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Macroprudential Liquidity Stress Testing in FSAPs for Systemically Important Financial Systems

by Andreas A. Jobst, Li Lian Ong and Christian Schmieder

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Abstract

Bank liquidity stress testing, which has become *de rigueur* following the costly lessons of the global financial crisis, remains underdeveloped compared to solvency stress testing. The ability to adequately identify, model and assess the impact of liquidity shocks, which are infrequent but can have a severe impact on affected banks and financial systems, is complicated not only by data limitations but also by interactions among multiple factors. This paper provides a conceptual overview of liquidity stress testing approaches for banks and discusses their implementation by IMF staff in the Financial Sector Assessment Program (FSAP) for countries with systemically important financial sectors over the last six years.

JEL Classification Numbers: C58, F3, G21, G32.

Keywords: Basel III, cash flow-based approach, liquidity risk, liquidity coverage ratio (LCR), net stable funding ratio (NSFR), solvency risk, stress testing.

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I. INTRODUCTION

The global financial crisis (GFC) underscored the critical importance of sound liquidity risk management for individual financial institutions, and consequently, for overall financial stability. A defining characteristic of the GFC was the simultaneous and widespread dislocation in funding markets which uncovered the weaknesses in banks' liquidity profiles, particularly their increased reliance on short-term wholesale funding and high levels of leverage. Funding weaknesses were rapidly propagated through a highly interconnected global financial system, triggering contagion across financial institutions and systems and amplifying solvency concerns (IMF, 2008, 2010a, and 2011a).

In the wake of the crisis, the focus of the financial industry and authorities rapidly turned to the shortcomings in liquidity risk management practices. The now-obvious vulnerabilities had been, for the most part, undetected leading up to the crisis. In hindsight, the omission could be attributed to a general lack of understanding (compared to the more familiar solvency risk) of—and hence insufficient attention to—funding maturity and currency mismatches at the time. In the aftermath, the regulatory perimeter was expanded to push banks to better manage and mitigate risks arising from their funding profiles.

This paper provides a conceptual overview of liquidity stress testing approaches developed by IMF staff and a survey of their application in assessing system-wide vulnerabilities to market and funding liquidity risks in the context of the *Financial Sector Assessment Program* (FSAP), focusing on countries with systemically important financial sectors. It is the companion paper to Jobst, Ong and Schmieder (2013), which reviews the IMF's bank solvency stress testing. In keeping with the mandate of the FSAP, the paper focuses on the *bilateral* surveillance of bank liquidity risk for macroprudential purposes, i.e., the extent to which disruptions to banks' liquidity management as a result of funding shocks results in system-wide vulnerabilities. The information in this paper also complements an internal guidance note ("Guidance Note") on liquidity stress testing for IMF staff (Catalán, 2015) by reviewing its implementation in FSAPs, including with cross-country comparisons.[2]

Consistent with market and regulatory developments, liquidity stress testing has become a core element of financial stability analysis in FSAPs, where solvency stress testing had historically been the primary focus. In doing so, IMF staff has taken steps to:

- Take stock of liquidity risk management practices (e.g., IMF, 2010a and 2011a);
- Improve liquidity stress tests by examining gaps in their previous design (e.g., Ong and Čihák, 2010; Schmieder and others, 2012; Schmitz, 2015);

[2] The *Guidance Note* is centered on the implementation of a stress testing methodology that focuses on the time structure of contractual cash flows. While the *Guidance Note* is an internal document for use by the IMF staff, the current version is also available upon request by the authorities of IMF member countries. A further revised and updated version of the *Guidance Note* is forthcoming.

- Develop methods to identify systemic liquidity risk (e.g., IMF, 2011a; Jobst, 2014); and

- Build models linking liquidity and solvency risks for more robust stress tests (e.g., BCBS, 2013b and 2015); the IMF's 2014 *Review of the FSAP* (IMF, 2014a) explicitly examines systemic effects encompassing the interaction of different risk types within and across the various financial sectors.

We consider the most recent FSAPs undertaken in 34 significant jurisdictions that completed an FSAP exercise between September 2010 and December 2016. This group comprises: (i) 29 countries identified by the IMF as having systemically important financial systems ("S-29"), which are subject to mandatory assessments every five years (IMF, 2010b, 2013a and 2014);[3] and (ii) the remaining five other G-20 members that are not among the S-29, as presented in Table 1 below. However, our sample for this paper excludes three of these 34 countries since liquidity stress tests were not part of the FSAPs for the European Union, Luxembourg and Mexico.

In reviewing the general concepts underpinning liquidity stress tests and their implementation in FSAPs, the paper covers the following elements:

- *Providing the rationale for liquidity stress testing.* It presents the conceptual underpinnings of liquidity stress tests, including the regulatory framework established in recent years as well as the premise for and challenges to liquidity stress testing.

- *Setting out a framework for macroprudential liquidity stress testing.* The framework introduces a taxonomy of the main building blocks of system-wide liquidity stress testing—the scope, data requirements, methodology and final output—to classify and compare the various approaches applied to FSAPs.

- Reviewing the parameters adopted in past FSAPs for the systemically important financial systems based on a comprehensive, cross-country Stress Testing Matrix (STeM). The information reflects the extent to which countries have elected to disclose the methodology and findings of the stress testing exercise in the respective Financial System Stability Assessment (FSSA) reports and accompanying Technical Notes on Stress Testing (Appendix I, Appendix Table 1).

- *Providing publicly available information on liquidity stress testing* to help country authorities prepare for future FSAPs and readers seeking to develop their own stress testing framework.[4]

[3] Note that Hong Kong, SAR, is not an independent country but part of the P.R. China; however, it was included in the sample due to its classification as a jurisdiction with a systemically relevant financial sector.
[4] The detailed information on the scope and specifications of the FSAP exercises may be useful reference for these purposes, together with the *Guidance Note* (Catalán, 2015).

While continuing efforts are being made by IMF staff to standardize FSAP liquidity stress tests, it is neither possible nor desirable to do so under all circumstances. In fact, the STeM reveals that the liquidity stress tests undertaken across FSAPs are far more heterogeneous than for solvency stress tests. There are several reasons for this:

- Each financial system has its own particular features, which also require qualitative factors and consequently, expert judgment, to be incorporated into the design of these stress tests.

- The availability and quality of data influence the choice of appropriate methods in ensuring the reliability and credibility of the results.

- The extent of the collaboration with the authorities (and individual banks) plays a crucial role.

The paper is organized as follows. Section II sets out the premise for running liquidity stress tests and discusses the conceptual underpinnings. Section III details the various components and elements of the liquidity stress testing framework and their application to individual FSAPs. The caveats to liquidity stress tests are presented in Section IV. Section V concludes with a discussion on advances in liquidity stress tests and areas for future improvement.

Table 1. S-29 and Other G-20 Countries: Status of FSAPs since FY 2010 S-29 and Other G-20 Countries: Status of FSAPs since FY 2010

Rank	Jurisdiction	Grouping	Completed FSAPs since FY2010		Reference	
1	United Kingdom	S-25/S-29*, G20, G7	2011, 2016		IMF (2011d), IMF (2016b)	
2	Germany	S-25/S-29*, G20, G7	2011, 2016		IMF (2011h), IMF (2016c)	
3	United States	S-25/S-29*, G20, G7	2010, 2015		IMF (2010c), IMF (2015c)	
4	France	S-25/S-29*, G20, G7	2012		IMF (2013f)	
5	Japan	S-25/S-29*, G20, G7	2012		IMF (2012c)	
6	Italy	S-25/S-29*, G20, G7	2013		IMF (2013h)	
7	Netherlands	S-25/S-29*	2011		IMF (2011b)	
8	Spain	S-25/S-29*	2012		IMF (2012b)	
9	Canada	S-25/S-29*, G20, G7	2014		IMF (2014c)	
10	Switzerland	S-25/S-29*	2014		IMF (2014e)	
11	P.R. China	S-25/S-29*, G20	2010		IMF (2011f)	
12	Belgium	S-25/S-29*	2013		IMF (2013d)	
13	Australia	S-25/S-29*, G20	2012		IMF (2012g)	
14	India	S-25/S-29*, G20	2013		IMF (2013c)	
15	Ireland	S-25/S-29*	2016		IMF (2016e)	
16	Hong Kong SAR	S-25/S-29*	2014		IMF (2014d)	
17	Brazil	S-25/S-29*, G20	2012		IMF (2013e)	
18	Russian Federation	S-25/S-29*, G20	2011, 2016		IMF (2011g), IMF (2016d)	4/
19	Korea	S-25/S-29*, G20	2014		IMF (2015a)	
20	Austria	S-25/S-29*	2013		IMF (2014b)	
21	Luxembourg	S-25/S-29*	2011		IMF (2011c)	
22	Sweden	S-25/S-29*	2011		IMF (2011e)	
23	Singapore	S-25/S-29*	2014		IMF (2013i)	
24	Turkey	S-25/S-29*, G20	2012, 2016		IMF (2012d), IMF (2017b)	
25	Mexico	S-25/S-29*, G20	2012		IMF (2012a)	3/
26	Denmark	S-25/S-29*	2014		IMF (2014f)	
27	Finland	S-25/S-29*	2010, 2016		IMF (2010e), IMF (2017a)	
28	Norway	S-25/S-29*	2015		IMF (2015d)	
29	Poland	S-25/S-29*	2013		IMF (2013g)	
	Argentina	G20	2013	1/	IMF (2016a)	
	European Union	G20	2013	2/	IMF (2013b)	
	Indonesia	G20	2010		IMF (2010d)	
	Saudi Arabia	G20	2011		IMF (2012f)	
	South Africa	G20	2014		IMF (2015b)	

Sources: IMF (2010b, 2013a); and authors. See http://www.imf.org/external/np/fsap/fssa.aspx for published FSAP country reports.
Notes: S-29 countries are ranked according to the size and interconnectedness of their financial systems. The IMF's fiscal year (FY) runs from May 1 the previous year to April 30 the current year.
*/ Four additional countries (Denmark, Finland, Norway and Poland) were added to the original S-25 list following the 2013 decision of the IMF's Executive Board (IMF, 2014).
1/ Publication delayed until February 2016.
2/ Stress tests were not conducted for the 2012/13 European Union FSAP.
3/ No separate liquidity stress test.
4/ Liquidity stress test integrated in solvency stress test in the 2011 FSAP.

II. WHY STRESS TEST FOR LIQUIDITY RISK?

A. Premise

The GFC highlighted the crucial role of liquidity risk in undermining the stability of the international financial system and emphasized the need for regular liquidity stress tests on banks and banking systems. Unlike bank solvency concerns, which tend to take time to build up, liquidity shocks can manifest rapidly as reflected in the scale and scope of their impact across financial systems during the crisis.

Unsurprisingly, the harrowing experience with liquidity risk during the GFC has spawned a raft of regulations, notably Basel III. These regulations comprise both quantitative (a range of metrics) and qualitative (related to risk management and supervision) aspects, as documented in Table 2.[5] Strong emphasis has been placed on supervisory guidance to the financial industry to improve their internal liquidity risk management practices.

Liquidity stress tests inform a comprehensive assessment of whether banks' own internal resources (in the form of liquidity buffers) are sufficient to withstand adverse shocks. They aim to shed light on the potential need for emergency liquidity assistance to viable banks. Parent banks represent another important external source of liquidity support during times of stress, although any assessment of their capacity to do so may be limited if they are in another jurisdiction (or supervisory guidance on ring-fencing restricts cross-border transfers).

[5] See http://www.bis.org/bcbs/basel3.htm for more information on the implementation of the Basel III framework.

Table 2. Liquidity Risk: Regulatory Initiatives on Liquidity Risk

Initiatives	Related Documents
A. Basel Committee on Banking Supervision (BCBS)	
• Established the *Working Group on Liquidity* (WGL) to review liquidity supervision of national authorities and transposed some basic principles of liquidity risk management into standard liquidity ratios, the *Liquidity Coverage Ratio* (LCR) and the *Net Stable Funding Ratio* (NSFR).	BCBS (2008a)
• Issued guidance on liquidity risk management processes around 17 principles, focusing on medium and large, complex banks.	BCBS (2008b)
• Proposed minimum liquidity standards via two quantitative measures (LCR and NSFR) complemented by other monitoring tools to be applied at a global level under the Basel III rules.	BCBS (2010a, 2012a, 2013a and 2014)
• Developed *Principles for Sound Stress Testing Practices and Supervision* in a recent review of supervisory authorities' implementation of stress testing principles, which integrates liquidity risk in the formulation of stress testing frameworks of banks.	BCBS (2012b)
• Issued guidance on the design of proposed monitoring indicators for intraday liquidity management with the aim of enabling bank supervisors to monitor banks' intraday liquidity risk management and their ability to meet payment and settlement obligations in a timely manner and even under stressed scenarios.	BCBS (2013b)
B. Bank for International Settlements (BIS) Research Task Force (RTF)	
• Surveyed existing industry and supervisory practices in liquidity stress testing with a view to improving methodologies and practices, in particular, with respect to the interaction with solvency and contagion stress testing.	BCBS (2013c)
• Surveyed existing literature of risk drivers of liquidity stress consistent with categories and concepts of LCR.	BCBS (2013d)
• Outlined several approaches to model the interaction between liquidity and solvency risks from a macroprudential perspective.	BCBS (2015)
• Surveyed the impact assessment of liquidity requirements and their interaction with capital requirements.	BCBS (2016b)

Sources: BCBS; and authors.

B. Concept

Liquidity stress tests aim to capture the risk that a bank fails to generate sufficient funding to satisfy short-term payment obligations arising from a sudden realization of liabilities. The tests assess the adequacy of the available funding sources over a defined stress horizon. These tests would usually—and appropriately—examine the resilience of individual banks or banking sectors without directly taking into account central banks' LOLR liquidity support (Box 1). There are two broad, mutually reinforcing types of liquidity risk (Figure 1 and Appendix II):

- *Funding liquidity risk* is the risk that a bank will not be able to meet its current and future cash flow needs in case of a run-off of its funding liabilities, contingent payment obligations and/or disruptions to cash inflows; specifically, a bank's funding capacity depends on whether it can manage scheduled and unscheduled cash outflows (including the loss of funding sources) against cash inflows that are related to maturing assets, the rollover risk stemming from any existing maturity mismatches, as well as the ability to access unsecured retail/wholesale funding markets.

- *Market liquidity risk* is the risk that a bank will not be able to buy or sell a sizeable volume of securities at a low cost and with a limited price impact (IMF, 2015f). Market liquidity is reflected in volume (e.g., turnover ratios) and price-based measures (bid-ask spreads, price impact of large trades). For liquidity (and partly also solvency) stress tests, banks assess the expected cash inflows from asset sales and secured funding in a stressed environment.

    - This involves mark-to-market (MtM) valuation changes (of securities that are classified as either trading or available-for-sale (AfS)) and possible extraordinary impairment losses of held-to-maturity (HtM) assets in the banking book from a defaulting obligor or the forced (discounted) sale of assets by the bank prior to the maturity date.

    - In this regard, assumptions about the decline in asset values and the extent to which assets are subject to haircuts when used as collateral for wholesale funding influence the severity of cash flow calculations.

    - In addition, the liquidity stress test would implicitly assume that in a systemic crisis, part of the eligible collateral subject to the applicable haircut would be repo-ed with the central bank as part of their usual open market operations (Chailloux and Jobst, 2012).

Incidents of re-enforcing downward liquidity spirals during the GFC highlight the potentially crippling relationship between the two types of liquidity risk (Figure 1). The re-pricing of risk occurs when market illiquidity turns into funding illiquidity, such as when a bank would refuse to accept withdrawals. Funding illiquidity can also lead to market illiquidity, such as

when swap markets dried up in late-2007 for European banks seeking U.S. dollar funding as a result of concerns over counterparty credit risk (IMF, 2008). Both funding and market liquidity risks characterize liquidity stress tests and differentiate them from solvency stress tests. The latter assess the capital impact of asset price shocks from valuation losses and impairments that are not directly triggered by adverse funding conditions although there is a close link to liquidity though this channel.

The proper identification, monitoring and mitigation of both market and funding liquidity risks requires a combination of both price and quantity-based information on bank balance sheets, monetary dynamics, and developments in funding markets (Table 3). Liquidity risk ratios, including the share of non-core funding (short-term, wholesale, foreign exchange) in total liabilities, are common indicators of funding vulnerabilities using institution-level information. In order to determine the soundness of diverse funding structures these core indicators are normally supplemented with a detailed decomposition of assets and liabilities, for example the share of HQLAs (high-quality liquid assets) in total assets (see Appendix III), asset-liability maturity mismatches, and gross open currency positions. The economic assessment of institutional and funding liquidity conditions varies with the development of monetary dynamics and general market conditions, e.g., interbank market turnover, securities issuance, or the volume of secured/unsecured borrowing. For small open economies, trends in short-term capital inflows through financial institutions (as captured by positions and flows of other investments and portfolio investments received by banks) are often important indicators of non-core funding and can represent sources of instability in the funding market (Nier and others, 2014).

The potential build-up of systemic vulnerabilities warrants comprehensive monitoring of liquidity risks, especially where the impact of disruptions to funding markets could be most wide-spread (Jobst, 2014). These risks are related to different funding sources which determine the time dimension of liquidity risk management and underscore the importance of timeliness of mitigating actions if cash shortfalls were to occur. Secured and unsecured funding sources via capital markets offset the more structural (bank-specific) aspects of asset-liability management. Money markets and deposit funding represent short-term funding channels that meet operational requirements, while central bank money via standing facilities and tenders help reduce funding contingencies (mostly overnight and over very short time periods). Meanwhile, traditional deposits still form the funding backbone of many banks so liquidity risk relating to deposits also needs to be part of the risk framework.

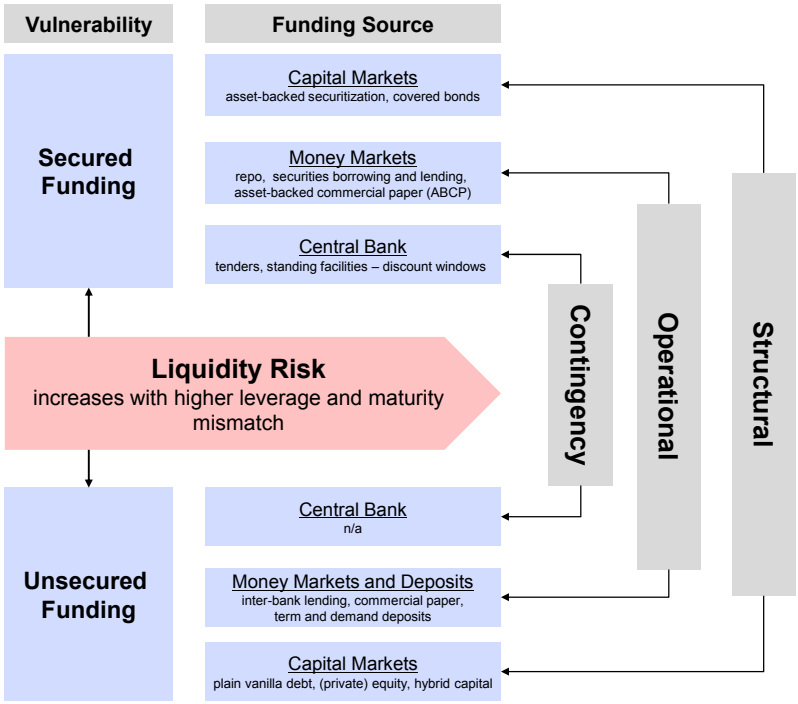
Box 1. Central Banks and Parent Banks as Liquidity Backstops

A natural counterbalancing role is played by central bank funding. In case of a severe crisis, the central bank could act as a lender of last resort (LOLR) to banks. For instance, during the global financial crisis, the U.S. Federal Reserve ("Fed") entered into swap agreements with several central banks, which, in turn, provided much needed U.S. dollar funding to their own domestic banks.[6] These facilities were extended twice, enabling the ECB, for instance, to provide unlimited three-month U.S. dollar funding after the re-intensification of funding strains in Europe. The ECB's own longer-term refinancing operation (LTRO) program also removed intermittent funding problems for banks during the height of the European sovereign debt crisis.

Parent banks could also step in to maintain or increase credit lines to subsidiaries if a subsidiary or branch loses access to funding sources. However, the GFC saw episodes of ring-fencing which restricted the transferability of capital and liquidity during stress periods (Cerutti and others, 2010). Nevertheless, parent funding by Western banks turned out to be more reliable than alternative funding sources (e.g., euro wholesale markets) for branches and subsidiaries in Central and Eastern Europe, supported by the *Vienna Initiative*, which sought to prevent the withdrawal of bank funding from the region. Historically, the majority of instances in which parent institutions do not provide additional liquidity for subsidiaries may be attributable to idiosyncratic liquidity shocks hitting the parent as a consequence of severe (perceived) solvency problems within the banking group.

[6] The Fed also provided liquidity to large international banks (in addition to the domestic U.S. financial institutions), but only to the U.S. branches of foreign banking organizations (FBOs).

Figure 1. Conceptualization of Liquidity Risk



Sources: Jobst (2012); and authors

Liquidity stress tests follow either a cumulative or a non-cumulative approach in identifying liquidity shortfalls. The economic importance of in- and outflows for the liquidity position of a bank or banking system under stress can be assessed in terms of a cumulative effect during a specified survival period (using implied cash flow tests) or non-cumulatively by means of a limit system (such as liquidity ratios and associated minimum requirements). Both approaches share the common objective of capturing the risk that a bank or banking system fails to generate sufficient funding to satisfy short-term payment obligations. Key benchmarks are the two liquidity metrics introduced under Basel III—the *liquidity coverage ratio* (LCR) and the *net stable funding ratio* (NSFR) (see Appendix III for further information).

More comprehensive macroprudential stress tests should, where possible, incorporate negative feedback loops between solvency conditions and liquidity risk in order to support a more nuanced assessment of potential systemic risk and differentiate across banks' varying susceptibility of solvency-induced liquidity stress. While solvency stress tests examine the impact of credit and market risk-related losses on bank capital, they would ideally also take into account diminishing funding opportunities and the price impact of rising counterparty risk under stress, particularly in the wake of a significant deterioration of solvency conditions (see Appendix IV for examples of research on this issue). Empirical evidence suggests that solvency and liquidity stress tests that do not account for the interaction between solvency and liquidity shocks substantially underestimate the risk exposure of individual banks and

banking systems (Puhr and Schmitz, 2014). However, the practical implementation of this concept in liquidity stress testing remains at an early stage (BCBS, 2013c and 2015).

Table 3. Overview of Liquidity Indicators

	Quantities	Prices
Monetary conditions and capital flows	Base money and broader montary aggregates	Policy and money market interest rates
	Access to central bank liquidity *(e.g., bidding volumes)*	Monetary conditions index (MCI) 1/
	Excess bank reserves	
	Volume of short-term capital inflows *(esp. if intermediated by banks)*	
Institutional and funding liquidity	Volume of secured/unsecured funding via securities financing transactions (SFTs) 2/	Spread between secured/unsecured wholesale funding rate and effective policy rate
	Liquidity ratios (LCR, NSFR, loan-to-deposit ratio, share of non-core funding, liquid asset ratio)	Unsecured lending rate and counterparty risk *(e.g., LIBOR and LIBOR-OIS spread)*
	Maturity mismatch measures	Valuation haircuts on collateral for securities financing transactions (SFTs) 2/
	Net cash flow estimates	FX swap basis
	Gross open foreign currency position	Violation of arbitrage conditions *(e.g., bond-CDS basis, covered interest parity)*
		Spreads between assets with similar credit risk characteristics
		Qualitative surveys on funding conditions
Market liquidity	Volume of securities issuance	Bid-ask spreads on selected assets
	Transaction volumes *(incl. average transaction size)*	Qualitative fund manager surveys

Sources: CGFS (2011); Jobst (2012); and Nier and others (2014). Note: 1/ such as the elasticity of aggregate demand to the real short-term interest rate and the real effective exchange rate; 2/ includes repo and securities lending. See also IMF (2015f), CGFS (2016), and Markets Committee (2016) for recent studies on market liquidity.

The design and calibration of scenarios for liquidity stress tests tend to be more challenging than for the solvency ones. The difficulty is attributable to a couple of factors:

- Liquidity crises are partly attributable to *psychological factors or confidence effects*, which tend to be idiosyncratic in nature and difficult to capture in any model; and

- *Limited availability of requisite granular data* (e.g., asset encumbrance levels, information on collateral, and the existence of available or existing repos or reverse repos) and/or the *confidentiality of bank liquidity information* have constrained the development of comprehensive liquidity stress testing models.

Funding liquidity risk has been a specific focus of recent system-wide stress tests. For instance, the 2011 and 2014 EU solvency stress tests conducted by the European Banking

Authority (EBA) included a cost of funding shock linked to the bank-specific impact of sovereign stress. They also assumed that banks would face higher wholesale and retail funding needs (without changes to their funding structure under stress) in both the baseline and adverse scenarios owing to higher short- and long-term interest rates, lower collateral values, and rising costs of deposit-taking. In the latter case, an explicit funding volume shock was simulated as part of the ECB macroeconomic stress testing framework.

III. A Framework for Bank Liquidity Stress Testing

Liquidity stress testing has become a core element of the FSAP financial stability analysis only during and after the GFC. Several aspects of liquidity stress testing are common to the financial stability module of FSAP exercises undertaken by IMF staff (Table 4). Also many countries have adopted comprehensive approaches to assessing system-wide liquidity conditions under stress, in most cases to support national versions of standard liquidity ratios.[7] The following section discusses the Fund's liquidity stress testing framework using examples of applications to FSAPs (Appendix I provides detailed information alongside these dimensions for 29 jurisdictions). This also includes brief review of implementation of liquidity risk measures under national liquidity reporting frameworks in the context of different types of liquidity stress tests.

A. Scope

Approach

In FSAPs, surveillance stress testing of banks' liquidity risk usually consists of either a top-down (TD) approach or, less used to date, a bottom-up (BU) approach. Underlying assumptions and calibrations are generally agreed between the national authorities and IMF staff:

- TD tests are often conducted by the authorities with inputs from IMF staff (e.g., Austria, Brazil, Italy and Poland) or jointly with IMF staff (e.g., Australia, Belgium, Germany, Hong Kong SAR, Ireland, Russia, Saudi Arabia, Spain and the United Kingdom) given the confidential nature of the supervisory data used. However, there are instances where some (or all) TD tests are conducted independently by national

[7] For instance, the U.S. Federal Reserve Board completes the Comprehensive Liquidity Assessment and Review (CLAR) as complement to the annual Comprehensive Capital and Analysis Review (CCAR) for large financial institutions covered by the Large Institution Supervision Coordinating Committee (LISCC) (i.e., currently 16 firms consisting of U.S. G-SIBs, U.S. systemically important insurance companies, and international broker dealers with a significant U.S. presence) in accordance with the Supervision and Regulation Letter SR 15-7 (April 17, 2015). Similarly, the Hong Kong Monetary Authority (HKMA) conducts the enhanced liquidity stress test (ELST), which forms part of the liquidity reporting framework for banks. The Oesterreichische Nationalbank (OeNB) uses a cash flow-based liquidity stress approach. During the financial crisis in 2008, the Austrian Market Authority (FMA) and OeNB required banks to report weekly cash flows based on a newly developed standardized liquidity reporting template which allows the simulation of impact of common shocks based on a uniform methodology (OeNB, 2009; Schmitz and Ittner, 2008). See also Appendix VII.

authorities (e.g., Canada, Hong Kong SAR, India, Korea, Sweden, and Switzerland) or by IMF staff only (e.g., France, Norway, and the United States).

- More recently, banks have been involved in BU liquidity stress tests for FSAPs (e.g., Belgium, China, Denmark, Korea, Singapore, and South Africa), which involve both the national authorities and IMF staff. This approach has been very useful in enhancing the technical detail of liquidity stress tests, given the granular data available at the bank level compared to the higher-level aggregated information that is used in most TD stress tests.

Coverage

The extent of institutional coverage is important for the usefulness of the exercise. In most financial systems, banks that are systemically important from a solvency perspective tend to be particularly relevant for the analysis of system-wide liquidity risk; however, the aggregate effect of many smaller banks with similar business models can also represent a vulnerability that could undermine the stability of the system. Some FSAP exercises were able to cover the entire banking sector, including cooperative and savings banks (e.g., Brazil, Denmark and Switzerland). Between September 2010 and December 2016, nine of the 29 FSAPs that incorporated liquidity stress tests (for which detailed information is made publicly available), included nearly all banks in their respective systems (e.g., Germany, India, Italy, Korea, Russia, Saudi Arabia, South Africa, Sweden and the United Kingdom); more than 80 percent of system assets were covered in eight other cases (Australia, Belgium, Canada, China, Denmark, France, India, and Turkey).

Sometimes, smaller banks may account for an important share of liquidity provision in the financial system. In this regard, the selection of relevant banks to include in the sample could be more complicated than in solvency stress tests, where the systemically important institutions may be more obvious. For example, investment banks (but also foreign branches and subsidiaries), which may not be included in corresponding solvency stress tests, tend to play an important role in funding markets and should ideally be incorporated (e.g., Ireland, Hong Kong SAR, and the United Kingdom).

Increasingly, bank liquidity stress tests would also need to be attuned to risks emanating from systemically relevant shadow banking activities and entities (FSB, 2012; IMF, 2014a). As an example, U.S. money market mutual funds are important providers of non-deposit (U.S. dollar) funding to European banks; they were subject to runs themselves during the peak of the crisis in 2008 and had to be rescued either by their bank sponsors or the government. Furthermore, banks are sometimes inherently intertwined with hedge funds or finance companies (that are dependent on short-term funding), both of which could also be susceptible to funding runs, resulting in spillovers to the banking system.

Table 4. A Framework for Macroprudential Bank Liquidity Stress Testing

Component	Description
1. Scope	
Approach	• Bottom-up (BU) by banks (using supervisory templates/assumptions; guidance from authorities/IMF staff) • Top-down (TD) by authorities (own assumptions/templates, possibly aligned with assumptions in IMF TD stress test) • Top-down (TD) by authorities (IMF templates/assumptions) • Top-down (TD) by IMF staff (IMF templates/assumptions)
Coverage	
Institutions	Mostly the largest banks, including foreign subsidiaries and branches
Market share	In most countries >80 percent of total banking sector assets.
Data	
Source	Banks' own data, supervisory data, and public data
Cut-off date	End-quarter or end of last fiscal year
Reporting basis	Mostly consolidated banking groups, but also unconsolidated domestic businesses/solo basis in many countries
2. Scenario Design	
Test(s)	• Implied cash flow test (cumulative/non-cumulative) over 5/30 days with focus on the sudden, sizeable withdrawal of funding (liabilities) and the sufficiency of existing assets to withstand those shocks under stressed conditions after taking into account valuation haircuts to liquid assets and amortization of outstanding assets; alternative scenarios: (i) restricted run-off to deposit and wholesale funding (i.e., selected customer deposits are unaffected), (ii) availability of intergroup funding, and (iii) unexpected cash outflows and drawdown of unused credit lines (behavioral cash flows) due to withdrawal of contingent liabilities and inability of rolling over maturing unsecured wholesale funding. • Asset-liability mismatch analysis over different risk horizon/maturity buckets (with and without rollover restrictions) • Basel III liquidity measures (Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR)); in many cases approximated based on assumptions about contractual maturities and credit quality of securities; for LCR, in most cases, the minimum parameters for deposit outflows were chosen; results were checked against the outcome of the preceding quantitative impact study (QIS-6) of the Basel III framework.
Risk Horizon	One or five working days (one week) and/or one month
Risk(s)	• Funding liquidity risk: run-off rates, renewal/call-back/rollover rates • Market liquidity risk: valuation haircuts (market-based or pre-defined)
Calibration	• Historical experience of banks after the collapse of Lehman Bros. and other episodes of liquidity stresses in the past • Expert judgment: assumptions about the performance of banks under stress (i.e., liabilities run-off, taking into account valuation haircuts to liquid assets, and amortization of outstanding assets)
Other issues	• Asset encumbrance • Link to solvency stress test (and scenarios) • Buffer: counterbalancing capacity; offsetting contractual inflows due to central bank support.
Benchmarks	
Metrics/Output	• Positive net cash inflow: ability of banks' liquidity buffers under stressed scenarios to cover expected and potential outflows over a given time period (i.e., liabilities run-off, taking into account valuation haircuts to liquid assets, and amortization of outstanding assets) • Regulatory liquidity ratio(s): LCR, NSFR, and/or national liquidity risk measure
3. Methodology	
Model	• IMF templates and assumptions: (i) implied cash flow approach (Čihák, 2007; Catalán, 2015; Jobst, 2016); (ii) LCR/NSFR templates (Schmieder and others, 2012) • Regulatory minimum measures: LCR and NSFR (Basel III liquidity risk framework) • Macro-financial model: econometric approach (possibly in combination with solvency feedback effect(s)), e.g., Barnhill and Schumacher (2011)
4. Communication	
Presentation	• Standardized output template for BU and TD results provided to banks and national authorities • Results discussed in the *Financial System Stability Assessment* (FSSA) (supported by more detailed description of both methodologies and findings in a *Technical Note on Stress Testing* (TN)); in most cases, both FSSA and TN are published.

Source: authors.

Data

Characteristics

Liquidity stress tests are run on granular, bank-level data. The comprehensiveness of these tests depends on the quality (i.e., accuracy and coverage) of the requisite information and the extent to which it is made available. Data granularity increases with the complexity of the system, including the diversity of sources and use of funds:

- The data for TD tests typically comprise confidential prudential information gathered from the supervisory liquidity reporting process. In many cases, the data also cover broad categories of assets and liabilities with breakdowns of maturity terms (e.g., Australia, Austria, Brazil, Germany, Hong Kong SAR, Korea, Poland, Spain, Sweden, Turkey and the United Kingdom) and differentiation by currency (e.g., Austria, Korea, Singapore and Turkey). However, in some countries public data also have been used (e.g., Norway and the United States).

- Separately, BU tests by banks themselves using own data (e.g., Belgium, China, Denmark, France, India, Japan, Korea, Singapore and South Africa) would require a determination of the quality of internal controls, risk management and corporate governance in order to include the findings in the FSAP assessment.

- The data cut-off date for a liquidity stress test would ideally coincide with that of the (parallel) solvency stress test, ensuring consistency in assessing banks' health at a particular point in time and facilitates the incorporation of feedback effects between the two exercises (if applicable).

Reporting basis (consolidation)

One dimension of liquidity stress that has received little attention so far is the level of consolidation of banks' financial accounts. Liquidity stress tests may be carried out on consolidated level data (which is very common) or on a legal entity (solo) basis. The latter is only relevant if the system consists of large financial conglomerates and/or international groups which may have considerable intragroup funding arrangements in place that could be vitiated by cross-border restrictions ("ring-fencing") of liquidity (and capital) during times of stress (as was the case during the financial crisis). This aspect is of particular importance in countries where a significant market share is held by (i) host-supervised banks, which could experience high liquidity outflows due to intra-group funding obligations; or (ii) large branches of international banks. For these countries, stress tests have been implemented on a solo basis (e.g., Germany, Ireland, South Africa and the United Kingdom) or on both solo and consolidated bases (e.g., Belgium, Hong Kong SAR and Singapore). In most FSAPs, however, stress tests have been applied on consolidated data. Cross-border liquidity stress tests using consolidated data are applied in the Spain FSAP (IMF, 2012) using the Espinosa-Vega and Sole (2011) methodology.

B. Scenario Design

Once the scope of the liquidity stress test has been determined, the scenario design is defined. It comprises: (i) the definition of the scenarios (i.e., scope, severity); (ii) the exogenous stress assumptions; as well as (iii) the pass/fail benchmarks. Liquidity stress tests assess the short-term or, in some cases, medium-term resilience of banks to sudden, sizeable withdrawals of funding (liabilities) together with insufficient call-backs on outstanding claims. Some tests are aimed at gauging the magnitude of shocks required to cause severe distress, i.e., constitute reverse stress tests ("until it breaks"), in addition to "traditional" tests which project liquidity positions under specified scenarios, usually involving either:

- *Cash flow mismatch analyses over different risk horizons*, with a focus on the sudden, sizeable withdrawal of short-term funding sources and the sufficiency of selling (unencumbered) existing assets to withstand those shocks under stressed conditions (with asset-specific haircuts); or

- Liquidity ratio-based analysis over a longer risk horizon.

Test(s)

FSAP stress tests typically assess changes to the funding condition of banks under different adverse scenarios within the framework of existing (or useful) liquidity risk management measures. These policy measures promote a more stable funding profile and improve the resilience of the banks to funding shocks (Nier and others, 2014):

- *Liquidity buffer requirements* encourage banks to hold sufficient liquid assets to cover outflows during time of stress,

- *Stable funding requirements* ensure that illiquid assets are funded by stable sources of funding,

- *Liquidity charges* impose a levy on non-core funding,

- *Reserve requirements* ensure that banks hold certain amounts of reserves with their central bank, and

- *Restrictions on open foreign currency positions* and/or foreign currency-denominated funding aim to limit banks' exposure to exchange rate risks.

Most exercises combine implied cash flow modeling and with standard liquidity risk measures, benchmarked on national and/or international regulatory standards calibrated to (or closely aligned with) the Basel III liquidity framework:

- *Implied cash flow (ICF) tests.* Balance sheet information is used to simulate a bank run-type withdrawal of deposits and wholesale funding together with drawdowns of

contingent claims and related party funding obligations (usually not decomposed into maturity buckets). Cash inflows from contingent funding sources as well as assumed proceeds from selling available liquid assets and/or using them as collateral for secured funding are applied fully, or in part, to counter-balance the assumed outflows due to the funding shock. These cash flow projections may be augmented with market-based measures of the sensitivity of funding costs to changes in the asset risk of banks based on observed or market-implied default probabilities and expected losses.

- *Basel III liquidity measures*. Under Basel III, banks are expected to maintain a stable funding structure, limit maturity transformation, and hold a sufficient stock of available assets to meet their funding needs in times of stress (BCBS, 2010b, 2010, 2012b and 2013a). The framework is based on two standardized ratios, the LCR and the NSFR, which are applied to banks on a consolidated basis.[8]

- *Standard liquidity ratios by national authorities*. Many bank regulators have enhanced their national liquidity reporting frameworks to support the implementation of liquidity risk measures (e.g., the former U.K. FSA's *liquidity reporting profile* (LRP), which has been complemented by the *liquidity metric monitor* (LMM),[9] and the National Bank of Belgium's *liquidity ratio*). Most standard liquidity ratios are assessed as non-cumulative measures of potential liquidity shortfall for stress periods covering the short- and medium-term resilience of individual banks and the overall system.

Risk(s) and risk horizon

The tests described above cover both funding and market liquidity risks. In most FSAPs, stress tests are modeled as cash flow tests of bank-run type funding shocks over short consecutive periods. Liquidity metrics focusing on structural asset-liability mismatches similar to the NSFR are applied to longer horizons. Commonly, the former is used to analyze either consecutive (cumulative) daily cash outflows over several days (typically five working days or one week) or one-off, non-cumulative aggregate cash outflows over 30 days, whereas the latter assesses the adequacy of stable sources to continuously fund cash flow obligations inside a one-year time horizon.

[8] The Basel liquidity rules only prescribe that the standards be applied on a consolidated basis. Legal entity application is left to national discretion.

[9] The LMM is designed to demonstrate some of the liquidity metrics calculated by the Prudential Regulation Authority (PRA) using prudential information in accordance with FSA047 and FSA048. It also provides estimates of the Basel III liquidity ratios (LCR and NSFR). See http://www.bankofengland.co.uk/pra/Pages/publications/liquiditymetricmonitor.aspx.

Calibration

Most FSAPs exercises entail deterministic stress tests using stress scenarios based on ICF approaches and fully-fledged cash flow tests. This is distinct from simulation approaches (possibly combined with network modeling), which have also been used in past exercises, albeit less frequently. Scenario assumptions are meant to be "extreme yet plausible" to effectively indicate existing vulnerabilities. This application is particularly challenging during benign times when there is greater uncertainty about the potential for financial risks to manifest. In some cases, it might also be useful to calibrate liquidity shocks to achieve some consistency with the sudden stop and boom-bust scenarios of solvency stress test. ICF tests and standard liquidity measures, including regulatory ratios, such as LCR and NSFR, contain a pre-defined set of assumptions (which can be subject to sensitivity analysis). Other deterministic stress tests may be based on historical worst case scenarios, expert judgment or statistical models/valuation approaches (and then mainly on the asset side).

Other considerations

The scenarios define the scope of the liquidity buffer as well as the contractual maturities of expected cash flows in stress situations. The quantification of assets and liabilities generating cash flows should, if possible, not be restricted to those included in the balance sheet. Assumptions are also made about potential cash flows from related and third parties in the form of committed but unused credit lines/liquidity facilities. These contingent claims/liabilities are an essential element of projected behavioral cash flows and are recorded as either off-balance sheet (e.g., liquidity facilities to special investment vehicles as well as long and short positions in derivatives) or on-balance sheet items if they are "instantaneous" or have no specific maturities (e.g., sight deposits) (Catalán, 2015). They receive special treatment, different from that accorded to assets and liabilities with non-contingent payoffs and an explicit maturity structure.

Asset encumbrance

The design of liquidity stress tests should, where possible, also include granular information about banks' *asset encumbrance* or liquidity from eligible collateral *ex post* haircuts (ESRB, 2012). The assessment of banks' funding risks under stress conditions is critically dependent on the market value of liquid assets, their current (or expected) encumbrance and/or the ability to monetize them:

- Banks with high *asset encumbrance* levels (e.g., through secured refinancing activities and on-balance sheet structured finance, such as covered bonds) have less capacity to withstand severe liquidity shocks as their access to collateral-backed funding is constrained. Other unsecured creditors, such as depositors, are also subordinated, increasing the risk of a run during stressful periods. Hence, the liquidity buffer considered in tests comprises only unencumbered liquid assets, i.e., assets that can (but

have not been) used as collateral to receive funding (with the exception of cash or cash equivalents). The stock of liquid assets normally excludes encumbered assets in cases when banks do not have the operational capability to monetize them in order to meet outflows during the stress period, i.e., if repo operations for commercial and/or central bank money are not possible.

- In most cases, liquidity reporting requirements of banks already include assumptions on asset encumbrance affecting the valuation of liquidity buffers and/or assumptions on the depletion of funding sources under stress ("behavioral adjustments"), such as in the United Kingdom. In other cases (e.g., Australia, Belgium, Brazil, Hong Kong SAR, Italy, Japan, Korea and Turkey), any encumbered assets were excluded from the scope of liquid assets from the exercise. Stress tests that include public data or supervisory data, for which a consistent application of these adjustments cannot be verified, assume a uniform degree of asset encumbrance for the valuation of liquid assets (in addition to the application of haircuts (Jobst, 2017)).

Link to solvency

Estimated changes in funding costs during times of stress (and their impact on net cash flows) can help link liquidity scenarios to the capital adequacy assessment in solvency stress tests. The macro-financial transmission of shocks affecting the capital assessment under stress also applies to corresponding liquidity stress tests insofar as any change in funding costs would be consistent with the assumptions applied to the solvency tests. Solvency stress tests in recent FSAPs estimate the impact of shocks to banks' balance sheets through the cost of funding of short-term debt and the maturing portion of long-term debt with a lag (e.g., Brazil, Germany, Spain and the United Kingdom).

Funding costs influence the profile of bank cash flows through the expected availability and maturity tenor of available funding over the risk horizon. Banks' applications of internal pricing mechanisms, which often include hedging of funding cost changes, are also important elements of the chosen cost-of-funding method. These costs typically take the form of an additional interest expense:

- The elasticity of funding costs is non-linear to changes in solvency conditions and could be differentiated across maturity tenors and types of funding, such as checking/term deposits, secured/unsecured wholesale funding, and short-term debt that would need to be rolled over within the risk horizon of the stress test.

- In case of non-commoditized bank debt, such as interbank funding arrangements, lending rates adjust in response to changes in counterparty risk.

Liquidity stress tests should, where possible, take into account *feedback or second-round effects* when considering the reaction to funding shocks. Funding costs are influenced by

banks' solvency conditions and changes in market prices during stress periods.[10] Impairment losses could also raise funding costs (Aiyar and others, 2015), in a dynamic between bank liquidity and solvency, but this issue remains to be addressed in stress tests. Outright rationing of funding, in addition to increases in cost, may arise for banks that are perceived to be weak vis-à-vis their peers. Moreover, liquidity stress can spill over to other (stronger) banks by affecting market liquidity and, ultimately, the availability of funding for these banks which could lead to solvency concerns. In this regard, sources of macro-financial shocks can be triggered, or at least propagated, by vulnerabilities to the adverse effects of such interactions in times of collective distress. Finally, there can be additional spillover effects associated with counterparty risk if weak banks are unable to honor, in part or entirely, their interbank exposures. However, the operational implementation of feedback loops in the context of system-wide stress tests remains at a seminal stage (Appendix IV).

Liquidity buffer

Counterbalancing capacity

The liquidity buffer represents banks' "counterbalancing capacity" under stress. It comprises cash and cash balances with central banks (excluding minimum reserve requirements) as well as unencumbered assets, which could generate inflows from outright sales or collateralized lending ("secured funding," e.g., repo and securities lending transactions). The evolution of trading assets in response to market risk shocks, such as to foreign exchange rates and interest rates, determines the degree of illiquidity affecting both price/valuation changes of fixed income holdings and their speed of disposal.

The buffer may be applied to cover short-term payment obligations (i.e., available assets that could be sold under stress). Different haircuts are imposed on these assets depending on their perceived (or assumed) liquidity under stress. These haircuts account for estimated valuation losses on the relevant exposures owing to potential illiquidity—whether in the banking, for-sale and/or trading books—and the resulting changes in funding (costs); a bank's access to funding markets (and thus its funding costs) will depend on the market's current valuation of the bank's entire portfolio and not on the accounting valuation on a hold-to-maturity basis. Recent European FSAPs (e.g., Belgium, France, Germany, Italy, Spain and the United Kingdom) have also acknowledged sovereign risk by estimating haircuts to relevant government debt holdings based on the impact of changes to credit risk on bond

[10] Schmitz, Sigmund and Valderrama *(forthcoming)* find evidence of non-linear effects between solvency and funding costs using a simultaneous equation approach drawing on supervisory data for 54 large banks from six advanced countries between 2004 and 2013. The study confirms earlier evidence in Annaert and others (2013), who show that the interaction between solvency and funding costs is indeed significant in a sample of 31 large euro area banks over the pre-crisis period from 2004 to October 2008. Similarly, Hasan, Liu and Zhang (2016) show that solvency has significant impact on bank funding costs using a sample of 161 global banks from 23 countries between 2001 and 2011. This is confirmed by Caceres and others (2016) when they examine the sensitivity of bank funding costs to bank solvency drawing on the FDIC call report covering 10,000 U.S. banks between 1993 and 2013.

prices—assuming that an increase in sovereign default risk that is consistent with market expectations impacting the valuation of local and foreign government debt.

Contractual and behavioral cash inflows

The amortization of existing (contractual) claims, depending on the renewal rate, and the emergence of contingent (behavioral) liabilities allow banks to generate cash inflows, which can be modeled on a cumulative (i.e., multi-period) or non-cumulative basis. Projected cash flows that stem from contractual rights or obligations and have a known maturity date are differentiated from those that are likely to materialize but have not yet been contracted and could exceed expectations (based on historical experience) or existing cash reserves.

Contractual cash flows remain firm and unchanged under stress while *behavioral* flows are expected but could change significantly. These behavioral flows could either mitigate or amplify contractual cash flows through (i) additional inflows related to either new secured and unsecured funding at shorter but also longer maturity terms (e.g., as new deposits, wholesale funding and debt issuance) or rollover/re-financing of contractual liabilities (e.g., part of the maturing time deposits are likely to be rolled over), and (ii) additional outflows associated with expected new loans, investments, or undrawn committed credit lines.[11] The most important funding sources are:

- *Expected cash inflows* related to the repayment of amortized lending with/without liquid financial assets as collateral (i.e., secured/unsecured lending);

- *Expected cash inflows* related to transactions with liquid securities and bank loans (i.e., asset sales) and funding from related parties (intra-group funding); and

- *Potential cash inflows* from related and third parties in the form of committed/uncommitted but unused credit lines/liquidity facilities as contingent liabilities (situation on reporting date).

The extent to which existing (contractual) liabilities are renewed and the emergence of contingent (behavioral) claims influence banks' funding conditions under stress—after accounting for expected and potential net contractual cash flows related to derivatives. These include:

- *Expected cash outflows* related to funding with/without liquid financial assets as collateral, i.e., secured/unsecured funding, including sight and regulated savings/term

[11] Note that *expected* cash inflows (outflows) reflect changes of required (available) funding through assets (liabilities); however, this relationship reverses for *potential* cash flows. For instance, the call-back rate on a reverse repo (as an asset) determines the extent to which *expected* cash inflows will materialize while the possible use of a repo (also an asset) by a related or third party to obtain funding during stress represents a *potential* cash outflow.

deposits by households, financial and non-financial corporates, sovereigns and other public sector organizations;

- *Expected outflows* to related parties (intra-group lending); and

- *Potential outflows* from related and third parties in the form of committed/uncommitted but unused credit lines/liquidity facilities as contingent assets (situation on reporting date).

Scenarios encompass both systematic shocks that affect all banks in the system as well as idiosyncratic shocks that impact individual banks only. Given that market-wide stresses amplify the individual liquidity risk, Schmieder and others (2012) advocate including combined scenarios similar to the one underlying the LCR. Where possible, scenarios should also be accompanied by consistent narratives underpinning the assumptions on all relevant cash flow parameters and risk factors, including: (i) call-back rates for lending/run-off rates for funding, (ii) valuation haircuts for assets sold at fire sale prices and drawings of contingent liabilities (Coval and Stafford, 2007; Shleifer and Vishny, 2010), and (iii) the impact of banks' rating downgrades as a result of deteriorating solvency conditions.

Benchmark(s)

The existing framework caters largely to TD stress tests. Hence, the emphasis is placed on running a set of consistent tests for all banks in the system (and relevant banks and non-banks outside of it) against common benchmarks, such as positive net cash inflows; the ability of banks' liquidity buffers to withstand stressed scenarios; and regulatory liquidity ratios.

C. Methodology

The methods selected for FSAP liquidity tests depend on the sophistication of the banking sector in question. Considerations include, among others:

- The importance of *deposits* relative to wholesale-based funding;

- The role of off-balance sheet derivatives funding;

- The concentration of *lending to related parties* relative to other lending; and

- The nature of *counterparty risk* (e.g., the relevance of market-based transmission channels of funding impacting the availability and pricing of funding, such as margin calls).

Usually, one or more quantitative stress test methods are applied to estimate liquidity shortfalls under the pre-defined shocks. Peer comparisons are also important tools in assessing liquidity risk through the estimation of the relative liquidity situation at other

banks, applying common scenarios and benchmarks, in situations where the stress tests carry a high degree of uncertainty:

- The TD tests run in FSAPs can be categorized as ICF tests. For banks with simple funding structures, these tests−in addition to standard liquidity ratios and minimum prudential requirements−are the most appropriate. A key prerequisite for carrying out ICF tests is access to a wide range of data on contractual cash flows for different maturity buckets and possibly behavioral data based on banks' financial/funding plans. In addition to assessments of maturity mismatches for specific time horizons under stress, they also include duration gap analyses. Deterministic liquidity stress tests developed by Čihák (2007), Schmieder and others (2012) as well as Jobst (2017) are applied in most FSAPs (see Appendix V).[12]

- Regulatory minimum measures such as the LCR and NSFR from the Basel III liquidity risk framework have become staple stress test methods.

- For more sophisticated financial systems (and banks) for which market data are available, stochastic methods may be used as a complement. These market-based models incorporate uncertainty using historical volatility and/or market information (e.g., Jobst, 2011 and 2012). They allow for sensitivity analysis (i.e., stress of one risk factor/type) or scenario analysis (i.e., stress of multiple risk factors/types).

- Still in its infancy as far as application is concerned, macro-financial econometric models which combine solvency feedback effects have been developed (e.g., Barnhill and Schumacher, 2011).

D. Communication

Presentation

The main objective of stress tests is to draw the attention of bank management, supervisors and regulators to potential risks and, if necessary, to galvanize action in addressing those risks. As noted in Jobst, Ong and Schmieder (2013), it is important that the findings be appropriately conveyed. In FSAPs, liquidity stress tests are based on a bank-by-bank analysis but results are generally aggregated by the authorities for confidentiality reasons, underscoring the importance of meaningful presentation of those results for analysis. Hence, the templates that are designed by the FSAP team for input by the authorities (Appendix VI, Figure 3) are:

[12] A comprehensive ICF test approach and the related tool which has been applied in FSAPs are available with this paper.

- consistent with any local regulatory requirements and, where relevant, any international regulatory standards (e.g., Basel III) for cross-country comparison purposes; and

- sufficiently granular, showing (i) peer groups, (ii) some measure of dispersion, such as the ratio buckets or maturity tenors, (iii) the number of banks failing to meet the benchmark, (iv) the percentage of total sample assets included in the tests failing to meet the benchmark, and (v) detailed assumptions, which also clarify key limitations to the implementation of the stress test.

As with the solvency stress tests, the findings of the liquidity stress tests are used for two main purposes: (i) provide quantitative support for FSAP stability risk assessments by estimating the impact from the realization of the pre-defined shocks, and (ii) facilitate policy discussions with the authorities on risk mitigation strategies and crisis preparedness.

Publication

The communication of stress test results is a critical element of any publicly-announced stress testing exercise, especially if enhanced transparency has macroprudential benefits. Any published analysis should aim to provide a complete assessment of the system-wide resilience to liquidity risk while avoiding causing either complacency or undue alarm. Moreover, the disclosure of system-wide liquidity conditions (if based on prudential data) is particularly sensitive given that market participants may be able to take positions against those banks in short-term money markets. For FSAP exercises, the following aspects are especially relevant:

- The objectives, definitions, assumptions, methods and limitations of stress tests are usually written up in detail, either in Technical Notes and/or as supplementary information in the FSSA report. Publication of these documents is voluntary for country authorities.

- Mandatory summaries of the stress testing exercises are also presented in the FSSA in a standard framework format, i.e., the STeM, to improve transparency and facilitate comparisons across countries.

- The *aggregated* results of a particular financial system are almost always disclosed in the reports. As a minimum, information about the performance of banks under stress (i.e., liabilities run-off, taking into account valuation haircuts to liquid assets, and amortization of outstanding assets) is presented in the form of liquidity ratios and/or maximum days of resilience. As with solvency stress tests, authorities rarely agree to make available the liquidity stress test results of individual banks.

To date, all the jurisdictions in our sample (30) have authorized the publication of at least the main results and general information on the stress testing framework of the FSAP. Almost two-thirds (19) have authorized the full publication of Technical Notes containing all details

of the liquidity stress test component of their respective FSAPs (i.e., Argentina, Austria, Belgium, Brazil, Canada, Denmark, France, Germany, Hong Kong SAR, Ireland, Italy, Korea, Norway, Russia, South Africa, Sweden, Switzerland, United Kingdom and the United States); for the remaining countries, the basic information on the methodologies and results of the stress testing exercise are published in the main FSAP document, the FSSA report.

IV. CAVEATS

Liquidity stress tests that aggregate individual liquidity risk measures across all banks do not necessarily capture the scope of system-wide risks. Prudential measures, such as ICF tests or standard indicators, such as prudential ratios, have an institutional focus. They assume that sufficient institutional liquidity greatly reduces the likelihood of funding shortfalls and any associated knock-on effects on an institution's solvency in distress situations. So, they do not take into account the system-wide effects from any herding behavior by banks and their joint sensitivities to funding shortfalls.

Liquidity stress tests do not explicitly assume potential refinancing via central banks which act as lenders of last resort. Assumptions made on haircuts to liquid and less liquid unencumbered assets for banks' counterbalancing capacity are often silent as to whether banks in such stress situations directly engage with the central bank or in wholesale funding markets (which are likely to be severely impaired in such situations). Larger liquidity buffers at each bank would, on average, lower the risk that multiple institutions would simultaneously face liquidity shortfalls especially if banks with surplus liquidity still provide secured repo funding to counterparties. Sufficient liquidity in interbank markets also implies that central banks would only be required to act as lenders of last—not of first—resort (Jobst, 2014). However, funding shocks often represent extreme outcomes, which could lead banks to draw on their "expensive" liquidity buffers to cover the probability of tail events.

Liquidity stress test results need to be put in context given their static nature and the implicit assumption that all banks face escalating liquidity risk at the same time. Depending on the stress testing methodology, any estimated liquidity shortfall is assumed to be the result of coincidental funding shocks. They should be interpreted in terms of a general vulnerability to the particular set of assumptions, rather than being representative of an actual liquidity need given the role played by central banks as a liquidity backstop. In other words, the calculated effect might overstate the actual impact from the realization of assumptions about varying cash flow scenarios. In addition, Schuermann (2012) cautions that the "dynamism" of liquidity positions which are subject to rapid change means that any snapshot at a particular point in time may not be very informative by the time of disclosure.

Stress test results need to be suitably qualified based on mitigating considerations. An example would be the likely reallocation of deposits within the banking sector in a situation when not all banks experience funding shocks simultaneously (and assuming that deposits largely remain in the banking system and are swiftly re-allocated with weaker banks having

to offer above average deposit rates to retain or attract depositors). Other mitigating factors include: (i) offsetting contractual capital inflows from maturing wholesale lending; (ii) possible central bank support via committed liquidity facilities and widening of eligible collateral; and (iii) the likely compensating outcome for the system from the deposit insurance scheme.

V. CONCLUSION

This paper provides a conceptual overview of liquidity stress testing of banks and discusses its implementation in the IMF's FSAPs for countries with systemically important financial sectors. The variations in the implementation of these stress tests—depending on the structural characteristics of individual financial systems and existing prudential requirements across member countries—help facilitate their consistent implementation across countries in future exercises.

As with all other aspects of stress testing, the evolving nature of bank business models, financial instruments and capital market conditions require adaptability. The future of liquidity stress testing will likely be multi-pronged with a shift towards comprehensive cash flow-based tests. Liquidity stress testing approaches will also require a deeper understanding of the inter-relationship between solvency and liquidity risks. In this regard, the work of the Research Task Force of the BCBS on liquidity stress testing could provide useful insights into the important solvency-liquidity risk interaction.

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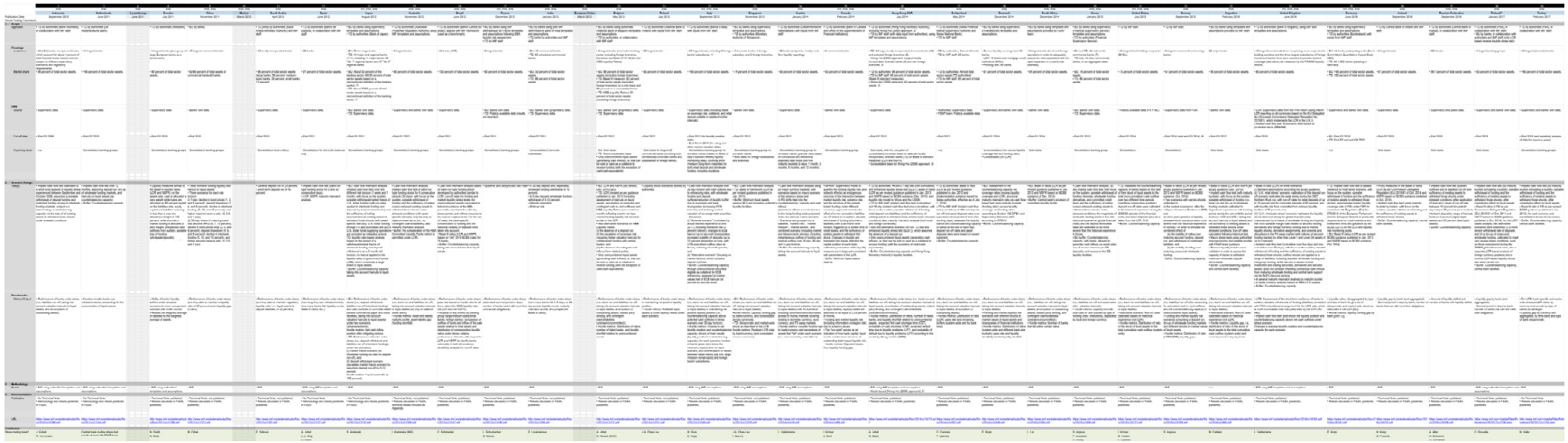
Appendix Table 1. Liquidity Stress Test Matrix (STeM) for FSAPs of Systemically Important Financial Systems (Illustrative)



Source: Authors.

Notes: The table presented here is a representation only—the full-sized matrix is available electronically as a MS Excel-file ("Attachment I_Appendix I_Liquidity STeM for Countries with Systemically Important Financial Systems") at http://www.imf.org/en/Publications/WP/Issues/2017/05/01/Macroprudential-Liquidity-Stress-Testing-in-FSAPs-for-Systemically-Important-Financial-44873. For jurisdictions that completed two FSAP exercises during the sample period (Finland, Germany, Russia, Turkey, United Kingdom and the United States), information about both FSAPs is contained in this table (but information about the preceding FSAP is contained in hidden columns).

*/ Staff from the Monetary and Capital Markets Department (MCM) of the IMF unless specified otherwise.

**/ Four additional countries (Denmark, Finland, Norway and Poland) were added to the original S-25 list following the 2013 decision of the IMF's Executive Board (IMF, 2014). At the time of the FSAP, Finland was not a S-29 countries (subject to the mandatory 5-year FSAP cycle). Note that the FSAPs for Finland and Turkey were completed during the last quarter of 2016; the respective Board discussions took place in December 2016 and February 2017.

APPENDIX II. FUNDING AND MARKET LIQUIDITY

For *funding liquidity risk*, the assessment reflects the realization (and potential change) of expected and contingent cash in- and outflows during times of stress, which includes assumptions on:

- Run-off rates for secured/unsecured wholesale and retail funding;
- Amortization/renewal rates for secured/unsecured wholesale and retail lending (at contractual maturities);
- Draw-down rates for interbank credit and liquidity facilities;
- The convertibility of foreign currency-denominated net cash flows and the scope of unsecured support in convertible currencies from related and third parties in the form of committed/uncommitted lines);
- The treatment of expected and contingent liabilities from related and third parties; and
- The capacity to access unsecured financing and complete securitization during times of stress.

The degree of *market liquidity risk* (i.e., valuation haircuts) affecting expected cash inflows from asset sales and the collateralization of secured funding are influenced by:

- The asset concentrations and banks' asset encumbrance;
- The potential impact of downgrades of marketable assets;
- The composition of the bank's liquidity buffer comprising marketable, or otherwise realizable, assets;
- The magnitude of foreign currency (FX) funding needs—on aggregate and for each currency (if there is no full convertibility between currencies over the stress testing time horizon);
- The relevance of derivatives trading for the management of liquidity risk, including asset and FX swaps (with the attendant potential for collateral and margin calls);
- The extent to which assets might be encumbered and are subject to haircuts when used as collateral for central bank and securities financing transactions (SFT) during times of stress, such as repos and securities lending; and
- The availability of funding via potentially re-usable securities received as collateral ("re-hypothecation").

APPENDIX III. REGULATORY LIQUIDITY RISK MEASURES UNDER BASEL III: LIQUIDITY COVERAGE RATIO (LCR) AND NET STABLE FUNDING RATIO (NSFR)

Subsequent to the global financial crisis, the Basel Committee has added liquidity risk to the regulatory perimeter of the Basel III framework (BCBS, 2009, 2010a and 2010b). Internationally active banks have to meet two quantitative liquidity metrics (and related monitoring tools) for two different time horizons (one month and one year, respectively) (Appendix Table 2) and comply with qualitative guidance liquidity risk management practices. As such, banks are expected to maintain a stable funding structure to withstand liquidity shocks by holding a sufficient stock of assets that should be available to meet its funding needs in times of stress and by limiting maturity transformation (BCBS, 2010b and 2012b).[13] Recent work by the BCBS (2016b) sought to shed light on effects of the liquidity reforms under Basel III and their interaction with capital standards.

Liquidity Coverage Ratio (LCR)

The LCR is intended to promote short-term resilience to potential liquidity shocks by requiring banks to hold a sufficient stock of unencumbered, high-quality liquid assets (HQLAs) to withstand the run-off of liabilities over a stressed 30-day scenario specified by supervisors. It defines the potential funding shortfall as cash outflows less cash inflows (subject to a cap of 75 percent of total expected cash outflows) that are expected to occur during in times of stress. A LCR value of less than 100 percent indicates a liquidity shortfall. More specifically,

> *"…the LCR numerator consists of a stock of unencumbered, high-quality liquid assets that must be available to cover any net [cash] outflow, while the denominator is comprised of cash outflows less cash inflows (subject to a cap at 75 [percent] of total outflows) that are expected to occur in a severe stress scenario* (BCBS, 2012b and 2013a)*."*

In January 2013, the Basel Committee finalized the specification of the LCR by reaching an agreement on a composition of HQLAs and parameters for net cash outflows resulting from deposits and contingent liabilities, as well as a transition period for introduction of LCR (BCBS, 2013a). The changes to the definition of the LCR include an expansion in the range of assets eligible as HQLA and some refinements to the assumed inflow and outflow rates to better reflect actual experience in times of stress. More specifically, the modifications comprise the following:[14]

[13] See Bucalossi and others (2016) for a detailed analysis of the potential impact of standardized liquidity risk measures on banks' liquidity management in the European context.

[14] See also BCBS (2014a).

- Extending the Level 2B category of the HQLA to include (i) residential mortgage-backed securities (RMBS) (rated "AA" and higher) with a haircut of 25 percent as well as lower-rated corporate bonds (between "A+" and "BBB-") and common equity (each subject to a 50 percent haircut); and increasing the cap of Level 2B assets from 10 to 15 percent;

- Applying a lower run-off rate of 3 percent to stable deposits where pre-funded and explicitly government-guaranteed deposit insurance schemes exist and where access to deposits is available the next day after deposit insurance is triggered;

- Lowering the draw-down rates from 100 to 30 percent for undrawn but committed liquidity facilities to non-financial corporates, sovereigns and central banks, public sector enterprises (PSE) and multilateral development banks,[15] from 100 to 40 percent for undrawn but committed credit/liquidity facilities to banks subject to prudential supervision, and from 75 to 40 percent for deposits from non-financials, sovereigns and PSEs;

- Increasing liquidity needs related to derivatives;

- Applying a zero percent run-off rate for operations with central banks for all types of assets (in addition to secured funding backed by Level 1 assets with any counterparty); and

- Providing for national treatment of trade finance obligations.

Net Stable Funding Ratio (NSFR)

The NSFR limits the stock of unstable funding by encouraging longer-term borrowing in order to restrict liquidity mismatches from excessive maturity transformation (BCBS, 2014b; see also BCBS, 2016a). It is currently subject to an observation period, which includes a review clause to address any unintended consequences prior to its implementation date of January 1, 2018. Based on the current definition banks are required to establish a stable funding profile over the short term, i.e., the use of stable (long-term and/or stress-resilient) sources to continuously fund cash flow obligations that arise from lending and investment activities inside a one-year time horizon.

The NSFR reflects the proportion of longer term (and less liquid) assets that are funded by stable sources of funding, including customer deposits, wholesale funding with maturities of more than one year, and equity (but excludes short-term liabilities). These sources and uses

[15] For committed credit facilities the drawdown rate declines to 10 percent. The assumed drawdown rate for both credit (liquidity) facilities extended to other non-bank financial institutions including securities firms, insurance companies, fiduciaries, and beneficiaries is 40 (100) percent (BCBS, 2013a).

(continued…)

of funds are not equally weighted but enter as risk-adjusted components into the calculation of the NSFR. A value of this ratio of less than 100 percent indicates a shortfall in stable funding based on the difference between balance sheet positions after the application of *available* stable funding factors and the application of *required* stable funding factors for banks where the former is less than the latter (BCBS, 2010c and 2014b).[16]

[16] Compliance with the NSFR, which emphasizes the availability of long-term sources of funding, could conflict with plans to make senior bondholders absorb bank losses under so-called "bail-in" clauses (Pengelly, 2012). Banks might find it difficult to lengthen the maturity of their balance sheet by issuing additional unsecured debt if mandatory bail-in clauses were attached to them, which would also result in higher funding costs compensating for investors for accepting bail-in risk.

Appendix Table 2. Overview of the Basel II and III Minimum Capital Requirements and Liquidity Standards

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Leverage Ratio	Supervisory monitoring		Parallel run January 2012 - January 2017; disclosure starts in January 2015					Migration to Pillar I	
Minimum Common Equity Capital Ratio			3.50	4.00	4.50	4.50	4.50	4.50	4.50
Capital Conservation Buffer						0.625	1.25	1.875	2.50
Minimum Common Equity + Capital Conservation Buffer			3.50	4.00	4.50	5.125	5.75	6.375	7.00
Phase-in of Deductions from CET1 1/				*20*	*40*	*60*	*80*	*100*	*100*
Minimum Tier 1 Capital			4.50	5.50	6.00	6.00	6.00	6.00	6.00
Minimum Total Capital			8.00	8.00	8.00	8.00	8.00	8.00	8.00
Minimum Total Capital + Capital Conservation Buffer			8.00	8.00	8.00	8.625	9.25	9.875	10.50
Phase-out of instruments that no longer qualify as non-core Tier 1 or 2 capital			Phased out over a 10-year horizon beginning 2013						
Liquidity Coverage Ratio (LCR)	Obs. period begins				Introduce min. standard				
					60	*70*	*80*	*90*	*100*
Net Stable Funding Ratio (NSFR)		Obs. period						Introduce min.	

Source: Basel Committee for Banking Supervision (BCBS), http://www.bis.org/bcbs/basel3.htm.
Note: See BCBS (2010b and 2010c). The introduction of the Liquidity Coverage Ratio (LCR) will be graduated (BCBS, 2013a). Specifically, the LCR will be introduced as planned on 1 January 2015, but the minimum requirement will begin at 60 percent, rising in equal annual steps of 10 percentage points to reach 100 percent on January 1, 2019.

APPENDIX IV. THE INTERACTION AND INTEGRATION OF SOLVENCY AND LIQUIDITY RISKS

More comprehensive macroprudential stress tests incorporate feedback effects between solvency conditions and liquidity risk in banking systems. While several papers have taken a more systematic approach into analyzing their interaction, the practical implementation of this concept remains at an early stage (BCBS, 2013c and 2015):

- Van den End (2008) developed a stress testing model that endogenizes market and funding liquidity risk by including feedback effects, which capture both behavioral and reputational effects.

- The Bank of England (Aikman and others, 2009) attempted to integrate funding liquidity risks and solvency risk in the Risk Assessment Model for Systemic Institutions (RAMSI). 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.

- Wong and Hui (2009) explicitly capture the link between default risk and deposit outflows. 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.

- Barnhill and Schumacher (2011) develop a more general empirical model, incorporating the previous two approaches that attempt to be more comprehensive in terms of the source of the solvency shocks and compute the longer term impact of funding shocks.

- Schmieder and others (2012) construct an Excel-based tool that allows liquidity tests informed by banks' solvency conditions, and to simulate the increase in funding costs resulting from a change in solvency.

- Jobst (2014) combines option pricing with market data and balance sheet information in the *Systemic Risk-adjusted Liquidity* (SRL) model to generate a probabilistic measure of the frequency and severity of multiple entities experiencing a joint liquidity event. The model links a bank's maturity mismatch between assets and liabilities affecting the stability of its funding with the characteristics of other banks, subject to individual changes in risk profiles and common changes in market conditions.

- The Bank of Canada's *Macro-Financial Risk Assessment Framework* (Anand, Bédard-Pagé and Traclet, 2014) includes a top-down liquidity stress test, which takes into account additional sources of pressure of banks' solvency due to outright rationing of funding—in addition to increases in its cost—and secondary effects from potential

spillovers with counterparty risk as weak banks may be unable to honor, in part or entirely, their interbank exposures.

- Hesse and others (2014) attempt to integrate macro-financial linkages, namely spillovers from the European periphery, to banks' solvency and liquidity resilience in a stress testing framework.

APPENDIX V. LIQUIDITY STRESS TESTING USING IMPLIED CASH FLOWS

Over the years, Fund staff has developed several liquidity risk stress testing tools for the system-wide assessment of the impact of negative shocks to banks' funding conditions. This paper presents one of these tools (Jobst, 2017), which was recently applied in the financial stability assessment modules of the FSAPs for Hong Kong SAR (IMF, 2014d) and the UK (IMF, 2016b).[17] The tool provides instructions regarding data requirements and assumptions and contains a complete calculation methodology consistent with the specific liquidity stress testing requirements of FSAPs.

The liquidity stress test captures the risk of a bank failing to generate sufficient funding to satisfy its short-term payment obligations over a pre-defined stress horizon. It follows a top-down implied cash flow (ICF) approach of modeling the impact of the sudden, sizeable withdrawals of funding (i.e., liabilities run-off) and unscheduled after taking into account the repayment of outstanding claims and availability of existing liquidity buffers ("counterbalancing capacity"). The funding shock is calibrated to assumptions about the expected (i.e., scheduled) and contingent cash in- and outflows related to existing claims and obligations ("funding liquidity risk") and the application of haircuts to available assets ("market liquidity risk") over risk horizons of five days (cumulative) and 30 days (non-cumulative). The ability to survive funding constraints is also influenced by the degree to which saleable assets are encumbered and the rollover risk stemming from maturity mismatches of assets and liabilities, which are assessed for both local and foreign currencies.

More specifically, several channels affecting the severity of cash flow calculations are considered (Appendix Table 3). They comprise: (i) the *decline in asset values under stress* and the extent to which they can be either used as collateral for secured wholesale funding or sold at stressed market values ("market liquidity risk"); (ii) *callback/renewal rates of scheduled and unscheduled cash flows from maturing assets and liabilities* ("funding liquidity risk"); and (iii) the *utilization rate of contingent claims and liabilities/funding swap arrangements*.[18] More specifically, these channels are defined as:

[17] The tool is available as MS Excel® workbook ("Attachment II_Appendix V_Liquidity Stress Testing Tool") at http://www.imf.org/~/media/Files/Publications/WP/2017/datasets/wp17102.ashx, which is published together with this working paper.

[18] The workbook requires firm-level data on liquid assets, in- and outflows from specified asset and liabilities, and net flows from derivatives which are separated into two "maturity buckets" of either: (i) one week/open maturity or (ii) longer than one week but up to month, corresponding to the respective ICF tests. The five-day test includes only data provided for the first maturity bucket, which are subject to the cumulative impact of specific call-back and run-off rate assumptions of assets and liabilities. The assumptions on valuation haircuts (for liquid assets), call-back rates (for cash inflows from the roll-off of outstanding claims and potential funding from contingent liabilities), and run-off rates (for cash outflows from the withdrawal/termination of funding and potential payments from contingent claims) are organized in separate worksheets and can be amended according to country-specific circumstances.

- *Liquid assets available for sale or collateralized funding* under the assumption of varying degrees of asset-specific valuation haircuts and encumbrance levels comprise: (i) cash and cash balances with central banks; (ii) securities and bank loans eligible for refinancing operations at the domestic and major central banks; (iii) securities and bank loans that can be mobilized in repo transactions (or another type of lending against financial collateral); and (iv) marketable securities in general.
- *Cash inflows* are determined by the expected repayment amount of outstanding credit with/without liquid financial assets as collateral, comprising: (i) expected outflows of cash and decline of liquid assets related to maturing transactions with/without liquid securities and bank loans (e.g., repo and securities lending transactions); (ii) expected and potential net cash flows related to derivatives (excl. credit derivatives); and (iii) potential inflows from committed/uncommitted credit lines to related and third parties.
- *Cash outflows* are defined by the run-off of maturing and non-maturity funding with/without liquid financial assets as collateral, comprising: (i) expected inflows of cash and increase of liquid assets related to transactions with/without liquid securities and bank loans (e.g., reverse repo and securities borrowing transactions); (ii) maturing repayments to related parties; and (iii) committed/uncommitted contingent claims to related and third parties.

The liquidity stress test is evaluated numerically as the ratio between potentially available liquidity and potentially required liquidity, which should be at least 100 percent or greater. A value lower than 100 percent would imply a liquidity shortage if the assumed stress scenario materialized. The test also includes several additional assumptions:

- *Only unencumbered liquid assets* (generating cash inflows), i.e., assets used as collateral to receive funding (with the exception of cash/cash-equivalents), are included in the test ("liquidity scope"); funding via potentially re-usable securities received as collateral ("rehypothecation") and cash inflows from new or renewed (secured/unsecured) wholesale lending (at contractual maturities) but full renewal of secured retail lending (e.g., secured lending with illiquid collateral such as residential mortgages) are not considered.
- There is *limited potential unsecured support in convertible currencies from related and third parties* (e.g., in the form of committed line) but full convertibility between currencies (within one week).

In the recent FSAP for the United Kingdom (IMF, 2016b), for example, the liquidity stress testing tool was applied to 10 institutions, consisting of seven major commercial banks and building societies, and the three largest subsidiaries of foreign investment banks covering 80 percent total banking assets. Results suggest for the five-day and 30-day implied cash flow tests suggest protracted non-cumulative stressed cash flows over a longer time horizon weaken banks' liquid buffers to a larger extent than cumulative stresses over a shorter period (Appendix Table 4 and Figure 2).

Appendix Table 3. Liquidity Stress Test Tool—Summary of Assumptions

Test	Definition	Basic Assumptions		Other Assumptions
		Assets (cash inflows)	Liabilities (cash outflows)	
5-day implied cash flow (ICF) test	Cumulative inflow and outflow over five consecutive days	Liquid financial assets: (i) cash and cash balances with central banks [**haircut**: 0 percent], (ii) securities and bank loans eligible at major central banks [0-15], (iii) securities and bank loans which can be mobilized in repo transactions (or another type of lending against financial collateral) [5-30], and (iv) marketable securities [10-35]. Cumulative cash inflows: (i) expected cash inflows related to credit extension without liquid financial assets as collateral [**call-back rate**: 20 percent per day], (ii) expected inflows of cash and liquid assets related to maturing transactions with liquid securities and bank loans (e.g., repo and securities lending transactions) [20], and (iii) potential inflows from committed/uncommitted credit lines to related and third parties [5/3].	Cumulative cash outflows: (i) maturing and non-maturity funding without liquid financial assets as collateral [**discount factor**: 5 percent per day] (i.e., all deposits and funding from financial and non-financial corporates as well as private households and SME clients) with the exception of sovereign and other public sector and central bank clients [0], (ii) expected outflows of cash and liquid assets related to transactions with liquid securities and bank loans (e.g., reverse repo and securities borrowing transactions) [20], (iii) maturing outflows to related parties [20], and (iv) committed/uncommitted contingent claims to related and third parties [5].	A ratio lower than 100 percent implies a liquidity shortage if the stress scenario would materialize at the reporting date (i.e., potentially required liquidity > potentially available liquidity); only unencumbered liquid assets (generating cash inflows), i.e., assets used as a collateral to receive funding (with the exception of cash/cash-equivalents) are included in the test ("liquidity scope"); new unsecured financing and securitization impossible within the time horizon; no offsetting cash inflows from new or renewed (secured/unsecured) wholesale lending (at contractual maturities) but full renewal of secured retail lending (e.g., secured lending with illiquid collateral (residential mortgages)); central bank eligible collateral can be monetized at appropriate haircuts; repo markets are open at appropriate haircuts; fire-sale of assets possible at appropriate haircuts; no consideration of funding via potentially re-usable securities received as collateral ("rehypothecation"); limited potential unsecured support in convertible currencies from related and third parties (e.g., in the form of committed lines); no renewal of term retail and wholesale deposits; and full convertibility between currencies (within one week).
		Cumulative net cash flows: expected and potential net cash flows related to derivatives (excl. credit derivatives) – net contractual cash flows [20] 1/		
30-day implied cash flow (ICF) test	Non-cumulative	Liquid financial assets: (i) cash and cash balances with central banks [0], (ii) securities and bank loans eligible at major central banks [0-20], (iii) securities and bank loans which can be mobilized in repo transactions (or another type of lending against financial collateral) [10-60], and (iv) marketable securities [20-70]. Non-cumulative cash inflows: (i) expected cash inflows related to credit extension without liquid financial assets as collateral [**call-back rate**: 100 percent], (ii) expected inflows of cash and liquid assets related to maturing transactions with liquid securities and bank loans (e.g., repo and securities lending transactions) [100], (iii) expected and potential net cash flows related to derivatives (excl. credit derivatives) – net contractual cash flows [100], and (iv) potential inflows from committed/uncommitted credit lines to related and third parties [23/12].	Non-cumulative cash outflows: (i) maturing and non-maturity funding without liquid financial assets as collateral [**discount factor**: 10-75 percent] (i.e., all deposits and funding from financial and non-financial corporates as well as private households and SME clients) with the exception of sovereign and other public sector and central bank clients [0], (ii) expected outflows of cash and liquid assets related to transactions with liquid securities and bank loans (e.g., reverse repo and securities borrowing transactions) [100], (iii) maturing outflows to related parties [100], and (iv) committed/uncommitted contingent claims to related and third parties [23].	
		Non-cumulative net cash flows: expected and potential net cash flows related to derivatives (excl. credit derivatives) – net contractual cash flows [100] 1/		

Source: Jobst (2017). Note: 1/ Note that many derivatives positions might be non-deliverable (typically, foreign exchange and interest rate swaps and forwards) and their valuation tends to be highly variable based on prevailing market conditions and expectations. For these positions, the valuation based on the firm's chosen accounting treatment should be considered, and potential net cash flows (variation margin/cash settlement cost) checked for consistency with the calibration of market risk under the Basel framework.

Appendix Table 4. Liquidity Stress Test Results—Implied Cash Flow Tests
(In billions of Pound Sterling)

Test 1a: Implied Cash Flow Test (5 Days)

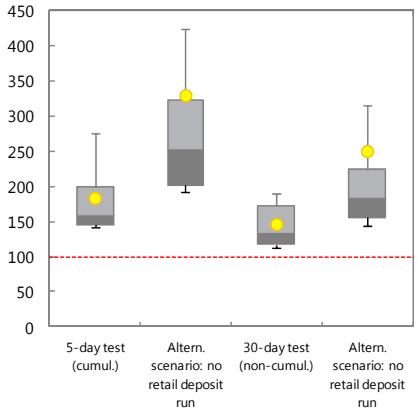
	Cumulative loss of unsecured funding (up to 1 week) (percent)	Cumulative loss of secured funding (up to 1 week) (percent)	Minimum number of days of survival	Banks illiquid (number)	Banks illiquid (percent of banking system assets)	Net cash shortfall relative to total liquid assets (percent)	Net cash shortfall relative to total assets (percent)
Day 1	5.2	5.4	1	0	0	0	0
Day 2	10.6	10.2	2	0	0	0	0
Day 3	16.4	14.5	3	0	0	0	0
Day 4	22.4	18.5	4	0	0	0	0
Day 5	315.0	243.7	5	0	0	0	0

Test 1b: Implied Cash Flow Test (30 Days)

	Cumulative loss of unsecured funding (percent)	Cumulative loss of secured funding (percent)	Survival	Banks illiquid (number)	Banks illiquid (percent of banking system assets)	Net cash shortfall relative to total liquid assets (percent)	Net cash shortfall relative to total assets (percent)
30 Days	27.5	100.0	No	0	0.0	0.0	0.0

Source: Bank of England staff estimates.

Appendix Figure 2. Implied Cash Flow Tests—Distribution
(In percent, solo basis)



Source: Bank of England staff estimates.
Note: The sample of banks included in the IMF top-down implied cash flow stress test includes the seven largest U.K. banks and three large subsidiaries of foreign banks representing 80 percent of the banking sector covered by routine liquidity reporting to the Prudential Regulation Authority (PRA). The boxplots include the mean (yellow dot), the 25th and 75th percentiles (grey box, with the change of shade indicating the median), and the 10th and 90th percentiles (whiskers). The red line indicates the lowest acceptable ratio value (threshold).

APPENDIX VI. LIQUIDITY STRESS TESTING: REPORTING TEMPLATE

Appendix Figure 3. Example of Output Template Provided to Authorities

[Country]: Aggregate Outcome of Liquidity Analysis

Total Number of Banks	27

Test 1: Implied Cash Flow Analysis

Test 1a: Implied Cash Flow Test (5 Days)

	Cumulative loss of all unsecured funding (In percent)	Cumulative loss of all secured funding (In percent)	Minimum number of days of survival	No. of banks illiquid	Percent of banks illiquid (In percent)	Net cash shortfall relative to total liquid assets (In percent)	Net cash shortfall relative to total assets (In percent)	Weighted avg. capital adequacy ratio of failing banks (In percent)	Weighted avg. Tier 1 capital ratio of failing banks (In percent)	Weighted avg. CET1 capital ratio of failing banks (In percent)
t_0	0.0	0.0	0	0	0.0	0.0	0.0			
Day 1	1.9	16.1	1	0	0.0	0.0	0.0	0.0	0.0	0.0
Day 2	3.7	29.0	2	16	59.3	-4.9	-0.6	6.7	7.8	9.0
Day 3	5.4	39.4	3	27	100.0	-36.2	-4.3	12.2	14.2	16.2
Day 4	7.0	47.6	4	27	100.0	-65.0	-7.7	12.2	14.2	16.2
Day 5	8.5	54.2	5	27	100.0	-89.8	-10.6	12.2	14.2	16.2

	Total Sample	Group 1	Group 2
Number of Banks failing the test	27	19	8
Liquidity Shortfall	-3,210,916	-2,367,750	-843,166
Liquidity Shortfall (In % of total assets)	-10.6	-11.6	-8.6
Liquidity Shortfall (In % of liquid assets)	-89.8	-98.9	-71.4

	Liquidity shortfall by percentile (acccording to assets)						Individual	
	Top 10% (i.e., largest banks)	10%-25%	25%-50%	50%-75%	75%-90%	90%-100%	max	min
Shortfall (abs)	-340,617	-421,583	-674,975	-852,080	-518,143	-403,517	-138,346	-100,426
Percent of Liquid Assets	74.9	72.2	81.5	95.4	153.0	84.9		
Number	3	4	6	7	4	3	27	

Test 1b: Implied Cash Flow Test (30 Days)

	Cumulative loss of all unsecured funding (In percent)	Cumulative loss of all secured funding (In percent)	Survival	No. of banks illiquid	Percent of banks illiquid (In percent)	Net cash shortfall relative to total liquid assets (In percent)	Net cash shortfall relative to total assets (In percent)	Weighted avg. capital adequacy ratio of failing banks (In percent)	Weighted avg. Tier 1 capital ratio of failing banks (In percent)	Weighted avg. CET1 capital ratio of failing banks (In percent)
	15.2	100.0	No	27	100.0	-152.4	-18.1	12.2	14.2	16.2
			Yes	0	0.0	0.0	0.0	0.0	0.0	0.0

	Total Sample	Group 1	Group 2
Number of Banks failing the test	27	19	8
Liquidity Shortfall	-5,447,709	-3,928,110	-1,519,600
Liquidity Shortfall (In % of total assets)	-18.1	-19.3	-15.5
Liquidity Shortfall (In % of liquid assets)	-152.4	-164.2	-128.7

	Liquidity shortfall by percentile (acccording to assets)						Individual	
	Top 10% (i.e., largest banks)	10%-25%	25%-50%	50%-75%	75%-90%	90%-100%	max	min
Shortfall (abs)	-591,310	-1,010,493	-1,765,809	-2,520,305	-2,512,344	-646,110	-218,850	-185,610
Percent of Liquid Assets	130.0	173.0	213.3	282.2	742.0	136.0		
Number	3	4	6	7	4	3	27	

Test 2: Maturity Mismatch Analysis

		Test 2a. Total B/S		Test 2b. FX only	
	Bucket	No. of banks with shortfall	Shortfall (In percent of total assets in bucket)	No. of banks with shortfall	Shortfall (In percent of total assets in bucket)
All banks	less than one week an	27	20.0	27	20.0
	1 to 4 weeks	27	20.0	27	20.0
	1 to 3 months	27	25.0	27	25.0
	3 to 6 months	27	33.3	27	33.3
	6 months to 1 year	27	50.0	27	50.0
	more than 1 year	27	60.0	27	60.0
Group 1	less than one week an	19	20.0	19	20.0
	1 to 4 weeks	19	20.0	19	20.0
	1 to 3 months	19	25.0	19	25.0
	3 to 6 months	19	33.3	19	33.3
	6 months to 1 year	19	50.0	19	50.0
	more than 1 year	19	60.0	19	60.0
Group 2	less than one week an	8	20.0	8	20.0
	1 to 4 weeks	8	20.0	8	20.0
	1 to 3 months	8	25.0	8	25.0
	3 to 6 months	8	33.3	8	33.3
	6 months to 1 year	8	50.0	8	50.0
	more than 1 year	8	60.0	8	60.0

Test 2a. Total B/S		Test 2b. FX only	
Number of failing banks (shortfall in lowest two maturity buckets)	Number of failing banks (shortfall in any maturity bucket)	Number of failing banks (shortfall in lowest two maturity buckets)	Number of failing banks (shortfall in any maturity bucket)
27	27	27	27

Source: Jobst (2017). Note: This summary table was taken from the liquidity stress testing tool presented in Appendix V.

APPENDIX VII. CASH FLOW-BASED LIQUIDITY STRESS TESTS

Fully fledged cash flow-based liquidity stress tests have been implemented by several central banks and the internal liquidity risk assessment by the European Banking Authority (EBA) in 2011 (and ever since then). They offer distinct advantages compared to "stock approaches" underpinning standard liquidity ratios (such as the LCR):

- Forward-looking by including banks' contractual cash out- and inflows as well as banks' expected counterbalancing capacity and should benefit from enhanced data availability and disclosure especially with regard to, for instance, asset encumbrance and securities funding such as repos or off-balance sheet funding;

- Enable detailed liquidity analysis and hence is better suited for capturing a bank's funding resilience and its liquidity risk bearing capacity compared to the rather limited stock approach (IMF, 2013b).

- Better capture banks' cumulative cash flows; standard measures follow a non-cumulative approach by focusing on a specific stress test window without accounting for other detailed maturity buckets (e.g., 30 days in the LCR case).

The Basel III regime[19] is moving towards cash flow-based liquidity monitoring and reporting through the LCR requirement. Cash flow-based liquidity stress tests have several advantages compared to other approaches by:

- Providing a more detailed analysis of liquidity positions similar to those carried out by banks (often daily) for their internal risk management purposes. The cash flow approach incorporates securities flows and ensures consistency between cash flows and securities flows;[20]

- Allowing for more granular maturity buckets (and may also be adapted to accommodate different currencies);

- Integrating granular information on banks' asset encumbrance levels from secured wholesale funding; and

[19] For instance, the Oesterreichische Nationalbank (OeNB) uses a cash flow-based liquidity stress approach. Given the implementation of Basel III via the CRR/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.

[20] This is especially important given the fundamental role unsecured and secured wholesale funding play for many large banks.

- Accommodating off-balance sheet activities, such as FX swaps or credit liquidity lines, and banks' behavioral cash out- and inflows, which might be more difficult in a standard stock approach.

Weaknesses of the cash flow approach include the high data intensity as well as initial set-up costs. A key prerequisite to carry out cash flow based liquidity tests is access to a wide range of data on contractual cash flows for different maturity buckets and possibly behavioral data based on banks' financial/funding plans. Additionally, while banks typically use a cash flow-based approach for internal liquidity monitoring and liquidity stress testing, regulatory liquidity ratios are often based on stock accounting data with often less data granularity than the cash flow-based templates.[21]

[21] For EU banks, the phase-in of cash flow-based maturity mismatch templates by the European Banking Authority (EBA) provides regulators and banks with standardized templates that would need to be regularly filled out and reported.