates of at least 50 percent (for no-financial corporates), most of it 100 percent (especially for financial institutions).

European Banks[36] use similar parameters for their internal stress tests, with retail deposit run-off rates mostly at 10 percent (up to 30 percent), and wholesale run-off rates ranging from 0 to 100 percent (100 percent is assumed by one fifth of the banks in the survey) (ECB 2008).

Table 3 also includes assumptions used by recent Financial Sector Assessment Programs (FSAPs) in different countries. However, these parameters were, in most parts, to be understood as input for sensitivity analysis, which is why the severity is higher. Further information on stress test parameters used in FSAP stress tests is provided in Appendix IV.

### C. Asset Side: Fire Sales & Rollover

The counterbalancing ability of banks depends on their ability to generate cash-inflows from liquid assets. This includes three elements (a) defining which asset types remain liquid (see Appendix IV for a distinction of assets according to their liquidity profile adopted by the ECB); (b) defining market liquidity, i.e., the loss in value (haircut) banks have to accept to sell the asset; (c) defining the portion of liquid assets that remain unencumbered. In the latter context, given recent events and the increased importance of secured funding (for example, repos and covered bonds), it becomes crucial to collect data on the level of unencumbered liquid assets on the one hand, and making assumptions about their availability under stress on the other, accounting for potential margin calls.[37]

[36] The survey is based on responses by 30 European banks in 2008.

[37] The Basel III definition appears a meaningful benchmark (BCBS 2010b, para. 27).

The haircuts should differentiate between asset categories, accounting for the level of stress simulated on the one hand,[38] the "quality" of assets (e.g., in case of debt securities the type and rating of the counterparty) on the other.[39] In principle, one could also use haircuts for the liabilities, to simulate a decrease in the availability of funding due to an increase in collateral requirements (due to margin calls). In any case, one has to avoid double-counting—(unencumbered) liquid assets can only be used to either generate cash or maintain the level of funding (as a substitute of encumbered assets used as collateral that have lost in value).

Potential haircuts to be modeled comprise:

(i) Haircuts for (unencumbered) liquid assets (Table 4).

(ii) Haircuts for encumbered liquid assets (i.e., collateral/margin calls, see Table 4)

(iii) Add-ons (positive haircut) for contingent liabilities (see Table 4)

Deriving model-based haircuts requires a substantial commitment of time and resources, but comes with the advantage of developing expert knowledge on the value of assets under stress.[40] Alternatively, stress testers can use supervisory haircuts foreseen to be used under the (comprehensive) Standardized Approach for solvency purposes (BCBS 2006, para. 147f.), for example. These haircuts constitute a proxy for the 99$^{th}$ confidence interval for different holding periods. Basel III distinguishes between two levels of high quality liquid assets (so-called "flight to quality" assets) and refers to factors that can be used to define whether funding remains liquid (BCBS 2010b, para. 22f.). A more granular classification of marketable assets is the one by the ECB (Appendix IV, Table AIV.1), which distinguishes between five categories, where category 1 and partially category 2 would correspond to the Basel III level 1 assets and category 2 and 3 to Basel III level 2. Category 4 and 5 are assets not considered as high-quality liquid assets under Basel III, but it is worth to run less severe scenarios simulating that they are liquid subject to a considerable haircut, for example.[41] An overview of valuation haircuts that are applied to eligible marketable assets by the ECB is displayed in Table AIV.2 in Appendix IV (ECB, 2011).

Table 4 provides an overview of supervisory haircuts as part of the Basel II solvency framework and the haircuts to be used for the Basel III liquidity tests. It is important to

[38] Market prices can be assumed to be substantially lower in case of severe shocks. Driven by the fact that multiple market participants will try to sell large amounts of the same assets at the same time in response to a market-wide shock.

[39] Maturities of the assets (and accounting for the holding period, i.e. the timing when the assets are likely to be fire sold) and currency mismatch could also play a role.

[40] Calculating the volatility of market prices of assets allows assigning probabilities for the occurrence of scenarios. A useful guideline how to do so is provided in BCBS (2006, para. 156ff.).

[41] Basel III outlines that the high-quality assets are likely to be comparable to the assets eligible for central bank funding, but also that "central bank eligibility does not by itself constitute the basis for the categorization of an asset as a 'high-quality liquid asset'" (BCBS 2010b, para. 25).

recognize that the purpose of the parameters is different—for solvency purposes the maturity is linked to the assets, while the maturity for liquidity purposes depends on the ratio referred to (and the corresponding time frame). One can see, for example, that the LCR assumes substantial stress, with equities becoming illiquid, for example.

**Table 4. Supervisory Haircuts Based on Solvency Regime (BCBS 2006, 2010) and Basel III Liquidity Regime (BCBS 2010b)**

| Haircut/Weight for.. | Basel II (2006, 2010) | | | | | Basel III (LCR) | Basel III (NSFR) |
|---|---|---|---|---|---|---|---|
| (1) Unencumbered liquid Assets | Cash | 0 | | | | 0 | 0, includes also short-term securities (less than 1 year) |
| | Issue Rating for Debt Security | Residual Maturity | Sovereign | Other issuers | Secu-ritization | | |
| | AAA to AA-/A-1 | < 1 year | 0.5 | 1 | 2 | Sovereign (RW 0%): 0; Corporate: 15 | Sovereign-type: 5; Corporate (< 1 year): 20 |
| | | 1 to 5 years | 2 | 4 | 8 | | |
| | | > 5 years | 4 | 8 | 16 | | |
| | A+ to BBB- and unrated | < 1 year | 1 | 2 | 4 | Sovereign (RW 20%, Rating A+ to A-): 15 | |
| | | 1 to 5 years | 3 | 6 | 12 | | |
| | | > 5 years | 6 | 12 | 24 | | |
| | BB+ to BB- | All | 15 | Not eligible | | | |
| | Equity (main index) and Gold | 15 | | | | 100 | 50 |
| | Other equity | 25 | | | | | |
| | Mutual funds (max of allowed asset mix) | Up to 25 (highest haircut applicable to any security in the fund) | | | | | |
| (2) Encumbered liquid Assets (collateral) | n.a. | n.a. | | | | Haircut on collateral for potential margin calls (3 notch downgrade) | n.a. |
| (3) Add-ons (contigent liabilities) | n.a. | n.a. | | | | Lines - Retail: 5; corporate, credit lines: 10; corporate, liquidity lines: 100; other: 100 | undrawn credit and liquidity lines: 5 |

At this point, reputational considerations—which featured prominently in the ongoing crisis—need to be built into the scenario assumptions. In particular, stress testers need to take into account contingent liabilities such as committed credit/liquidity lines to customers and sponsorships of Special Purpose Vehicles (SPVs) and outflows related to derivatives (i.e. margin calls). This is a risk that is particularly high under market-wide funding market dislocations. The LCR provides a valuable benchmark for contingent liabilities, including for derivatives (in terms of the number of rating downgrades to be simulated).

As a general rule, stress tests should focus on the ability of banks to weather severe but plausible liquidity shocks as going concern. That implies that the bank is able to maintain its franchise value. To do so, it needs to keep generating new business (i.e. roll-over maturing assets) and honor its commitments, which is the underlying assumption under Basel III, but also by banks (see Deutsche Bank 2010, for example).

The tool also explicitly allows simulating how liquidity support provided by parent banks and central banks would alter the outcome of the tests. In the former, any estimated liquidity shortfall of a subsidiary could indicate the possible needed amount of additional parent funding support. In the latter case, the central bank could assess whether its regular (e.g. reduction of required reserves requirements or repos) and emergency liquidity support is sufficient and to determine how much additional liquidity might be need to be earmarked for worst case situations, e.g. to close funding shortages in specific maturity buckets.

### D. Link Between Liquidity and Solvency

There have been some recent attempts to link solvency and liquidity risk, which particularly applies to (a) funding costs; and (b) the closure of funding markets once solvency conditions deteriorate further.

The link between solvency and funding costs comprises two dimensions: (i) an increase of the price to be paid for funding as such–wholesale funding is particularly sensitive to changes in solvency, but recent competition for retail deposits is an indication that retail deposits also becomes more price-sensitive going forward; (ii) an increase of collateral needs for secured funding sources (margin calls).

The former dimension can be derived based on empirical evidence. One way is to use econometric models to determine the increase in funding costs (i.e., interest expenses) on the liability side, while also accounting for the effect on earnings on the asset side (interest income).[42] As an illustrative example[43], a non-linear relationship between solvency (measured as implied IRB capitalization) and funding costs has been established for Germany. The procedure is illustrated in Appendix V (Figure AV.1) based on an example and explained below. The funding costs encompass a proxy for an average German bank (the funding costs were weighted by the portion of each funding source and the pertinent costs, using market data provided by the OECD and the ECB), based on the sample of all German banks available in Moody's KMV. For the illustrative example, the funding costs were compared against the (one-year) EDF of the German banks for 12 quarters from 2007-2009, i.e., a period of stress in funding markets. In the next steps, the EDF has been translated into a capitalization ratio using the IRB formula[44], inferring the minimum capital ratio based on the confidence interval corresponding to the EDF, and adding an additional capital cushion of 2.5 percentage points (in line with the observation that banks hold more capital than the minimum). It should be noted that the resulting implied capitalization is purely based on quantitative elements and subject to the limitations of the Basel IRB model. The implied rating, both in terms of the letter rating (which uses Moody's (2010) to create the link between the EDFs and rating letters) and capitalization should therefore not be confused with external ratings granted by rating agencies, which are subject to comprehensive analysis based on both qualitative and quantitative criteria, taking into account implicit government guarantees, for example, which

[42] The impact of changes in funding costs in net interest income ultimately depends on banks' ability to pass through their costs, but short-term developments also depend on the portion of assets and liabilities that can/will reprice. In the example used for this study, it has been assumed that banks cannot pass on any increase of funding costs to customers, which is very conservative.

[43] Stress testers need to recalibrate it for the situation at hand, which differs widely across countries and banks, depending on, for example, the country as such, the situation in the financial markets, the fiscal position of a country, the regulatory environment, etc.

[44] This was done by using through-the-cycle credit risk parameters—a probability of default (PD) of 1 percent and a loss given default (LGD) of 45 percent. The capital requirements for market risk and operational risk have been assumed to amount to 20 percent of the ones for credit risk for a confidence interval of 99.9 percent.

alters the situation. The ratios could serve as some conservative, quantitative benchmark which capitalization levels would be needed to reach certain ratings on a standalone basis. For the computation of the funding costs, it has been assumed that banks cannot pass on any increase to customers, which is conservative and could be relaxed (e.g., by using a pass-on rate of 50 percent).

For secured funding, counterparty credit risk plays an important role, as collateral requirements depend on the rating of a counterpart. Hence, a deterioration of solvency (i.e., a rating downgrade) leads to an increase of collateral requirements and thus a reduction of funding. While the impact is highly bank-specific, it is non-linear, at least once banks drop below the investment grade level. Deutsche Bank, for example, reports that a drop of its rating by 1 notch results in a loss of funding of about 2 percent, and that the drop is about 6 times for a rating deterioration by 6 notches (Deutsche Bank, 2010).

Once market conditions deteriorate further, driven by general market conditions and/or idiosyncratic strains at single banks, funding markets will close. An attempt to model to capture the deterioration of various factors and link it to the closure of funding markets is part of the RAMSI model, with a calibration for the United Kingdom (see Aikman et al., 2009).[45]

The tool provides a template to simulate different scenarios with respect to funding costs on the one hand and the (partial) closure of funding sources on the other. A key focus of the tests is peer comparison. It is essential to ensure that the calibration is adequate for the banks and/or system at hand, which remains at the discretion of the stress tester.

### E. Liquidity Stress Tests in Recent FSAPs and Benchmark Scenarios

Table AIV.3 in Appendix IV provides an overview of scenarios used for the liquidity stress tests in selective countries during FSAPs. It should be noted, though, that some tests were meant as sensitivity tests, whereby they are more conservative as assumptions used for scenario analysis.

The scenarios covered a broad scope of potential events, catering for the needs in specific circumstances, including limited access to parent credit lines (where applicable), separate run-off rates for foreign deposits, but also the impact of rating downgrade.[46]

For instance in the case of Austria's FSAP concluded in 2008, TD stress tests included a market-wide scenario and six combined scenarios (the market-wide shock plus an idiosyncratic shock for each of the six participating banks individually). The exercise was embedded in the solvency stress test which focused on a macro-economic debt crisis. It employed an implied cash-flow approach based on reported stocks of short-term assets plus

[45] Empirical relationships between default probabilities, funding withdrawal, and (in the case of the GFSR) deleveraging rates have been documented by Van den End (2008) and IMF (2011), but the ultimate impact will remain very specific to the circumstances at hand.

[46] The withdrawal of parent support is particularly relevant for systems with foreign-owned banks, for example.

liquid asset and short-term liabilities. The implied cash-flows from short-term assets and the stocks of liquid assets received different liquidity factors across a range of sensitivity analysis, to test for variations in the roll-over rates of short-term loans to non-banks (100 and 50 per cent, respectively) and to banks (100 and 0 per cent dependent on the residual maturity between O/N and 3 months). Four sensitivity analyses were conducted: (a) liquid bonds minus 25 percent, (b) equity portfolio minus 35 percent, (c) withdrawal of 40 percent of all interbank short-term funding, and (d) withdrawal of 50 percent of nonbank deposits. In addition, a scenario analysis that combined a severe disruption of the money and credit markets (a market shock) with an idiosyncratic shock (a name crisis) for each bank was performed. The market shock included a decrease in bond and equity market prices of 20 and 30 per cent, respectively. Inflows from interbank loans received a haircut of 5 per cent to account for potential liquidity problems at counterparties. The idiosyncratic shock assumed a substantial shortening non-bank deposit outflows (sight deposits -10 per cent, term deposits with a residual maturity of up to one and three months -20 and -30 per cent, respectively).

In the Austria Article IV consultation the Austrian Central Bank presented the results of a concerted round of common liquidity stress tests (combining a BU approach based on the scenarios and a TD approach concerning the second round effects) based on the weekly standard Austrian maturity mismatch reporting template plus a separate template for measures taken by banks in the face of the assumed shocks. The market scenario focused on an assumed return of the Eurosystem to pre-crisis liquidity policy. The volumes of secured and unsecured interbank deposits were capped at the low averages of the first half of 2008. Furthermore, the exercise included BU estimates of the P&L effects of the scenarios plus a substantial widening of the Euribor-OIS spreads (up to 3 M+50 basis points, up to 12 M+75 basis points). The idiosyncratic shock consisted of a significant run-off of retail and non-bank corporate deposits (-5 percent and -10 percent, respectively, spread out over the first month). On the wholesale side, each banks faced a 100 percent run-off rate of unsecured wholesale funding from banks and financial institutions; DCM closed for the bank; 80 percent of repos are rolled over; committed interbank lines are not available for the bank.

Based on the previous considerations, we define *severe* benchmark scenarios stress testers could refer to in order to simulate moderate, medium, severe and very severe stress (Table 5). The level of severity of stress is oriented on the past crisis, relative to levels of stress observed at the times of the Lehman collapse.[47] While the Lehman calibration is not to be understood as being scientific, it is meant to represent the situation of banks hit hard during the first month after the Lehman collapse, and, very importantly, it is intuitive. Accordingly, the moderate scenario is one quarter of Lehman crisis conditions, while medium, severe and very severe are 0.515, 1 and 22 times Lehman. We have labeled the case study in section V will assess banks against stress conditions equal to moderate, medium, severe and very severe stress.

[47] Please note that this benchmark scenario remains hypothetical, and is geared towards large banks in OECD countries. For smaller banks, the benchmark could be different, with even higher run-off rates for customer deposits in case of a name crisis, for example. Expert judgment is needed to design the most plausible scenario for the situation at hand.

**Table 5. Benchmark Scenarios**

| Scenario | Moderate Stress Scenario | Medium Stress Scenario | Severe Stress Scenario | Very Severe Stress Scenario |
|---|---|---|---|---|
| Severity (x times Lehman/1) | 0.25 | 0.5 | 1 | 2 |
| **Liquidity Outflows** | | | | |
| Customer Deposits | | | | |
| *Customer deposits (Term)* | 2.5 percent | 5 percent | 10 percent | 20 percent |
| *Customer deposits (Demand)* | 5 percent | 10 percent | 20 percent | 40 percent |
| Wholesale Funding | | | | |
| *Short-term (secured)* | 5 percent | 10 percent | 20 percent | 40 percent |
| *Short-term (unsecured)* | 25 Percent | 50 Percent | 100 Percent | 100 Percent |
| Contingent liabilities | 0 Percent need funding | 5 Percent need funding | 10 Percent need funding | 20 Percent need funding |
| **Liquidity Inflows** | | | | |
| *Haircut for Cash* | 0 Percent | 0 Percent | 0 Percent | 0 Percent |
| *Haircut for Government Securities/2* | 1 Percent | 2 Percent | 5 Percent | 10 Percent |
| *Haircut for Trading Assets/3* | 3 Percent | 6 Percent | 30 Percent | 100 Percent |
| *Proxies, specific assets* | Equities: 3; Bonds: 3 | Equities: 4-6; Bonds: 3-8 | Equity: 10-15; Bonds (only LCR eligible ones): 5-10 | Not liquid |
| *Haircut for other securities* | 10 Percent | 30 Percent | 75 Percent | 100 Percent |
| *Proxies, specific assets* | Equities: 10; Bonds: 10 | Equities: 25; Bonds: 20 (some not liquid) | Equity: 30; Bonds (only LCR eligible ones): 20-30 | Not liquid |
| *Percent of liquid assets encumbered/4* | 10 Percent (or actual figure) | 20 Percent (or actual figure plus 10 ppt) | 30 Percent (or actual figures plus 20 ppt) | 40 Percent (or actual figures plus 30 ppt) |
| 1/ The Lehman type scenario would correspond to a scenario encountered by banks that were hit severely during the 30 day period after the Lehman collapse, i.e. a stress situation within a stress period rather than an average; The scenario has been put together based on expert judgment, using evidence as available. | | | | |
| 2/ The haircut highly depends on the specific features of the government debt held (rating, maturity, market depth) and can be higher or lower. The figures displayed herein are meant for high quality investment grade bonds, taking into account recent market conditions. The same applies for the remainder of the liquid assets. For the securities in the trading book, it is assumed that they are liquidated earlier, resulting to lower haircuts. | | | | |
| 3/ A haircut of 100 Percent means that the asset is illiquid, i.e., the market has closed. | | | | |
| 4/ The figures account for a downgrade of the bank, which triggers margin calls, and higher collateral requirements for generally. Please note that the unencumbered portion applies to a gradually narrower definition of liquid assets. | | | | |

Source: Authors.

As a caveat, it should be highlighted that the level of stress to be considered medium, for example, depends on the specific circumstances and all liquidity stress tests must be adapted

for the specific country, economic situation, and potential vulnerabilities.[48] It is strongly recommended to run a series of stress to assess the sensitivity of system vis-à-vis stress, including reverse stress to test the threshold that systems can withstand.

## V. CASE STUDY

### A. Case Study Implied Cash Flow Analysis

In order to illustrate the mechanics of the tool, we constructed three stylized banks (Table 6), namely "average" banks (i.e., with median asset and liability structures) based in the OECD, the ECs and LICs as defined in Appendix II.[49]

**Table 6. Implied Cash Flow Case Study—Sample Banks**

| Bank | OECD | EC | LIC |
|---|---|---|---|
| Assets | 100 | 100 | 100 |
| Cash | 4.2 | 11.2 | 13.5 |
| Government Securities | 4.1 | 7.8 | 8.3 |
| Other Securities | 21.4 | 8.6 | 6.5 |
| Customer Loans | 52.7 | 56.2 | 47.1 |
| Loans to Banks | 12.4 | 12.7 | 18.5 |
| Other Assets | 5.4 | 3.6 | 6.1 |
| Liabilities & Equity | 100 | 100 | 100 |
| Demand Customer Deposits | 19.8 | 23.3 | 39.6 |
| Term Customer Deposits | 27.9 | 41.8 | 33.2 |
| Short-term wholesale funding | 17 | 11.2 | 6.6 |
| Long-term Funding | 16.7 | 7.4 | 2.9 |
| Other Liabilities | 12.3 | 5.1 | 6.2 |
| Equity | 6.3 | 11.2 | 11.6 |
| Contigent Liabilities | 21.9 | 17.6 | 13 |

Source: Authors.

In the first step, we run ICFA based on the reverse stress test type setting (see Table 2 and Appendix III). We simulate the impact of moderate, medium, severe and very severe stress

[48] "Moderate" is already a substantial stress event in terms of overall stress, but in some countries this could be less severe as in others, depending on the quality of the safety nets that are in place (particularly the deposit insurance system).

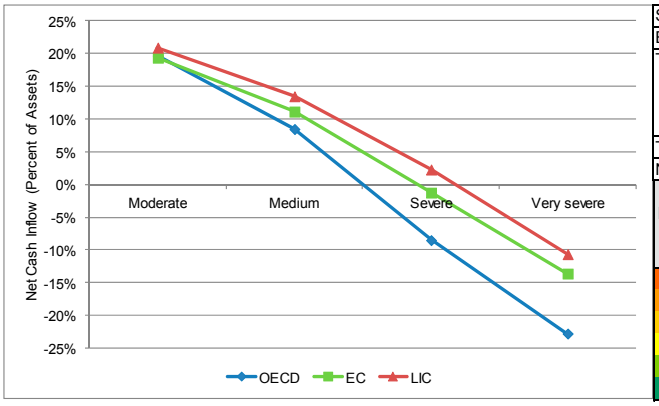
[49] Please note that the sample of banks (the universe of banks in Bankscope) is biased towards banks in advanced countries, where a broad coverage is achieved. For emerging markets and even more importantly for low income countries, the sample is biased towards larger institutions and thus not fully representative.

conditions as displayed in Table 5, whereby cumulative impact during 5 weeks, made up by the gradual impact during each of the 5 weeks, equals the figures as displayed in Table 5.[50]

Figure 2 (left hand panel) the cumulative outcome of the gradual ICFA test after 5 weeks in terms of net cash inflows as a percentage of total assets. The two panels on the right hand side provide more information on the drivers and gradual development for the severe test, i.e., show the evolution of stress during week one to five rather than the cumulative effect. The test reveals that all three banks survive the moderate and medium shock for the entire test horizon (i.e., five weeks). However, the severe shock would be too harsh for both the stylized OECD and EC bank, while the LIC just passes the test. Under very severe conditions, all banks fail and the liquidity shortfall is substantial. The very severe scenario simulates an outflow of 30 (LIC) to 35 (OECD) percent of funding, while only cash and government securities remain to counterbalance, i.e. 20 percent for the LIC banks and less than 10 percent of assets for the OECD bank.

The gradual effect for the severe scenario (the two panels on the right hand side1) reveals that the OECD bank runs short of funding during the third week, while the EC banks would only fail in the last period. The key reason for the weaker performance of the OECD bank is that it suffers a higher outflow of wholesale funding (12.8 vs. 8.4 and 5; OECD:EC:LIC) and thereby also in total (21.8 vs. 19.5 (EC) and 16.7 (LIC)), while the inflow of cash through fire sales is lower due to its comparably lower buffer with respect to high quality liquid assets.[51]

**Figure 2. Outcome of Implied Cash Flow Stress Tests for Stylized Banks**




| Severe Scenario: Analysis of Drivers | | | |
|---|---|---|---|
| Bank | OECD | EC | LIC |
| Total Outflow of Funding | 21.8 | 19.5 | 16.7 |
| *Outflow of Deposits* | 6.8 | 9.3 | 10.4 |
| *Outflow of Wholesale Funding* | 12.8 | 8.4 | 5.0 |
| *Change of other funding* | 2.2 | 1.8 | 1.3 |
| Total Cash Inflow | 11.4 | 15.3 | 16.7 |
| Net Cash Inflow | -10.3 | -4.1 | 0.1 |

| Minimum number of periods of survival | Number of Banks illiquid | Survival - Percent of Banks |
|---|---|---|
| 0 | 0 | 100.0% |
| 1 | 0 | 100.0% |
| 2 | 0 | 100.0% |
| 3 | 1 | 66.7% |
| 4 | 1 | 66.7% |
| 5 | 2 | 33.3% |

Source: Authors.

[50] Hence, it is assumed that 1/5 of the total funding is withdrawn in the first week, another 1/5 in the second, and so on. We assume that 30 percent of the other securities are in the trading book and that all short-term wholesale funding is unsecured.

[51] As a caveat, it should be noted that it is assumed that government bonds held by banks remain liquid as such, which could be too benign especially in ECs and LICs., but also that the haircuts are same, which is unlikely to happen in reality but simplifies the test. Likewise, the run-off are likely to be higher during "typical" bank runs in ECs and LICs.

## B. Case Study Fully Fledged Cash Flow Analysis

To illustrate the mechanics of the fully fledged cash flow analysis we construct a stylized cash flow template of a random universal bank. In contrast to the previous section, this example is purely fictional and emphasises the key prerequesite for the usage: access to granular, bank specific contractual cash-flow data and plausible assumptions for the behavioural (planned) future cash flows[52].

The table below shows an example of the liquidity parameters of Bank A under the baseline and under a simple stress scenario. Instead of providing the full range of contractual / behavioral cash-flows, the example is restricted to the aggregate positions in eight maturity buckets:

- the sum of cash otuflows in each maturity bucket(1)
- the sum of cash inflows in each maturity bucket (2)
- the net funding gap in each maturity bucket (3), equal to: (2)–(3)
- the counterbalancing capacity cumulated across maturity buckets

Under a given scenario (i.e. set of assumptions) Bank A remains liquid without further (management) action as long as the latter remains positiv, which is the case in all maturity buckets in the baseline scenario.

The stress scenario takes into account assumptions about a sudden drop in market confidence combined with an idiosynchratic shock for Bank A[53]:

- Steady decline in market prices for a bank's assets available for counterbalancing liquidity gaps from 10 to 30 percent (depending on asset quality),
- Dry up of funding markets, preventing issuance of new bonds,
- Strong decline in secured and unsecured wholesale funding (ranging from 10 to 60 percent over time),
- Increase of NPLs reflected by a decrease in cash-inflows from customer loans (5 to 10 percent over time) and
- About 80 percent of credit lines granted by Bank A are drawn within one month.

[52] The assumptions for the behavioral (planned) future cash flows can be replaced by bank data (i.e. funding plans) for the year ahead.

[53] The assumptions were applied symmetrically for in- and outflows.

**Table 7. Outcome of Fully Fledged Cash Flow Stress Tests for Stylized Banks**

| **Bank A baseline** | *1 Day* | *7 Days* | *1 Month* | *3 Months* | *6 Months* | *6-12 Months* | *12-24 Months* | *>24 Months* |
|---|---|---|---|---|---|---|---|---|
| Sum of cash outflows | 17,800 | 6,500 | 5,850 | 6,850 | 7,400 | 9,750 | 3,750 | 7,950 |
| Sum of cash inflows | 1,875 | 4,275 | 8,925 | 7,200 | 6,375 | 5,100 | 13,000 | 23,800 |
| Net funding gap | -15,925 | -2,225 | 3,075 | 350 | -1,025 | -4,650 | 9,250 | 15,850 |
| Cumulative counterbalancing capacity (after HC and net funding gap) | 22,925 | 20,700 | 19,725 | 18,875 | 15,900 | 8,400 | 11,350 | 7,400 |
| **assumptions** | *1 Day* | *7 Days* | *1 Month* | *3 Months* | *6 Months* | *6-12 Months* | *12-24 Months* | *>24 Months* |
| Sum of cash outflows | 20,340 | 14,860 | 5,070 | 5,090 | 4,500 | 6,150 | 3,750 | 7,950 |
| Sum of cash inflows | 1,545 | 3,525 | 7,665 | 5,670 | 5,055 | 4,140 | 11,835 | 21,585 |
| Net funding gap | -18,795 | -11,335 | 2,595 | 580 | 555 | -2,010 | 8,085 | 13,635 |
| Cumulative counterbalancing capacity (after HC and net funding gap) | 12,900 | 1,393 | 170 | -15 | -833 | -5,333 | -2,445 | -3,990 |

Source: Authors.

As shown in the table the survival period of the bank under the applied assumptions is reduced to 1 to 3 months, when the increasing funding gap can't be covered any more by the bank's unencumbered reserves.

## VI. CONCLUSION

In this paper we have argued that liquidity risk has–unjustifiably–flown under the regulatory radar with the advent of the Basel I framework and its focus on banks' capitalization. However, the fact that liquidity risk turned out to be one of the key threats to financials stability throughout the recent financial crisis, lead to reconsideration, with a reemerging focus on liquidity in industry as well as regulatory circles.

The purpose of this paper and the tool presented therein reflects this development and aims at providing stress testers with a flexible and easy-to-use platform to assess the liquidity situation of banks top-down from different angles. The pre-defined tests can easily be adapted to bank-specific situations and/or specificities of banking systems to be assessed. A key objective was striking a balance in terms of data requirements and stress test sophistication, allowing for tests with parsimonious data on the one hand and more complex / demanding tests on the other.

While the obvious way to stress test liquidity is the use of cash flow data, it is often not available (yet) at regulatory/supervisory institutions. One of the main contributions of this paper consists in providing input templates for cash flow-based tests that could also serve regulators/supervisors as a first step towards fully-fledged cash flow analysis based on regular data collection from banks. Once available, the cash flow module allows simulating detailed funding structures of single banks, which enables to draw some broader conclusions for the system wide situation of banks and potential contagion effects, respectively. Moreover, the presented tool allows for easy peer comparisons that should always play an important role for liquidity stress tests and can readily reveal vulnerabilities. Finally, the paper contributes to existing work on liquidity by modeling the link to solvency stress (tests) explicitly. Although this should not be misinterpreted as the final solution to this highly complex problem, the

inclusion of a module in the tool to account for this link in an easy to use fashion should facilitate practitioner's work significantly.

Future research will focus on better understanding the link between banks' solvency and liquidity strains. Both are inherently interrelated, and stand-alone stress tests that only examine either solvency or liquidity stress testing, potentially risk producing downward biased results. For example, a bank's severe funding strain could swiftly mutate into solvency concerns with the market putting pressure on the bank to increase its capital. The focus in this paper has been predominantly to analyze the link from solvency to stress testing but the feedback loop can also originate with liquidity.

## Appendix I. Reviewing Liquidity Issues During the Financial Crisis

Investment banks were among the first ones to experience liquidity shortages, due to their funding mix that relied heavily on the wholesale market as well as interconnectedness in the financial system that led many banks to start hoarding liquidity during the systemic crisis episodes because of counterparty risks.[54] For the same reason[55], namely uncertainty on the solvency conditions, funding also drained for banks that had aggressively collected deposits before the crisis, such as Icelandic banks (see Ong and Čihák, 2010) and the systemically important financial institutions (SIFIs) that were heavily exposed to securitized products and asset-backed commercial paper (ABCP) funding. While the latter banks were subject to wholesale bank runs, the most prominent recent "victim" of a (pure) liquidity squeeze was Northern Rock, which was subject to a classical bank run with customers queuing to withdraw their money after a wholesale funding run and emergency liquidity assistance from the Bank of England (see Section IV and Appendix IV for an outline of major recent liquidity shocks).

The liquidity squeeze particularly affected the most sensitive liquidity channels, namely unsecured cross-border funding as well as foreign currency swaps in countries as diverse as Australia, Korea, and Kazakhstan. Foreign currency lending (and thereby funding) played an important role in Central and Eastern Europe, for instance in Hungary and Poland, where banks increasingly used foreign exchange swaps to fund their domestic lending activities. With the unfolding of market turbulences in international money markets after the Lehman Brothers demise U.S. dollar funding dried up. The situation for Euro funding was less precarious as the foreign-owned subsidiaries and branches refinanced their Euro exposure largely via their parent banks.

Below, we will review in more details the events and channels of contagion. The financial crisis in general and liquidity problems more specifically began with the deteriorating quality of U.S. subprime mortgages, a credit, rather than a liquidity event. A wide range of different financial institutions had exposures to many of the related mortgage-backed securities, often off-balance sheet entities such as conduits or structured investment vehicles (SIVs). The SIVs or conduits were funded through the issuance of short-term ABCP in order to take advantage of a yield differential but resulting in a maturity mismatch. Due to the increasing uncertainty with regard to their exposure to and the value of the underlying mortgage-backed securities, investors became unwilling to roll over the corresponding ABCPs (IMF, 2008, 2010; Frank et al, 2008).

[54] Demirguc-Kunt and Huizinga (2009), for example, found that business models that rely heavily on non-deposit short-term funding and non-interest income appear to be riskier in terms of liquidity.

[55] A CEBS report on lessons learnt from the crisis (Committee of European Banking Supervisors 2009a) found that the majority of the EU cross-border banking groups that faced severe idiosyncratic liquidity problems were also subject to substantial doubts concerning their solvency or even insolvent, e.g. the Icelandic banks.

As the problems with SIVs and conduits deepened, banks came under increasing pressure to rescue those that they had sponsored by providing liquidity or by taking their respective assets onto their own balance sheets. As a result, the balance sheets of those financial institutions were particularly strained by this reabsorption, which in addition was amplified due to declining asset values and the evaporation of market liquidity in structured products. A further strain on banks' balance sheets came from warehousing a higher than expected amount of mortgages and leveraged loans, the latter usually passed on to investors in order to fund the highly leveraged debt deals of private equity firms. Both the market for mortgages and leveraged loans dried up from the collapse of transactions in the mortgage-related securitization market and collateralized loan obligations (CLOs). Banks also felt obliged to honor liquidity commitments to alternative market participants, such as hedge funds and other financial institutions that also suffered from the drain of liquidity. With regard to alternative channels of liquidity provision, stress in the FX swap markets and the negative reputational signal resulting from using the Fed discount window limited options further.

Consequently, the level of interbank lending declined both for reasons of liquidity and credit risk. In addition, the money market disruptions at the beginning of the crisis (August 2007) led to a general shift to a more conservative risk tolerance. Before the onset of the crisis, banks had relied on a (perceived) "insurance function" of unsecured money markets against negative liquidity shocks. As this perception evaporated and market depth and the breadth of the unsecured money markets deteriorated, banks shifted to self-insurance (liquidity hoarding). Subsequently, money markets were severely affected especially in advanced countries in the form of lower supply of liquidity, a shortening of tenors, and a widening of the Libor–overnight index swap (OIS) spreads, which in turn led to increased funding costs. Some banks were shut-out of the market completely. The funding situation of many banks was exacerbated by a deliberate shortening of funding maturities of many banks in the first phase of the crisis. Spreads over mid-swap increased for banks. Hoping that the situation would improve, many banks postponed issuance.

When debt capital markets closed for banks in late 2008, many banks had accumulated a substantial issuance back-log. Finally, the evident deterioration of market and funding liquidity conditions had implications with regard to the solvency position of banks for several reasons. First, financial institutions saw a decline in the values of the securitized mortgages and structured securities on their balance sheets, which in turn resulted in extensive write-downs. The drying up of many of these markets and the built-in leverage of many of the products, increased the uncertainty with respect to their valuation and consequently with respect to the solvency situation of many banks. Second, funding liquidity pressures forced rapid deleveraging during this period, further depressing asset prices. Third, funding costs increased due to rising money market and debt capital market spreads, which was amplified by the fact that many financial institutions had become increasingly reliant on funding from wholesale money markets. Jointly, these pressures with the key role that solvency concerns played resulted in a decline in the capital ratios throughout the banking sector, and as a result of which credit default swap (CDS) spreads increased significantly across the industry during the crisis. At the same time, increased uncertainty with respect to asset quality and valuation led investors to raise the bar for banks; before the onset of the crisis a core-tier 1 ratio of 6

percent was generally considered sufficient. During the crisis that requirement increased to 10 percent. ("10 is the new 6").

Re-enforcing *liquidity spirals* and a re-pricing of risk occurred when, on the one hand, market illiquidity turned into funding illiquidity, such as when the French bank BNP Paribas announced in August 2007 it would refuse to accept withdrawals from three of its investment funds. Funding illiquidity also led to market illiquidity, when for instance, European banks in late 2007 required dollar funding through foreign exchange swaps, but due concerns over counterparty credit risk, liquidity, typically obtained in the underlying swap market dried up. The collapse of Lehman Brothers in September 2008 was then the watershed event that caused a near break-down of secured and unsecured interbank and debt capital markets with sharply increasing counterparty risks and banks hoarding liquidity (in reaction to increased funding liquidity risk and tightening risk tolerance), haircuts and dollar shortages as well as led to rapid spillovers to emerging market countries, and soaring uncertainty across asset markets.

These liquidity spillovers have been facilitated by recent structural changes in the financial markets and by financial innovation during the last decade. In this context, banks have become increasingly reliant on wholesale funding and short term liquidity lines. Also, increased complexity of securities has led to great information asymmetries among market participants. Favorable macroeconomic conditions, especially low interest rates in recent years, have increased investors' risk appetite and the demand for high yield products in order to satisfy profit margins. Finally, increased correlations between returns of differing asset classes due to algorithmic trading, such as by quantitative hedge funds, has heightened the vulnerability with regard to the transmission of illiquidity.

In any case, the vast availability of underpriced liquidity in the pre-crisis period and the eventual evaporation of funding liquidity with the onset of the subprime crisis in the summer of 2007 proved challenging for many financial institutions. Solvency risks[56] quickly morphed into liquidity risks and vice versa in some cases, even though many of the rescued banks surpassed minimum regulatory capital requirements, as funding did not only become more expensive, but key funding markets closed entirely.[57]

Additional bank runs were prevented with the help of policy measures such as an increase of the level of deposit insurance, providing banks with access to central bank funding (i.e., through a lender of last resort) and by guaranteeing interbank market exposure.[58]

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[56] The simultaneous drying up of market liquidity in some asset markets (i.e. ABS) lead to increased uncertainty with respect to the solvency of institutions with high exposures in these asset classes.

[57] In fact, the link between solvency and liquidity is highly complex, with effects working both ways. Banks with solvency problems are natural candidates to run into liquidity traps (once markets dry up), but solvent banks can, under certain circumstances, also be hit by strains on the liquidity side.

[58] An overview of market interventions during the financial crisis and their effectiveness can be found in IMF (2009).

Nevertheless, two years after the beginning of the financial crisis bank funding remains problematic, subject to elevated costs and/or dependent on public support measures, with confidence not yet re-established (see GFSR, April 2011). Recently, banks based in peripheral Europe have become highly dependent on funding by the European Central Bank (ECB)—one of the signs that interbank funding markets have not yet fully recovered since the onset of the crisis.[59]

With the underpricing of liquidity risk prior to the crisis, a return to the same pre-crisis liquidity pattern is not expected. Furthermore, there is widespread consensus that banks' pre-crisis extensive reliance on deep and broad unsecured money markets is to be avoided in the future (and in current market conditions there is no appetite for that anyway). Creating substantial liquidity buffers across the board (i.e., to be followed by all banks) is the explicit aim of a number of regulatory responses to the crisis, such as the CEBS Guidelines on liquidity buffers (CEBS 2009b) and the Liquidity Coverage Ratio (LCR), one of the two new Basel III liquidity standards. As time goes on, liquidity management needs to be prepared for the materialization of tail risks, which is, the simultaneous closure of various funding and assets markets and the tapping of off-balance sheet positions—highly positive correlations as in the case of solvency risks.[60]

[59] Some Irish banks, for example, suffered a silent deposit run over a period of a few months when large corporate clients withdrew deposits.

[60] See ECB (2008b, pp. 35) for empirical evidence on the short-comings of banks' liquidity stress tests exposed by the crisis.

**Box AI.1. Regulatory Initiatives to Stress Test Liquidity Risk**

## A. Basel III

Basel III takes into account lessons learnt during the crisis, namely that liquidity risks can trigger solvency problems in banks and vice versa, as illustratively shown at the example of U.S. investment banks. Basel III (BCBS 2010b) is based on two minimum standard ratios for funding liquidity, namely the LCR and the NSFR. The former is meant to put banks into a position to withstand sudden funding stress for one month, while the second ratio attempts to limit the maturity mismatch conditional on banks' asset composition, and over-reliance on short-term wholesale funding in particular. In addition to that, the BCBS has published basic principles of liquidity management, essentially guidance on the risk management and supervision of liquidity risks for banks and supervisors (BCBS 2008). Additional analysis on liquidity risk in broader terms has also been undertaken by the Committee of the Global Financial System (CGFS).

Both ratios are introduced with a transitional observation period, in order to provide banks with time to adjust, and subject to additional revisions. For the LCR, the observation period beings in 2011 and the ratio will be introduced in 2015 (BCBS 2010a). The NSFR is scheduled to be introduced in 2018, with a monitoring period starting in 2011. A recent Quantitative Impact Study (QIS 6) revealed average LCRs of 83 percent for Group 1 banks and 98 percent for Group 2 banks, based on data from 23 countries, with 46 percent of the banks meeting the standard (BCBS 2010c). For the NSFR, 43 percent of the banks met the standard and the averages of Group 1 and 2 banks were at 93 percent and 103 percent, respectively. On average, European banks underperformed the other banks (CEBS 2010). The main conclusion from the QIS is that the liquidity risk exposure and the liquidity risk bearing capacity of banks differed widely across the international sample, depending on their maturity profile (for the NSFR), the portion of stable funding (customer deposits) and liquid assets, respectively.

Basel III also enforces monitoring activities for liquidity risk, with a focus on contractual maturity mismatch, concentration of funding, the availability of unencumbered liquid assets, currency-specific liquidity assessment (through LCR) and market-related monitoring tools (2010b).

## B. U.K. Liquidity Regulation Adopted in October 2009

In 2009, the then U.K. Financial Services Authority (FSA) introduced revised liquidity standards (Policy Statement 09/16). In November 2010, however, the FSA announced that it will reconsider the calibration of the standards with a view not phase in its own liquidity rules unilaterally, but the implementation of the qualitative elements is under way. The new standard includes the following elements and could be treated as general guidelines for further evolutions in terms of liquidity management:

- Improved control and system requirements for sound liquidity risk management.
- Adequate liquidity and self-sufficiency.
- Stricter stress testing scenarios including short- and long-term stress scenarios.
- Individual liquidity guidance to each firm.
- Comprehensive and detailed examination of contracts (e.g., maturity buckets, asset type, or currency).
- New definitions of liquid assets and risk-based buffers.
- Granular and frequent reporting requirements (daily, weekly, monthly, quarterly).

## Appendix II. Cross-Country Funding Pattern

Figure AII.1 shows the average[61] asset (left hand side) and liability (right hand side) composition of banks in OECD countries[62], emerging market countries (ECs) and low income countries (LICs) based on the end 2010 situation[63] for the universe of banks available in Bankscope.[64] The asset side includes the off-balance sheet items (mostly guarantees, committed credit lines and other contingent liabilities), whereby the total is above 100 percent.[65]

The graphs show that the portion of long-term customer loans on the banks' total business is about 50 percent, slightly higher for ECs (56 percent) and OECD banks (53 percent) and somewhat lower for banks in LICs (47 percent) and that total loans (customer loans and loans to banks) account for about two thirds of the balance sheet in all three regions. The main differences show up in terms of the composition of cash and securities held by banks: in terms of the most liquid assets (cash and government securities), LICs are best off (24 percent), followed by the ECs (19 percent), while OECD banks exhibit only 8 percent on average. However, banks in OECD countries hold more than 21 percent other securities, which can be used for fire sales provided that they are liquid. In sum, banks hold the same portion of securities which can, in principle be sold or pledged to generate liquidity (30 percent). In terms of off-balance sheet items, the OECD countries lead (22 percent) by a low margin, driven by a few countries with very substantial off-balance sheet items.

On the liability side, the differences are more pronounced, as the reliance on deposits is far higher in the ECs (65 percent) and LICs (73 percent) than in OECD countries (48 percent), while the opposite is true for wholesale funding, both short- (OECD: 17 percent: EC: 11 percent; LIC: 7 percent) and long-term (OECD: 17 percent: EC: 7 percent; LIC: 3 percent). Through the long-term funding, OECD banks make up a noteworthy portion of the gap in terms of deposit funding compared to ECs and LICs. It is also shown that banks in ECs and LICs are substantially less leveraged than banks in OECD countries, which increases the gap once more. The ultimate question becomes how the composition of funding sources related to the maturity profile, which is where maturity gap analysis, the second test category, comes into play.

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[61] In the first step, the unweighted average was computed for each country and then the unweighted average for the three country types.

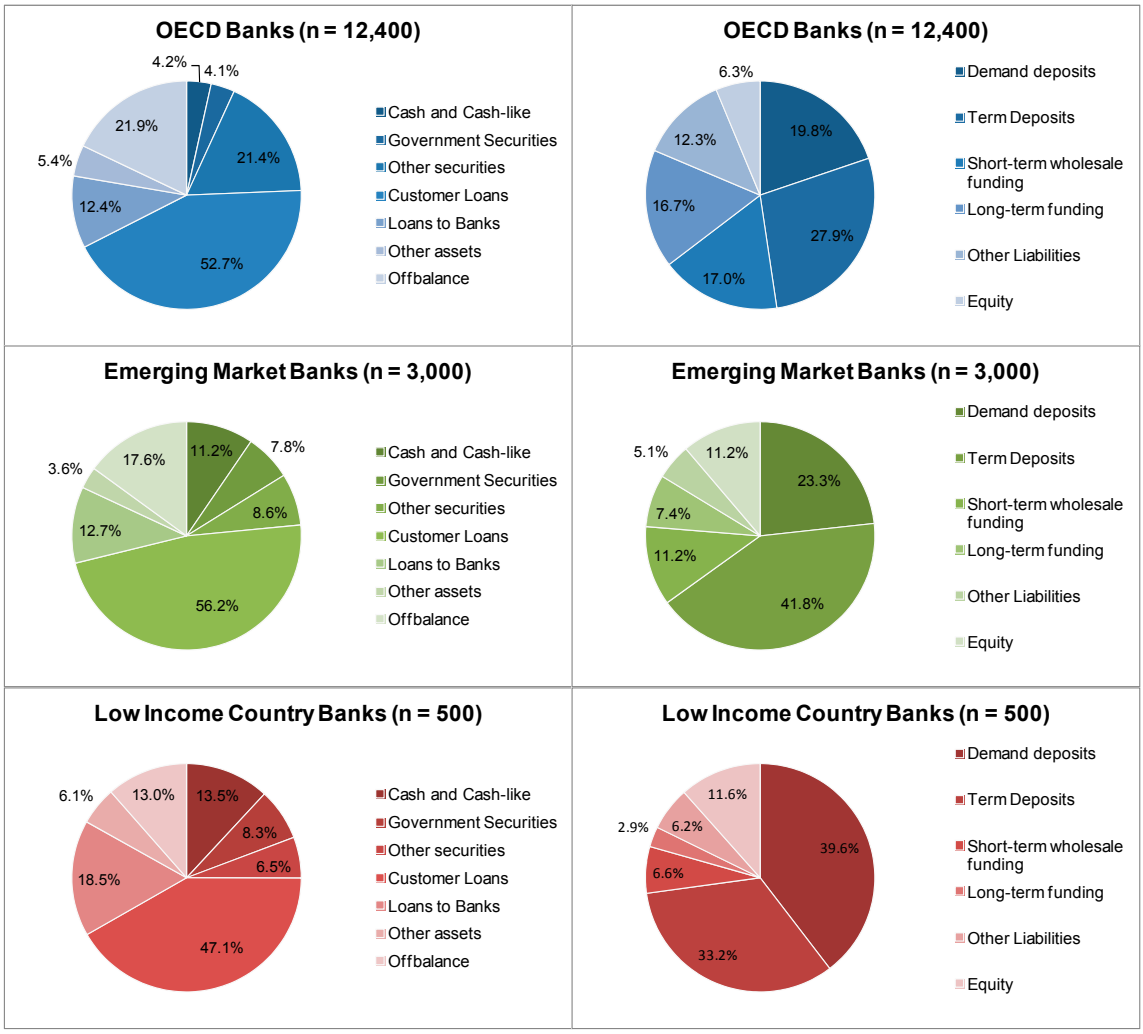
[62] The figures for the OECD country banks are closely in line with a study by the BCBS/FSB ("An assessment of the long-term economic impact of stronger capital and liquidity requirements", August 2010) for a sample of 6,600 banks in 13 OECD countries for the period from 1993 to 2007.

[63] For most banks, the data were from end 2010, otherwise mostly from 2009.

[64] It should be noted that the data contains a higher portion of banks in OECD countries, reflected by the fact that the median OECD bank is smaller than the median EC bank (but larger than the median LIC bank).

[65] The total percentage of all assets is 100 percent for the on-balance sheet items plus the off-balance sheet positions as a percentage of total assets.

**Figure AII.1 Composition of Assets (left) and Liabilities (right) for Banks in OECD Countries, ECs and LICs**




Source: Authors based on universe of Bankscope data for last available date (mostly end 2010). Please note that the sample of banks is biased towards advanced countries, and for emerging markets and low income countries tends to capture the larger banks only.
Note: All figures are relative to total assets; the asset side figures include off-balance sheet items, whereby the total is above 100 percent

## Appendix III. Details on all Modules of the Stress Testing Framework

### Implied Cash Flow Analysis (ICFA)

**Overview**

The global financial crisis has shown that a deposit run on a seemingly non-systemic financial institution such as Northern Rock can have serious implications not only domestically but also in cross-border terms. The ICFA module allows simulating a run on bank funding sources, both on wholesale deposits (in case of a name crisis and/or a general confidence crisis) as well as on retail and wholesale deposits (in case of a severe name crisis or a systemic banking crisis). This stress testing component extends Čihák (2007) by allowing for greater granularity on the asset and liability side of banks' balance sheets. The test pays particular attention to defining which assets remains liquid, and defining the level of market liquidity under stress, i.e., setting haircuts. By allowing for a gradual withdrawal of funds during 5 periods (e.g., days, weeks or months), the module allows assessing the point where specific banks and the system more generally become illiquid in a reverse test type manner; The module also contains a similar, cumulative liquidity test for 30 days/3 months, and keeps in line with Basel III by allowing running a (simplified) Basel III LCR test.[66]

**Assumptions**

In the assumptions' worksheet stress testers have to specify which asset categories remain liquid, the level of haircuts, if applicable, as well as the portion of assets that are unencumbered under stress. The liabilities are divided into demand and time deposits (both further broken down into retail/wholesale and domestic/foreign currency with the option to break down even further) as well as wholesale short-term and long-term funding on the interbank market. The user has to input assumptions for the percentage of deposit withdrawals and other funding sources per period (e.g., a day, week, month) in the 5 day/other period (30) day test. There is flexibility to decompose the deposit categories according to specific data availability.

The user can decide whether the assumptions apply to all banks uniformly. In the other case, there is a switch button to "bank-specific" from "market-wide/ uniform" in the results' worksheet that allows the user to manually input the assumptions for the asset and liability side of each bank. Please also note that funding withdrawal does not assume an explicit policy reaction but they can be implicitly incorporated by, for instance, modifying the level of haircuts and eligibility of unencumbered securities. Finally, any deposit withdrawal would also lead to a release of the according required reserves. It is advisable to include the required

[66] It should be noted that running the LCR test requires granular data and/or expert judgment.

reserves separate from cash and balances with the central bank on the asset side and then proportionally to the assumed deposit run-off rates include a release of required reserves with a haircut.[67]

For the LCR test, the user can make assumptions for the withdrawals of (less) stable deposits, which are defined as minimum ratios. While the other ratios are pre-defined, the tool allows simulating different parameter levels to test the sensitivity of the system.

**Results**

The results' worksheet for the five- period test provides the liquidity situation of each bank before the stress test. It then lists for each of the 5 periods the outflow of funding (by broad categories), the cumulative impact, as well as the inflow from fire sales of liquid assets for the first period. For each day, the change in net cash flows since the beginning of the test is computed, and most importantly, whether any bank becomes illiquid. The ICFA module therefore allows for an explicit examination whether and how long any bank can withstand a shock. Similarly, in the 30 day/3 months deposit run, the ex-ante liquidity position of each bank is listed, and then the outflow of funding and inflow of assets, the change in net cash flows and whether banks become illiquid. For all tests, a potential shortfall of funding is computed.

The designed LCR test already shows which banks are likely to be below the required ratios. A fully-fledged test requires comprehensive data, though. The outcome of the LCR test reveals the stock of high quality liquid assets, as well as potential cash outflow and cash inflows, and thereby the ratio of liquid assets (i.e. cash inflows to cash outflows). If the ratio is above 1, a bank is considered "safe", whereas the opposite is the case for ratios below 1. Again, a potential liquidity shortfall is calculated for each bank and the system as a whole, together with the LCR ratio(s).

Deposit runs are usually rare but when they happen they can cause large damages to the affected banks, their depositors, the financial system and its reputation. In the case of Northern Rock, the deposit run even exacerbated an already fragile financial system. The ICFA test is flexible enough to allow for different types of deposit runs (retail versus wholesale) and for a run on foreign deposits if currency mismatches play an important role in the banking system. The level of detail on both the asset and liability side makes the ICFA test more realistic especially since there are often differences among banks, and asset categories exhibit different liquidity levels and haircuts.

[67] For example, if the average level of required reserves is 10 percent and the average deposit run-off rate is 20 percent, then this would amount to a freeing of required reserves of ca. 20 percent so a haircut of 80 percent could be used.

## Maturity mismatch and liquidity rollover stress testing

### Overview

The global financial crisis has shown that many of the failed financial institutions suffered from a liquidity maturity mismatch caused by very short-term (wholesale) funding (and thereby a sizeable duration gap), making them vulnerable to a loss of confidence and counterparty credibility and an eventual liquidity squeeze. The liquidity gap analysis module matches liability and asset maturities and identifies liquidity gaps at each maturity bucket and under different scenarios. There are three different types of tests: (a) a static maturity gap analysis of each bank and the overall banking system; (b) a static maturity gap analysis taking into account rollover risks; and (c) a dynamic maturity gap analysis taking into account rollover risks. In the latter case potential liquidity gaps can be closed by free liquid assets at lower maturities (if available). This liquidity stress testing module allows for a clear examination of the funding structure by maturity buckets of each individual bank and the overall system. The module also implements the Basel III NSFR test.

### Assumptions

The assumptions' worksheet differentiates between the liabilities (overall liabilities and more granular buckets, such as interbank and long-term debt, if available) by maturity that cannot be rolled over (on a continuous basis) and the various asset categories. For the assets, the user has to input the level of illiquidity of each asset category and the asset-specific haircut for a fire sale to cover potential liquidity gaps at specific maturity buckets. There is also an assumption on the portion of loans that are reinvested when maturing.

The user can decide whether the assumptions apply to all banks uniformly. In the other case, there is a switch button to "bank-specific/manual" from "market-wide/ uniform" in the results' worksheet that allows the user to manually input the assumptions for the asset and liability side of each bank.

As all tests the liquidity rollover tool is designed for a non-intervention of central bank liquidity. But the assumptions' worksheet enables the user to specify the additional available central bank and intra-group funding (as percentage of bank liabilities) that could be used ex-post the stress test to cover part or the entire liquidity shortfall.

Finally, no explicit assumptions on the parameter have to be made for the NSFR, but weights different from the pre-defined ones could be simulated to assess sensitivity.

### Results

The results' worksheet first provides a descriptive (static) maturity mismatch analysis showing the total system and bank liquidity shortfall by maturity in amounts and in the number of banks that experience a possible shortfall in each maturity bucket. Second, the liquidity tool becomes dynamic and allows for free and liquid assets to close liquidity gaps in other maturity buckets. Suppose that bank X has a liquidity shortfall in maturity bucket "Due within 1 to 3 months," then excess liquidity in the maturity bucket "Demand" is automatically allocated to the shortfall maturity bucket. If not sufficient, then excessive liquidity from the next available maturity will be used until all liquidity gaps are closed or in the worst case, a shortfall position for a bank can be discerned. Ultimately, the test assesses up to what horizon banks remain liquid, and different thresholds to pass the tests can be set by the stress tester.

With the assumption on additional (collateralized) central bank funding (by percentage of liabilities), the user can specific how much central bank liquidity would be needed to close the liquidity gap by bank and system. Alternatively, the user can use common benchmarks from past liquidity crises domestically (or cross-country) or central bank regulations to discern the impact of central bank funding on alleviating the liquidity shortfalls.

The NSFR test to examine a structural maturity mismatch first calculates the available stable funding and then the required stable funding based on the different categories from the Basel III proposal followed by the ratio for each bank and the system and the according shortfall/ surplus.

**Cash Flow Data based Stress Testing**

**Overview**

A key prerequisite to carry out cash flow based liquidity tests is access to a wide range of data. Even though Basel III requires a maturity mismatch approach to liquidity monitoring in the future, only few jurisdictions already have such a monitoring tool in place.[68] The difference between cash flow tests run by banks and those run by authorities for monitoring purposes is that the latter requires standardized templates, which then allows simulating the impact of common shocks based on a uniform method.

The input data consist of contractual gross cash-flows in various buckets of residual contractual maturities (e.g. 1 day, 1 week, 1 month, 3 months, 6 months, 12 months, 2 years and more than two years). In addition, stock data is required for many items. The definition

[68] Given the implementation of Basel III via CRD IV framework in the European Union, uniform cash-flow templates for liquidity reporting / stress testing are likely to become a standard in other jurisdictions as well.

of items is usually tailor-made for liquidity stress tests and does not necessarily mimic traditional accounting / supervisory information.

The cash flow template in this paper / tool is structured in three broad categories: cash-inflows, cash-outflows, and the counterbalancing capacity (including stocks of liquid assets and haircuts). The template distinguishes between contractual in- and outflows[69] which are already fixed and behavioral cash flows which cover the expected cash flows banks use for their liquidity planning. Figures should be provided at the consolidated level (or sub-consolidated level for local subsidiaries of foreign banks). In order to enhance usability and for usage of the cash flow template as a monitoring tool, the user can always check the CF monitoring tabs that provide a bank specific overview on structure and the funding situation itself. If foreign currencies play an important role for a banking system, the template can be duplicated and submitted for all other significant foreign currencies.[70]

As is the case for all risk analysis, plausibility and robustness checks are required. In this context, the collection of comprehensive data provides a check on the quality of liquidity risk management at the banks in the jurisdiction and their compliance with the BCBS Principles of sound liquidity risk management and supervision.

The following table provides a detailed description of the default items within all three broad categories of the cash flow module:

| | |
|---|---|
| **Cash-flows** | The following positions contain all contractual (already fixed) and behavioural (expected) Cash Outflows. If a position that has a material liquidity risk is not covered by the predefined outflow items, they have to be aggregated within position for other cash flows.<br>All positions have to be split according to their contractual maturity into the corresponding buckets. Within the contractual Cash Flows no rollover of existing liabilities is assumed to take place. Behavioural (expected) cash flows reflect the banks funding plans for the following 12 month period.<br>Symmetry should always be obeyed and there should be no double counting of cash flows in the template at all. |
| **Contractual Outflows** | This section contains all contractual (already fixed) outflows split into 8 maturity buckets. For contractual cash flows the stock value should always equal the sum of all maturity buckets (since they cover an infinite time horizon) |
| Own issuances due | This position refers to the outflow of maturing |

[69] The template does not include the non-financial business related cash-flows, for example, from wages, facility management (office rents) and similar items.

[70] Given the variation in business models and activities across banks, a standardized template implies that banks only have to provide data on items and currencies in which they are exposed to material liquidity risk.

| | |
|---|---|
| | commercial papers (bonds, private placements, CDs, FRN, etc.) issued by the bank itself. The outflows also contain the principal the bank has to pay periodically. They have to be split according to their contractual maturity into the corresponding buckets. |
| Unsecured wholesale funding *due from non-financial corporates* | These wholesale positions refer to outflows resulting from maturing liabilities from various entities that are not secured by repos or similar. They usually differ from retail deposits in deposit size, higher concentration and higher professionalism of the counterparties.<br>Financial institutions are Monetary Financial institutions (MFIs) excluding central banks (predominantly banks and credit institutions) while financial corporates refer to other undertakings that provide financial services (e.g. insurance).<br>The line for Institutional networks is only relevant for credit institutions that are part of a tiered sector structure (e.g. cooperative banks with an apex institution) and should be used to reflect deposits placed by other members of that network. |
| Unsecured wholesale funding *due from financial corporates* | |
| Unsecured wholesale funding *due from financial institutions* | |
| Unsecured wholesale funding *due from government/ public entities* | |
| Unsecured wholesale funding *due from institutional networks* | |
| Secured wholesale funding due, *secured by sovereign debt 0 percent r/w* | In contrast to the items above this section refers to outflows from maturing liabilities that are secured (e.g. repos, etc.). The items are split according to the quality of the security instruments used.<br>A repo will create a cash outflow at its maturity date; correspondingly the security which has been repoed out will enter as a positive value in the maturity bucket in which the repo transaction matures in the Counterbalancing Capacity (security inflow).<br>Risk weights for asset classes follow the Basel II standardized approach. |
| Secured wholesale funding due, *secured by sovereign debt 20 percent r/w, covered bonds up to AA-, non-financial corporates* | |
| Secured wholesale funding due, *secured by equity* | |
| Secured wholesale funding due, *secured by other instruments* | |
| Repos due with central banks | Outflows resulting from maturing open market operations with Central Banks are included in this section. The security which is repoed out will enter the corresponding unencumbered CB eligible collateral position in the Counterbalancing Capacity in the same maturity bucket (security inflow). Rollover is not assumed to take place here. |
| Retail (incl. SME) funding due*, term deposits* | Contractual retail and SME deposit maturities should be reported in this section.<br>Term deposits are commonly reported according to their maturity buckets, demand deposits should be reported in the "1 Day" maturity bucket. |
| Retail (incl. SME) funding due, *demand deposits* | |
| Outflows from derivatives (other than FX-Swaps) | Outflows from derivatives refer to contractual flows only. |
| Outflows from maturing FX-Swaps | The Outflows from maturing FX Swaps (including also cross currency swaps) result from the rescindment of the FX Swap at the end of its maturity. The Cash Flows have to be split according to the currencies with material liquidity risk. (e.g. If USD outflows are swapped for EUR inflows create an EUR outflow and a USD inflow at maturity) |
| Other contractual outflows | This position is intended to include all other contractual outflows that do not match the description for the predefined items above, but have an impact on liquidity |

| | |
|---|---|
| | risk. Typically this would be significant outflows like dividends or tax payments (no operating expenses) |
| **Behavioral Outflows** | Due to the fact that a serious estimation of expected in-/ outflows can't be quantified for an indefinite time horizon the behavioural section covers only the maturity buckets up to the next 12 months.<br>Assumptions should always be conservative and reflect the current macroeconomic conditions as well as the experience of the bank in former time periods. Ideally they are based on solid statistical evidence. The data would usually stem from the banks' business plans for the next year. |
| Expected new loans | This position should reflect a modelled / planned estimation of outflows resulting from all new loans the bank is going to grant within the next 12 months (Wholesale and Retail/SME). This estimation should be conservative and should be in line with former periods. |
| Expected new financial investments | If a bank plans to invest in financial assets (e.g. bonds). If these will be a part of the counterbalancing capacity, they have to be reflected also in the corresponding line of that section, so that the final position of the cumulated counterbalancing capacity remains unchanged (security inflow). |
| Expected outflow and stock volume of undrawn committed credit/liquidity lines *of financial institutes (incl. SPVs)* | The stock value should reflect the sum of all committed lines the bank has granted. Banks should report the maximum exposure to an (unconsolidated) SPV based on the SPV's current debt maturities. The outflows should reflect conservative expectations of the lines that are going to be drawn over the next 12 months and should take into account macroeconomic conditions, past experience and statistical assumptions. |
| Expected outflow and stock volume of undrawn committed credit/liquidity lines *of others (corp., gov, etc.)* | |
| Expected outflows from new FX-Swaps | This covers the outflows due to new FX Swaps a bank is expecting within the next 12 months. The Cash Flows have to be split according to the currencies with material liquidity risk. (e.g. If USD outflows are swapped for EUR inflows create an EUR outflow and a USD inflow at maturity) |
| Expected other behavioral outflows | All other outflows that the bank expects to happen in the next 12 months that do have a material impact on the liquidity situation and that do not fit into a category above should be included here. |
| **Contractual Inflows** | This section contains all contractual (already fixed) inflows split into 8 maturity buckets. For contractual cash flows the stock value should always equal the sum of all maturity buckets (since they cover an infinite time horizon) |
| Maturing loans to financial institutions | This position covers all inflows that result from contractual (already fixed) credit claims split by financial institutions (interbank deposits) and all other entities. |
| Other maturing loans (including installments) | |
| paper in own portfolio maturing | This line covers inflows that result from maturing papers and should also include principal from marketable securities held by the reporting institution. There should be no double-counting of inflows reported on other lines. If the maturing paper influences the counterbalancing capacity it has to be also subtracted in the corresponding |

| | |
|---|---|
| | CBC maturity bucket (security outflow). |
| Reverse repos, *secured by sovereign debt 0 percent r/w* | A reverse repo will create in inflow at maturity date. Reverse repos should be booked with the cash inflow at maturity in these lines corresponding to the risk weights. Risk weights for asset classes follow the Basel II standardized approach. The counterbalancing capacity will be reduced by the corresponding amount (security outflow). |
| Reverse repos, *secured by sovereign debt 20 percent r/w, covered bonds up to AA-, non-financial corporates* | |
| Reverse repos*, secured by equity* | |
| Reverse repos*, secured by other instruments* | |
| Inflows due to maturing FX-Swaps | The Inflows from maturing FX Swaps (including also cross currency swaps) result from the rescindment of the FX Swap at the end of its maturity. The Cash Flows have to be split according to the currencies with material liquidity risk. |
| Inflows from derivatives (other than FX-Swaps) | The inflow of derivatives refer to contractual flows only |
| Other contractual inflows | This position is intended to include all other contractual inflows that do not match the description for the predefined items above. (e.g. sale of a business unit) |
| **Behavioral Inflows** | Due to the fact that a serious estimation of expected in-/ outflows can't be quantified for an indefinite time horizon the behavioural section covers only the maturity buckets up to the next 12 months.<br>Assumptions should always be conservative and reflect the current macroeconomic conditions as well as the experience of the bank in former time periods. Ideally they are based on solid statistical evidence. The data would usually stem from banks' funding plans for the next year. |
| Expected new debt issuances | This position refers to the expected inflow created by new placements of debt / own issuances a bank is planning within the next 12 months. |
| Expected new retail deposits | The expected funding by retail and wholesale deposits within the next 12 months has to be conservative and should be based upon the expected macroeconomic conditions and should reflect experience from former periods.<br>Inflows from expected new repo transactions refer to secured wholesale funding. If a repo causes also an outflow in commercial papers the corresponding positions within the expected outflow section and position within the counterbalancing capacity have to be adjusted appropriately. |
| Expected new secured wholesale funding | |
| Expected new unsecured wholesale funding | |
| Expected inflows due to new FX Swaps | This covers the inflows due to new FX Swaps a bank is expecting within the next 12 months. The Cash Flows have to be split according to the currencies with material liquidity risk. (e.g. If USD outflows are swapped for EUR inflows create an EUR outflow and a USD inflow at maturity) |
| Expected other behavioral inflows | All other inflows that the bank expects to happen in the next 12 months that do have a material impact on the liquidity situation and that do not fit into a category above should be included here. |
| **Counterbalancing Capacity - contractual and behavioural Security** | The 'Counterbalancing Capacity' contains information on the institutions' holdings of liquid assets. Assets are |

| | |
|---|---|
| **Flows** | divided into relevant subgroups based on asset characteristics, such as central bank eligibility. Like in the Cash Flow section, the CBC is also differs between contractual and behavioural security flows. (if for example repos from behavioural in-/outflows trigger a change in the liquid asset composition used for counterbalancing, these effects should be reported in the behavioural security flow section of the CBC)<br>All the assets reported in the counterbalancing capacity must be unencumbered.<br>The column 'stock' contains the current unencumbered stock of assets available to the institution. The Maturity buckets contain contractual and expected flows of securities in the counterbalancing capacity.<br>Institutions should apply haircuts (orange box) reflecting conservative assessments about the marketability of the assets in each class and the possibility to be used in repo transactions.<br>Cash-inflows are not to be accounted for in the 'Cash and Central Bank reserves' position in the 'Counterbalancing Capacity' to avoid double counting.<br>Negative flows should be reported for securities at their maturity date or at the maturity of reverse repos. Positive flows should be reported at the maturity of repo transactions, or at the settlement date or any purchases. Corresponding cash flows should be reported in the inflows or outflows section of the template. |

Source: Authors.

**Assumptions**

In the Assumption's worksheet the stress tester specifies the ratio of the various contractual and behavioral cash flows that will be rolled over on a continuous basis for each time bucket. Concerning the security flows to counterbalance the net outflow of funding the user has to apply haircuts on the contractual and behavioral security flows with regard to the stress scenario. For potential counterbalancing assets the user can also set haircuts for asset prices.

The stress tester can either choose to use general assumptions that apply to all banks uniformly or to set bank specific haircuts and roll over rates in order to differentiate between single banks due to an idiosyncratic stress scenario.

**Results**

The result sheet contains the (cumulative) funding gaps and the corresponding (cumulative) counterbalancing capacity for each maturity bucket after haircuts and roll over rates. These can be compared across banks and with the aggregated banking system. A positive counterbalancing capacity over the observation period is the main indicator for the funding

situation of the bank and serves as pass criterion for the fully-fledged cash flow analysis. However, the user can adjust the pass criterion for each maturity bucket in which banks have to remain liquid.

**Liquidity and solvency**

**Overview**

There is a natural link between solvency and liquidity, and as the recent global financial crisis has shown, they can reinforce each other. For example, during the European crisis in the spring of 2010, market concerns about solvency of some sovereigns as well as their domestic banks led to a liquidity crisis with banks finding it harder to access wholesale and interbank funding and haircuts increasing for collaterals at the ECB. Downgrades by rating agencies exacerbated this situation.

This liquidity stress testing tool allows simulating the link between liquidity and solvency from three different complementary perspectives. First, it simulates the increase in funding costs from a change in solvency (based on a simplified macro-financial credit risk model, which should be re-calibrated to country-specific circumstances) or a rating downgrade. Second, the tool allows simulating the (partial) closure of funding markets (both long and short-term) depending on the level of capitalization. Central bank and intra-group funding as well as the sale of liquid assets (subject to a haircut) can partly compensate for the liquidity drain. Third, it examines the impact of concentration risk on funding, both in terms of name concentration (through wholesale funding) and concentration in specific currencies, again with the possibility of additional central bank funding and sales of liquid assets. To cater to the needs of the first two tests, the liquidity framework hosts a simplified solvency template. For most sophisticated tests, a fully-fledged solvency tool (such as Schmieder, Puhr and Hasan 2011) should be used.

**Assumptions**

For the *first* stress test on the increase in funding costs arising from a change in solvency and a rating downgrade, the user can either refer to the bank-specific one-year PD or the equivalent external rating. The mapping between the ratings and the PD is based on empirical evidence observed by Moody's during the last three decades (from 1983 to 2009). The link between funding costs and a bank's default probability has to be determined based on a regression model (there is a pre-defined model, but country-specific circumstances vary widely). Depending on the number of notches a bank is simulated to be downgraded the funding costs will increase accordingly, which feeds back to a solvency ratio under stress. The test reveals the additional loss of solvency (capitalization) under stress, and is meant to be linked to a solvency test. It is crucial to decide on the portion of the funding costs to be passed on to customers, which alters the situation of banks.

For the *second* stress test, the user needs to specify whether either Tier 1 capital or the total capital ratio is used for the liquidity/ solvency test. Then assumptions have to be made for the threshold for the closure of funding markets (long and short-term) conditional on the capital ratio. It is important that the capital threshold is based on historical evidence and/or expert judgment. Finally, the user decides whether there's additional inflow of cash through central bank funding and/or intragroup support (intragroup support could also be negative) as well as the inflow of assets (e.g. through fire sales and subject to an appropriate asset-specific haircut).

For the third stress test on the simulation of the impact on funding concentration, there are two different tests (a) in the first test, the user selects the number of the largest (non-intra-group) liquidity providers assumed to default (0-5) as well as the underlying recovery rate; and (b) the second test simulates the liquidity position of a bank if funding for different currencies closes. Again, assumptions have to be made with respect to intragroup funding and central bank funding.

The user can decide whether some of the assumptions apply to all banks uniformly. The manual data entry worksheet allows for bank-specific assumptions on the inflow of cash from fire asset sales. For the concentration risk solvency test both the central bank funding and change in intra-group funding can vary by bank.

**Results**

The results' worksheet provides an overview for the three liquidity and solvency stress testing modules. For the *first* stress test on the link between ratings/ PD and funding costs, the key result is the ex-post total capital (tier 1) ratio *without/ with* the increase in funding costs (which reveals the additional number of failures due to higher funding costs). The liquidity stress test without the funding cost component is just the simplified macro-financial credit risk stress test. Adding the funding costs explicitly links solvency to liquidity. This provides an easy examination whether credit or liquidity risks (in terms of their contribution to the ex-post capital ratio) are more important for individual banks and the system. The user can specify a desired hurdle ratio for the chosen capital ratio (tier 1 or total) which then gives the number of banks that fail due to the funding shock alone.

For the *second* stress test on the closure of funding costs depending on the capital level, the results show the loss of funding (short and long term), the available assets to compensate from additional central bank and intra-group funding and sale of liquid assets and finally, whether any bank or the system has become illiquid from the liquidity shock.

In similar vein, for the third stress test on the impact of concentration risks on bank funding, the results break down the overall loss of funding due to concentration risk (from the default

of a number of liquidity providers or due to a closure of funding for a specific currency). It then lists available assets (both central bank funding, intra-group funding and liquid assets) to compensate for the loss of funding as well as whether any bank/ the system have become illiquid.

# Appendix IV. Additional Information on Scenario Specification

## Historical Scenarios

### Deposit run on Northern Rock in 2007

Northern Rock was a former building society that, having demutualized in 1997, began to expand rapidly. By the end of 2006, its assets had grown six-fold to £101 billion. This expansion was aided by the increasing reliance on wholesale funding, comprising about three-quarters of total funding, with over 40 percent alone in residential mortgage-backed securities (as shown in Appendix IIII, the OECD average is 28 percent). Only a quarter of total funding (OECD average: 44 percent) came from deposits, down from nearly two-thirds in 1997.

Beginning in August 2007, concerns about exposure to U.S. subprime mortgage assets led wholesale markets to seize up. Northern Rock came under pressure, as it was able to find only limited liquidity in wholesale markets. A retail run, the first significant bank run in the U.K. since 1878, began on September 14. Northern Rock faced heavy withdrawals, and its share price halved. Although most withdrawals were made through the internet, phone, or mail, lines forming outside some branches were the most visible sign of the run. The run was stopped only when the Chancellor, on September 17, announced arrangements to guarantee all existing deposits in Northern Rock, "during the current instability in the financial markets."

In terms of withdrawal magnitudes, according to Shin (2009), between December 2006 and December 2007, overall retail funding fell from 24.4 to 10.5 billion pounds. While typical branch based customer deposits only fell from 5.6 to 3 billion pounds, withdrawals on phone, internet and offshore deposits were relatively larger. In addition, the wholesale funding squeeze was substantial with overall wholesale funding falling from 26.7 billion pounds in June 2007 to 11.5 billion pounds in December 2007.

### Deposit run on Latvian Parex Bank in 2008

Latvia's second-largest bank (the largest domestic bank), Parex, was nationalized to maintain its solvency in 2008 by the national government after a run on deposits took it to the brink of bankruptcy. Parex, with 3.1bn lats ($5.6bn) in assets, lost 25 percent of its deposits from end-August to end-November 2008 (i.e., within 3 months).

### Wholesale funding squeeze for Kazak Banks

Over 2002–07, banks were able to sustain rapid expansion of their balance sheets through high levels of foreign borrowing. Banking sector external debt, facilitated by high economic growth and a burgeoning oil sector, grew to about 44 percent of GDP by 2007 (nearly

$45 billion) from around 6 percent in 2002. During this period, the loan to deposit ratio nearly doubled, peaking above 200 percent in 2007, which was among the highest relative to comparable countries. Limited (tenge) deposits—as well as a lack of tenge term liquidity—encouraged banks to take advantage of cheap foreign capital, which was largely channeled to risky sectors, and to borrowers without foreign currency income streams.

Half the funding for the banking sector in Kazakhstan came from the wholesale market. A combination of structural weaknesses and external factors left the Kazakhstani banking system highly vulnerable to the sudden stop in capital flows. This contributed to the failure of two large banks and two smaller institutions. The authorities were forced to intervene in two top banks, take stabilizing equity stakes in two other leading banks, and provide widespread liquidity support, including the targeted placement of deposits of state owned enterprises throughout the system.

**Deposit runs on Icelandic Banks**

The size of Iceland's banking sector was about nine times the country's gross domestic product (GDP) at the end of 2007, funded largely by external debt. The banking system was dominated by three large commercial banks, Kaupthing Bank hf. ("Kaupthing"), Landsbanki Íslands hf. ("Landsbanki") and Glitnir banki hf. ("Glitnir"). The banks had relied heavily on market funding for their operations, and had previously been criticized for a lack of diversification in their funding profile, in particular, for the low proportion of deposits in their funding. As a result, these banks intensified their focus on gathering deposits, and successfully so. At the end of 2007, some 40 percent of their funding was in the form of deposits, up from 28 percent in 2006, with more than two-thirds sourced from non-residents.

Iceland's banking sector collapsed in early-October 2008, following severe liquidity and solvency problems at the banks and collapse of the exchange rate. On September 29, 2008, the Prime Minister announced that an agreement had been reached between the Government and the largest owners of Glitnir, the country's third largest bank, whereby the government would contribute new share capital and take up a 75 percent stake in the bank. A week later, on October 6, Iceland's parliament, the *Althing*, passed emergency legislation enabling the government to intervene extensively in Iceland's financial system. On October 7, the FME put Landsbanki into receivership; Glitnir and Kaupthing followed on October 8 and 9, respectively. By that stage, the three banks combined had amassed debt of an estimated $61 billion—about 12 times the size of Iceland's economy—and were unable to secure short-term funding to continue servicing their obligations. A number of private interbank credit facilities to Icelandic banks were shut down, and banks were unable finance their debts through short-term borrowing. In an attempt to alleviate depositor concerns, the government offered an unlimited guarantee to all depositors in banks and branches in Iceland. By that stage, however, deposit runs on the overseas branches of Icelandic banks had already started (Ong and Čihák, 2010).

## Haircuts for Liquid Assets

Treatment of Marketable Securities by the ECB (2011)

**Table AIV.1: Liquidity Categories for Marketable Assets Used by the European Central Bank (ECB 2011)**

| Category I | Category II | Category III | Category IV | Category V |
|---|---|---|---|---|
| Central Government Debt Instruments | Local and regional government debt instruments | Traditional covered bonds | Credit institution debt instruments (unsecured) | Asset back securities |
| Debt instruments issued by Central Bank | Jumbo covered bonds | Debt instruments issued by corporate and other issuers | Debt instruments issued by financial corporations other than credit institutions (unsecured) | |
| | Agency debt instruments | Other covered bank bonds | | |
| | Supranational debt instruments | | | |

**Table AIV.2: Haircuts Applied to Eligible Market Securities (ECB 2011)**

| Credit quality | Residual Maturity (years) | Category I | | Category II | | Category III | | Category IV | | CV |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | |
| AAA to A- | 0-1 | 0.5 | 0.5 | 1 | 1 | 1.5 | 1.5 | 6.5 | 6.5 | 16/1 |
| | 1-3 | 1.5 | 1.5 | 2.5 | 2.5 | 3 | 3 | 8.5 | 9.0 | |
| | 3-5 | 2.5 | 3 | 3.5 | 4 | 5.0 | 5.5 | 11.0 | 11.5 | |
| | 5-7 | 3 | 3.5 | 4.5 | 5 | 6.5 | 7.5 | 12.5 | 13.5 | |
| | 7-10 | 4 | 4.5 | 5.5 | 6.5 | 8.5 | 9.5 | 14.0 | 15.5 | |
| | >10 | 5.5 | 8.5 | 7.5 | 12 | 11 | 16.5 | 17.0 | 22.5 | |

1/ Some additional conditions apply to this category.

| Credit quality | Residual Maturity (years) | **Category I** | | **Category II** | | **Category III** | | **Category IV** | | **CV** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | Fixed Coupon | Zero Coupon | |
| BBB+ to BBB- | 0-1 | 5.5 | 5.5 | 6.0 | 6.0 | 8.0 | 8.0 | 15.0 | 15.0 | NA |
| | 1-3 | 6.5 | 6.5 | 10.5 | 11.5 | 18.0 | 19.5 | 27.5 | 29.5 | |
| | 3-5 | 7.5 | 8.0 | 15.5 | 17.0 | 25.5 | 28.0 | 36.5 | 39.5 | |
| | 5-7 | 8 | 8.5 | 18.0 | 20.5 | 28.0 | 31.5 | 38.5 | 43.0 | |
| | 7-10 | 9 | 9.5 | 19.5 | 22.5 | 29.0 | 33.5 | 39.0 | 44.5 | |
| | >10 | 10.5 | 13.5 | 20.0 | 29.0 | 29.5 | 38.0 | 39.5 | 46.0 | |

**Scenarios used in FSAPs**

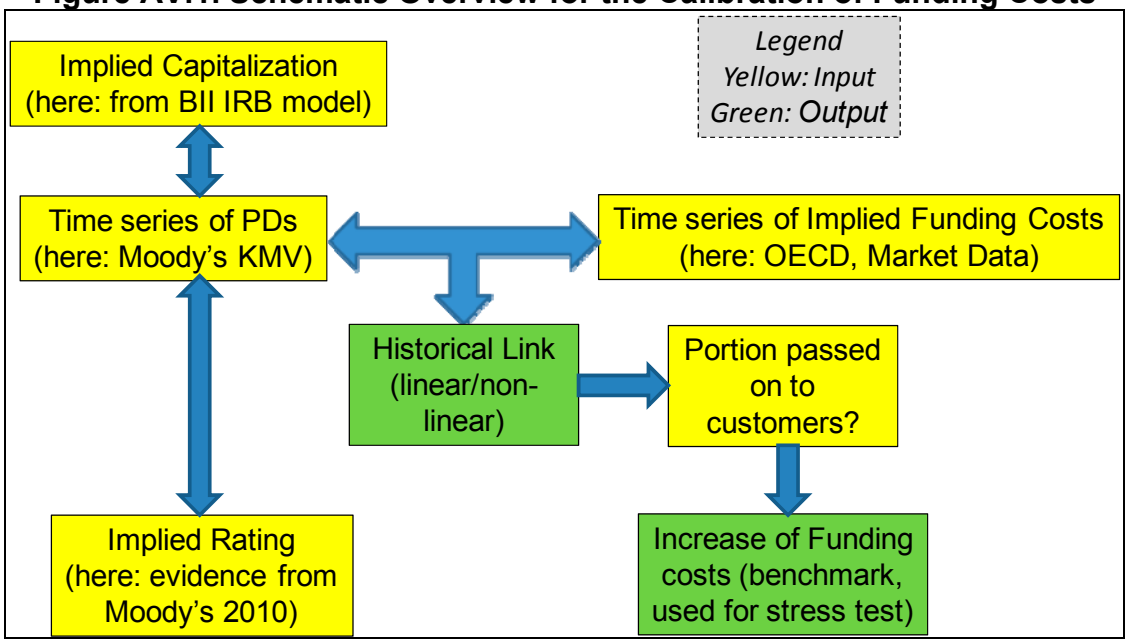
## Table AIV.3. Liquidity Risks Stress Tests as Part of the Recent FSAPs

| Liquidity Outflows | Example 1 | Example 2 | Example 3 |
|---|---|---|---|
| Deposits | | | |
| *Retail* | Russia (2008): 30 percent | Austria (2007): 50 percent of ST nonbank customers | Ireland (2006): 10,30 and 50 percent |
| *Corporate* | Russia (2008): 30 percent of current and 5 percent of time deposits | Serbia (2009): 2 percent daily for 5 days | Spain (2005): 10-20 percent of demand deposits (retail and corporate) |
| *Government* | UAE (2007): 35 percent | | |
| *Non-resident* | UAE (2007): 30 percent | Belarus (2008): 25,50 and 75 percent (both households and corporates) | |
| *Foreign bank* | Lithuania (2007): 80 percent | | |
| Other funding | | | |
| *Interbank* | Russia (2008): No access | UAE: 30 percent of foreign interbank funding | Lithuania (2007): 100 percent of domestic interbank deposits |
| *Credit Lines granted by banks* | Romania (2009): Limited access to committed and uncommitted lines | | |
| *Parent Funding* | Lithuania (2007): 50 percent of liabilities to parent | Romania (2009): Limited access | Serbia (2009): Full withdrawal with maturity of less than 1 year |
| *Contingent liabilities* | South Africa (2008): Tapping 50 percent of committed credit lines | | |
| **Liquidity Inflows** | **Example 1** | **Example 2** | **Example 3** |
| *Definition of Liquid Assets* | Varies widely, most conservative: only cash and government bonds remains liquid | Isle of Man (2008): Interbank funding and intra-group funding not available | |
| *Haircuts on Liquid Assets* | Austria (2007): Decrease in value of liquid bonds by 25 percent and equity by 35 percent | Ireland (2006): 10, 20 percent for debt securities and government bonds. | Russia (2008) and South Africa (2008): 20 percent on liquid assets |
| *Shrinkage of Eligible Collateral below Threshold* | Austria (2007): Eligible colllateral in secured mkt shrinks by 30 percent and 30 percent of the eligible assets become ineligible (i.e., their rating falls below single A). | | |
| Note: ST = Short-term | | | |

Source: Authors.

## Appendix V. Link Between Solvency and Liquidity

**Figure AV.1. Schematic Overview for the Calibration of Funding Costs**




*Illustrative example for a sample of large German banks*

| Rating | EDF or PD (One-year, Percent) | Funding costs (spread above T-bills, bps) | Economic capital ratio (Basel II (quasi-IRB) | Change of Funding spread (CAR Elasticitity) |
|---|---|---|---|---|
| AAA | 0.00004 | 8.7 | 28.1% | |
| AA+ | 0.00006 | 8.7 | 27.3% | 0.00 |
| AA | 0.0001 | 8.7 | 26.2% | 0.00 |
| AA- | 0.001 | 8.9 | 21.2% | 0.00 |
| A+ | 0.002 | 9.0 | 19.7% | 0.00 |
| A | 0.026 | 11.9 | 14.3% | -0.01 |
| A- | 0.032 | 12.7 | 13.9% | -0.02 |
| BBB+ | 0.1 | 21.0 | 11.7% | -0.04 |
| BBB | 0.139 | 25.9 | 11.1% | -0.08 |
| BBB- | 0.291 | 44.6 | 9.9% | -0.15 |
| BB+ | 0.682 | 92.7 | 8.5% | -0.35 |
| BB | 0.728 | 98.4 | 8.4% | -0.57 |
| BB- | 1.791 | 229.4 | 7.1% | -1.03 |
| B+ | 2.45 | 310.5 | 6.7% | -2.01 |
| B | 3.827 | 480.2 | 6.2% | -3.16 |
| Note: capital ratio includes 2.5 ppt voluntary buffer above regulatory minimum; funding costs without equity costs | | | | |

Source: Authors based on Moody's KMV and OECD data.

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