



# IMF Working Paper

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Of Runes and Sagas:  
Perspectives on Liquidity Stress Testing  
Using an Iceland Example

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## IMF Working Paper

Monetary and Capital Markets Department

### Of Runes and Sagas: Perspectives on Liquidity Stress Testing Using an Iceland Example

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#### Abstract

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The global financial crisis revealed weaknesses in the stress testing exercises performed on financial institutions and systems around the world. These failures were most evident in the area of liquidity risk, where now-obvious vulnerabilities were left largely undetected, with stress tests having largely focused on solvency risk. This paper uses publicly available data from a now-defunct bank in Iceland, where liquidity shocks were immense, to demonstrate how a combination of stress tests of the various risks would have provided a clearer picture of existing vulnerabilities. We show that, ultimately, stress test models do not necessarily need to be complex or overly sophisticated. Basic stress tests, using appropriate assumptions and shocks, could reveal key areas of risk to inform contingency planning. The liquidity stress test templates used in this paper are included.

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## I. INTRODUCTION

The global financial crisis revealed weaknesses in the stress testing exercises performed on financial institutions and systems by country authorities, as well as by international financial institutions, including the International Monetary Fund (IMF). Post-mortems on risk management, in general, and stress-testing, in particular, have pointed to weaknesses in the design of these tests, and have led to intensified focus on strengthening the analysis in this area.<sup>2</sup> The “failure to stress” was particularly evident in the area of liquidity risk, where now-obvious vulnerabilities across banks and banking systems were left largely undetected.<sup>3</sup> Stress testing work by country authorities, as well as that done by the IMF, would typically highlight many of the key risks, but specific vulnerabilities were not always adequately singled out, and the potential magnitudes of the identified problems were not fully quantified.

In the lead-up to the global financial crisis, stress tests had shown that banking systems in many countries could comfortably absorb significant shocks. More often than not, the stress tests did not provide indications that banking systems or individual banks were on the brink of significant stress.<sup>4</sup> A relevant example is Iceland, where the banking sector imploded in the space of 10 days in the fall of 2008, and the government took over the domestic operations of the country’s three largest banks. Stress test results published by the country’s financial supervisor, the Financial Supervisory Authority (FME), as late as mid-2008, showed that the three largest banks could comfortably weather large, concurrent shocks to financial markets and loan quality.<sup>5</sup> Separately, stress tests of credit risk, performed by the Seðlabanki, the country’s central bank, in 2008 suggested that Icelandic banks’ capital positions were sufficiently strong to meet increases in unexpected losses, but that they would need to bolster their capital under certain scenarios.

The objective of this paper is to demonstrate why stress tests focusing largely on solvency may have failed to trigger early warnings of the problems that manifested in banks in general during the global financial crisis. We apply basic stress testing techniques, using publicly available data from a now-defunct Icelandic bank (to avoid implicating any existing and viable institution). The aim is not to criticize the quality stress tests that were done in Iceland per se—there were no “international best practice” standards available—as the weaknesses have also been manifest in the stress tests performed in many countries around the world,

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<sup>2</sup> See, for instance, Basel Committee on Banking Supervision (BCBS, 2008a; 2009a; 2009b).

<sup>3</sup> The BCBS had highlighted the issue of liquidity risk shortly before the problem reached its nadir during the latter part of 2008 (BCBS, 2008b; 2008c).

<sup>4</sup> See Čihák and others (2010, forthcoming) for a discussion on the weaknesses in the design of stress tests and areas for improvement.

<sup>5</sup> See <http://www.fme.is/?PageID=168>.

including work done here at the IMF.<sup>6</sup> Rather, the intention is to show, more broadly, how inadequate focus on certain risks—notably liquidity risk—and the omission of crucial assumptions in designing scenarios, could reduce the usefulness of stress tests and potentially lead to a false sense of security.<sup>7</sup>

Our findings reveal several key weaknesses in the design of stress tests, in general, and highlights areas for improvement. Specifically, the typical emphasis of stress testing on solvency needs to be expanded to give due attention to liquidity risk as well. Off-balance sheet information could prove very useful for calibrating stress tests; and it is also crucial that stress tests consider “unthinkable” scenarios, however unpalatable or impolitic they may be. Importantly, we show that stress tests need not be overly complex, nor do stress testing models need to be too sophisticated to adequately capture risks. Stress tests—viewed holistically—may be useful in highlighting key areas of risk, to inform contingency planning.

The paper is structured as follows. Section II presents the Iceland case study to demonstrate how stress tests could be designed to appropriately capture pertinent risks, using data from one of the country’s largest banks at the time of the crisis in order to highlight the areas for improvement in stress testing exercises in general. Section III concludes with recommendations of how stress tests of banks could generally be enhanced to more usefully provide early indications of potential problems.

## **II. THE ICELAND CASE STUDY**

### **A. Background on the Banking Crisis**

The size of Iceland’s banking sector was about nine times the country’s gross domestic product (GDP) at the end of 2007, funded largely by external debt. The banking system was dominated by three large commercial banks, Kaupthing Bank hf. (“Kaupthing”), Landsbanki Íslands hf. (“Landsbanki”) and Glitnir banki hf. (“Glitnir”). The banks had relied heavily on market funding for their operations, and had previously been criticized for a lack of diversification in their funding profile, in particular, for the low proportion of deposits in their funding.<sup>8</sup> As a result, these banks intensified their focus on gathering deposits, and successfully so. At the end of 2007, some 40 percent of their funding was in the form of deposits, up from 28 percent in 2006, with more than two-thirds sourced from non-residents.<sup>9</sup>

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<sup>7</sup> More broadly-based stability assessments performed by IMF staff had warned of the risks, were not specific enough on the source and potential impact of the shocks. See IMF (2008), Mitra (2006) and Ong (2007) for an assessment of developments in Iceland’s financial sector and risks to the outlook.

<sup>8</sup> See Seðlabanki (2008).

<sup>9</sup> Almost 80 percent of deposits were in foreign currency, including 45 percent in pound sterling; some 56 percent of deposits were time deposits, and 86 percent of those time deposits had a maturity of three months or less. Landsbanki introduced the Icesave retail deposit product in the United Kingdom in October 2006, which

(continued...)

Iceland's banking sector collapsed in early-October 2008, following severe liquidity problems at the banks. On September 29, 2008, the Prime Minister announced that an agreement had been reached between the Government and the largest owners of Glitnir, the country's third largest bank, whereby the government would contribute new share capital and take up a 75 percent stake in the bank. A week later, on October 6, Iceland's parliament, the *Althing*, passed emergency legislation enabling the government to intervene extensively in Iceland's financial system. On October 7, the FME put Landsbanki into receivership; Glitnir and Kaupthing followed on October 8 and 9, respectively. By that stage, the three banks combined had amassed debt of an estimated \$61 billion—about 12 times the size of Iceland's economy—and were unable to secure short-term funding to continue servicing their obligations.<sup>10</sup>

The nadir of the crisis, during the first week of October 2008, was marked by severe shocks to Iceland's financial system. The value of the króna plummeted, and on October 7, 2008 the Seðlabanki attempted to peg the króna—trading at 172 against the euro at the time—at 131 against the euro; the peg was abandoned the next day. Trade in the currency was subsequently suspended, and payments in and out of Iceland effectively came to a standstill. A number of private interbank credit facilities to Icelandic banks were shut down, and banks were unable finance their debts through short-term borrowing. In an attempt to alleviate depositor concerns, the government offered an unlimited guarantee to all depositors in banks and branches in Iceland. By that stage, however, deposit runs on the overseas branches of Icelandic banks had already started.

Could the extent of the devastating liquidity crisis that struck Iceland's banking sector have been estimated? The Icelandic authorities had placed significant importance on their stress testing of the banking system, and had worked to enhance their modeling of the risks:

- The FME had performed stress tests of the country's individual banks on a quarterly basis. Indeed, the FME was one of the most transparent of supervisors in that the shock parameters of its stress tests and the results for individual banks were made available on its website. The stress scenarios assumed by the FME also appeared adequately conservative, incorporating significant shock parameters and scenarios (see discussion below). The acknowledged weakness in the stress test was that it did not incorporate any second round effects from shocks to the banking sector.<sup>11</sup>

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became by far its most important source of deposit funding. Icesave was introduced in continental Europe on May 30, 2008, with its launch in the Netherlands. Separately, Kaupthing introduced Kaupthing Edge, an online retail savings account, to eleven countries in Europe. The purpose was to diversify the liabilities on Kaupthing's balance sheet by currency, customer type and country. Kaupthing Edge was first launched in Finland, in October 2007.

<sup>10</sup> See Seðlabanki (2009) for a detailed discussion of the financial crisis in Iceland.

<sup>11</sup> See Ong (2007).

Additionally, an IMF report recommended that the FME stress tests be expanded to evaluate significant tail events (IMF, 2008).

- Separately, the Seðlabanki had estimated banks' resilience against loan losses and shocks to their portfolios.<sup>12</sup> The distribution of loan losses was divided into expected and unexpected losses—the former is covered through provisioning, while the latter is covered with capital, up to specified tolerance levels. Expected and unexpected losses were estimated based on specified shocks.

In the years leading up to the crisis, the stress tests by the FME and the Seðlabanki had focused largely on solvency risk, and in hindsight, did not adequately capture the potential tail-risks of a liquidity shock. The Seðlabanki's rules on the liquidity ratio for credit institutions subject to minimum reserve requirements represented a liquidity stress test of sorts.<sup>13</sup> However, as we demonstrate below, the appropriateness of the weightings applied to the individual items may be questionable during crisis periods, when extreme shocks occur. Indeed, the Seðlabanki had more formally introduced liquidity stress tests of individual banks in late-2007, using severe shock scenarios, as global financial conditions continued to deteriorate, and had identified vulnerabilities. As it turned out, it was too late to adequately address the problems at the banks by that stage.<sup>14</sup>

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<sup>12</sup> See Seðlabanki (2007; 2008).

<sup>13</sup> Rule No. 317/2006 on the Liquidity Ratio for Credit Institutions governs the ratio of weighted liquid assets and liabilities, whereby assets and liabilities are weighted using specific coefficients reflecting the probability of recovery of particular short-term assets, and the probability of that particular short-term liabilities must be repaid. The liquidity ratio is required to be calculated on the basis of data at the end of each month, and presented in a separate report to the central bank.

<sup>14</sup> The Seðlabanki's stress tests did not apply set stress scenarios across the banking sector. Rather, shocks were varied according to the different risk factors faced by different banks and the situation developing in financial markets. They included: closed access to credit lines, a significant drop in securities prices, a depreciation in the króna, increased defaults in the bank's loan portfolios; banks were also stressed to determine how much of their deposits could reasonably be paid out. The results of the stress tests were never made public. Subsequently, the Seðlabanki, in cooperation with the FME, gathered additional liquidity information from the banks, with greater frequency, as input into liquidity stress tests.

## B. Example: Landsbanki Íslands hf

In this section, we analyze the design of the stress tests that were performed on the Icelandic banking sector by replicating the actual shocks to one of the country's largest banks.<sup>15</sup> Specifically, we use end-2007 data published by the then-second largest bank, Landsbanki—which had operations encompassing Iceland, Continental Europe, the Nordic countries, the United Kingdom, Ireland, and North America—to recreate the liquidity situation at the bank. Detailed financial information is available in Landsbanki's 2007 *Annual Report*, in the bank's *Notes to the Consolidated Financial Statements* (Landsbanki, 2008).

On the surface at least, Landsbanki appeared to be in a sound, solvent position at the end of 2007. The bank's capital adequacy ratio (CAR) at the time was 11.7 percent, and its Tier 1 ratio was 10.1 percent. When the FME's stress test shocks were applied, Landsbanki's CAR fell to 10.5 percent—still above the regulatory minimum 8 percent—and its Tier 1 ratio declined to 8.8 percent (Landsbanki, 2008). Separately, the Seðlabanki's credit risk stress test results suggested that individual banks, including Landsbanki, could withstand an expected increase in defaults in 2008 (Seðlabanki, 2008).

Landsbanki also seemed to have sufficient liquid assets to cover its short-term liabilities. At the end of 2007, the parent bank's liquidity ratio, calculated in accordance with the central bank's rule No. 317/2006, was 2.23—well above the required ratio of higher than one for the next three-month period—even though the bank's non-derivative cash flow obligations as at end-2007 revealed that its short-term assets (less than one-year) were lower than its short-term liabilities (Table 1). Under normal conditions, Landsbanki's total assets, held to maturity, should have been sufficient to cover its total obligations.

### Liquidity Position

To assess Landsbanki's liquidity position in greater depth, we first re-construct the bank's overall liquidity position using data from the Notes to the Consolidated Financial Statements (Table 2).<sup>16</sup> Specifically, we:

- Combine the information presented on: (i) liquidity risk; (ii) derivative cash flows; and (iii) currency risk, to derive the balances of the individual items by currency.<sup>17</sup>

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<sup>15</sup> Comparisons with stress tests performed by the FME and Seðlabanki focus on publicly available information; the authorities' specific liquidity stress tests on individual banks are not analyzed.

<sup>16</sup> See Appendix I.

<sup>17</sup> The individual country amounts for each asset and liability item as a percentage of the total are used to prorate the individual country amounts across each maturity group. The total for "other" is assumed to be held in equal proportions in Denmark, Norway and Sweden.



- Limit our focus to the bank's short-term position, of one year or less, to highlight the key liquidity risk items.
- Consider the more liquid short-term assets, i.e., those that are ostensibly the easiest to liquidate in order to obtain funds quickly. These items are in row 1 and rows 4–7.<sup>18</sup>

The short-term liquidity position at Landsbanki, as at end-2007, is as follows:

- The total short-term assets amount to 1.70 trillion króna; the total liquid short-term assets are 728 billion króna.
- The total short-term liability amount to 1.95 trillion króna.

Under normal conditions, a negative net asset position does not necessarily reflect a liquidity crisis. Some short-term assets and liabilities are usually rolled over when they mature. One such item is deposits, which are typically not required to be paid back in their entirety in a short period of time, and therefore are usually considered a stable source of funding. Indeed, Landsbanki (2008) had noted that, *“Deposits, particularly retail deposits, have historically provided the bank with more stable funding than capital markets.”* In the case of Landsbanki, deposits from customers (row 13) alone appear more than sufficient to cover any liquidity shortfall (rows 23 and 24). Notably, customer deposits in the United Kingdom and Iceland represented the main sources of funding for the bank.

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<sup>18</sup> We define cash, bonds and equities, as well as hedged securities and derivatives held for trading as being very liquid assets, assuming a market exists at the time of sale. Derivatives held for hedging are likely to be more difficult to unwind given the potential implications for capital adequacy, while loans and advances may be more difficult to claim from debtors, who may default.

Table 1. Landsbanki: Net Assets by Maturity, as at December 31, 2007  
(In millions of króna)

	Up to 3 months	3-12 months	1-5 years	Over 5 years	Total
Total assets	1,321,104	337,526	945,953	706,549	3,311,132
Total liabilities	1,644,157	261,887	730,413	425,452	3,061,909
Net assets	-323,053	75,639	215,540	281,097	249,223
Cumulative net assets	-323,053	-247,414	-31,874	249,223	

Sources: Landsbanki 2007 Annual Report; and authors' calculations.

Table 2. Landsbanki: Initial 12-Month Liquidity Position as at December 31, 2007  
(In millions of króna)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ISK	EUR	USD	GBP	CHF	DKK	NOK	SEK	Total
<b>Short-term assets</b>									
(1) Cash and cash balances with Central Bank	69,285	8,510	0	1,145	0	873	873	873	81,559
(2) Loans and advances to financial institutions	22,066	58,378	14,935	57,015	1,184	2,281	2,281	2,281	160,423
(3) Loans and advances to customers	212,113	170,879	70,921	120,789	79,598	33,434	33,434	33,434	754,600
(4) Bonds	116,166	170,072	59,917	11,730	823	1,303	1,303	1,303	362,617
(5) Equities	19,656	17,802	1,199	6,421	7	6,441	6,441	6,441	64,407
(6) Hedged securities	92,931	40,169	23,157	11,440	399	2,695	2,695	2,695	176,181
(7) Derivatives held for trading	15,430	11,696	7,934	2,149	505	1,721	1,721	1,721	42,876
(8) Derivatives held for hedging	131	81	1,193	36	1	5	5	5	1,457
(9) Unsettled securities trading	3,724	26,270	799	27,982	0	23	23	23	58,845
(10) <b>Total short-term assets</b>	<b>551,503</b>	<b>503,857</b>	<b>180,055</b>	<b>238,706</b>	<b>82,517</b>	<b>48,776</b>	<b>48,776</b>	<b>48,776</b>	<b>1,702,965</b>
(11)=(1)+(4)+(5)+(6)+(7) <b>Total liquid short-term assets</b>	<b>313,468</b>	<b>248,249</b>	<b>92,207</b>	<b>32,885</b>	<b>1,734</b>	<b>13,032</b>	<b>13,032</b>	<b>13,032</b>	<b>727,640</b>
<b>Short-term liabilities</b>									
(12) Deposits from financial institutions	19,202	91,010	20,410	25,130	6,010	58,923	58,923	58,923	338,530
(13) Deposits from customers	291,329	186,174	19,851	870,148	1,324	3,154	3,154	3,154	1,378,288
(14) Borrowings	14,731	68,347	23,881	915	2,589	1,490	1,490	1,490	114,934
(15) Financial liabilities designated at fair value	0	1,797	43	0	0	359	359	359	2,918
(16) Subordinated loans	453	5,128	1,955	0	0	62	62	62	7,721
(17) Trading liabilities	843	2,387	1,414	2,110	67	95	95	95	7,105
(18) Derivatives held for hedging	0	765	0	0	12	5	5	5	792
(19) Tax liabilities	5,255	0	0	0	0	0	0	0	5,255
(20) Unsettled securities trading	0	22,122	443	23,516	2,285	11	11	11	48,399
(21) Derivatives held for trading	20,844	12,803	153	12,850	750	14	14	14	47,443
(22) <b>Total short-term liabilities</b>	<b>352,657</b>	<b>390,534</b>	<b>68,149</b>	<b>934,669</b>	<b>13,036</b>	<b>64,113</b>	<b>64,113</b>	<b>64,113</b>	<b>1,951,385</b>

Sources: Landsbanki 2007 Annual Report; and authors' calculations.

## Stress Tests of Liquidity Risk

In a severe financial crisis, the probability of extreme and unlikely events occurring increases. In Iceland's case, it meant that the weightings assigned to liquid assets and liabilities per the Seðlabanki's requirements were unlikely to hold. During periods of extreme stress, weightings on liquid claims are likely to fall on the back of any sharp drop in the market value of securities portfolios; additionally, repayment of maturing loans and advances may fall significantly as asset quality deteriorates. Conversely, the weightings placed on liquid liabilities are likely to rise significantly as depositors pull out their funds and lenders refuse to roll over their financing.

Buiter and Sibert (2008a, 2008b) observe in their assessment of the Icelandic banking sector that even fundamentally solvent banking systems could be brought down by a severe liquidity crunch. The authors posit that liquidity crises could be the result of either conventional bank runs by depositors and other creditors ("funding liquidity crises"), or through illiquidity in the markets for its assets ("market liquidity crises"). More specifically, the authors note that, *"There is no such thing as a safe deposit-taking bank on its own, even if its assets are of good quality and it has enough liquid assets to cope with normal variations in the net flow of deposits and other short-term liabilities."* They argue that any highly leveraged institution with assets that are mostly long-term and illiquid and liabilities that are mostly short term could suffer "catastrophic" liquidity shortages.

We consider such possibilities by applying different sets of shocks to the Landsbanki liquidity data constructed in Table 2. The different sets of shocks are summarized in Table 3:

- The first set of shocks (the first column) comprises the shocks used in the FME's stress tests. Although the FME shocks do not include shocks to specific liability items, we assume that all short-term liabilities are redeemed except for deposits from customers which remain stable, for demonstration purposes.
- The second set of shocks comprises a combination of the FME shocks with the Seðlabanki's liquidity shocks per rule No. 317/2006.
- The third set of shocks is an actual replication of the actual shocks that hit Icelandic markets and banks between end-2007 and October 2008.

The differences among these three scenarios lie in the types of shocks that are applied and the magnitudes of the common shocks. A key assumption is that the bank's financial position as of December 31, 2007 remains static. In our presentation of the results, short-term liabilities that are assumed to be redeemed are recorded as outflows, while short-term assets available for liquidation are presented as inflows.

Table 3. Iceland: Stress Test Shock Scenarios

	FME 1/	FME and Seðlabanki 1/	Actual: Between December 31, 2007 and October 7, 2008
Change in domestic stock prices	-35	-35	-52
Change in foreign stock prices	-25	-25	Between -24 and -44
Change in value of NPLs 2/	-20	-20	-100*
Change in bond prices 3/	-7	-50	Up to +700 basis points in yields
Change in krona levels	-20	-20	Between -35 and -55
<b>Liquid claims 4/</b>			
Repayment of claims against domestic credit undertakings	--	90	100 less NPLs
Repayment of claims against foreign credit undertakings	--	100	100 less NPLs
Repayments of claims against other parties	--	80	100 less NPLs
Positive market value of derivative agreements	--	90	--
<b>Liquid Liabilities</b>			
Withdrawal of approved loan commitments	100	-80	-100
Withdrawal of time deposits in krona 5/	100/0	-5	-43
Withdrawal of other deposits 5/	100/0	-10	-43
Borrowings	100	-100	-100

Sources: Bloomberg; FME; Seðlabanki; and various media reports.

- 1/ The FME stress test does not assume shocks to specific liability items; for demonstration purposes, we assume that all short-term liabilities are redeemed except for deposits from customers and deposits from central banks which remain stable.
- 2/ Where FME and Seðlabanki shocks overlap, the larger shock is applied (e.g., the loss of value in bonds and stocks).
- 3/ Given the illiquidity of Icelandic bonds at the time of the crisis—partly as a result of the suspension in króna trading—we use the change in credit default swap spreads to price those bonds during that period. In calculating the change in bond prices under the actual scenario, we make the assumption that the bonds which have maturities of up to 12 months have each has a duration of one-year.
- 4/ The NPL ratio as at end-2007 was 0.9 percent. The ratio at around the time of the banking crisis was estimated at around 3 percent although it was likely to have been higher; we assume a 50 percent loss in NPLs. Under the actual shock scenario, is assumed that the repayment of all claims by debtors are for the full amount less the reported NPLs, as there is no evidence of debtors being unable to repay the bank at the time of the shock.
- 5/ In the absence of available information, it is assumed that 43 percent of all deposits are withdrawn under the “actual” scenario—the same proportion as that calculated for the United Kingdom—before the accounts are frozen.

### *Stress test with FME shocks*

Under the scenario where the FME shocks are applied, the impact is largely on the asset side of the balance sheet, given the focus on solvency risk (Table 4). Specifically, the items in rows 2–5 are shocked. The exchange rate shock would impact both foreign currency assets and liabilities (all items in columns 2–8, which are reported in króna). The stress test results suggest that:

- Landsbanki’s deposit funding from customers clearly drives its liquidity position:
  - If all deposits from customers were to be redeemed, the net short-term asset balance would show a deficit of 162 billion króna, widening to a deficit of 1.28 trillion króna if only liquid short-term assets are taken into account (rows 23 and 24, column 9).
  - Assuming the stability of deposits from customers, of about 1.60 trillion króna, the overall liquidity position shows a positive net balance of 1.43 trillion króna if the redemption of liabilities are covered by all short-term assets (row 25, column 9); the balance falls to 311 billion króna if only liquid short-term assets are realized to cover redemptions (row 26, column 9).
- Naturally, the liquidity position would improve if it is assumed that some creditors providing market funding would continue to roll over their short-term loans (rows 12 and 14).
- The bank’s liquidity position differs across currencies following the shock:
  - If all deposits were redeemed, net short-term assets would be positive for the króna, euro, U.S. dollar and Swiss franc positions (row 23, columns 1–3 and 5), but only the U.S. dollar operations would show a surplus if liquid short-term assets are recoverable (row 24, column 3).
  - Assuming stable deposits, the net short-term asset balances for the króna, euro and U.S. dollar show surpluses when either the short-term assets or the liquid short-term assets are taken into account (rows 23 and 24, columns 1–3); liquidity positions in the other currencies are largely negative (rows 23 and 24, columns 4–8), suggesting that the bank’s operations in the former set of currencies may have to cover the liquidity needs in the other currencies.
- The bank’s liquidity position in pound sterling is notable in that short-term deposits from customers in this currency are the largest by far, accounting for 65 percent of total short-term deposits (row 13, column 4). Any run on those accounts alone would have caused significant funding problems for the bank.

Table 4. Landsbanki: 12-Month Liquidity Situation as at December 31, 2007 after FME Shocks are Applied  
(In millions of króna)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ISK	EUR	USD	GBP	CHF	DKK	NOK	SEK	Total
<b>Short-term assets available for liquidation</b>									
(1) Cash and cash balances with Central Bank	69,285	10,212	0	1,374	0	1,048	1,048	1,048	84,014
(2) Loans and advances to financial institutions	22,106	70,054	17,922	68,418	1,421	2,738	2,738	2,738	188,134
(3) Loans and advances to customers	212,495	205,055	85,105	144,946	95,518	40,120	40,120	40,120	863,479
(4) Bonds	108,034	189,800	66,867	13,091	918	1,454	1,454	1,454	383,074
(5) Equities	12,776	16,022	1,079	5,779	6	5,797	5,797	5,797	53,052
(6) Hedged securities	92,931	40,169	23,157	11,440	399	2,695	2,695	2,695	176,181
(7) Derivatives held for trading	12,190	11,790	7,997	2,166	509	1,734	1,734	1,734	39,855
(8) Derivatives held for hedging	131	81	1,193	36	1	5	5	5	1,457
(9) Unsettled securities trading	3,724	31,524	959	33,578	0	28	28	28	69,869
(10) <b>Total short-term assets available for liquidation</b>	<b>533,673</b>	<b>574,706</b>	<b>204,279</b>	<b>280,828</b>	<b>98,772</b>	<b>55,619</b>	<b>55,619</b>	<b>55,619</b>	<b>1,859,115</b>
(11) <b>Total liquid short-term assets available for liquidation</b>	<b>295,217</b>	<b>267,993</b>	<b>99,101</b>	<b>33,850</b>	<b>1,833</b>	<b>12,728</b>	<b>12,728</b>	<b>12,728</b>	<b>736,176</b>
<b>Less: Short-term liabilities that are redeemed</b>									
(12) Deposits from financial institutions (assuming 100 percent redemption by other credit institutions)	7,713	43,870	9,838	12,113	2,897	28,402	28,402	28,402	161,638
(13) Deposits from customers (assuming 100 percent redemption)	291,329	223,409	23,821	1,044,178	1,588	3,785	3,785	3,785	1,595,680
(14) Borrowings	14,731	82,016	28,657	1,099	3,107	1,788	1,788	1,788	134,975
(15) Financial liabilities designated at fair value	0	2,156	51	0	0	431	431	431	3,502
(16) Subordinated loans	453	6,153	2,346	0	0	74	74	74	9,175
(17) Trading liabilities	843	2,864	1,697	2,532	80	114	114	114	8,357
(18) Derivatives held for hedging	0	765	0	0	12	5	5	5	792
(19) Tax liabilities	5,255	0	0	0	0	0	0	0	5,255
(20) Unsettled securities trading	0	26,546	532	28,219	2,742	13	13	13	58,079
(21) Derivatives held for trading	16,467	12,906	154	12,953	756	14	14	14	43,279
(22) <b>Total short-term liabilities that are redeemed</b>	<b>336,791</b>	<b>400,687</b>	<b>67,095</b>	<b>1,101,094</b>	<b>11,182</b>	<b>34,627</b>	<b>34,627</b>	<b>34,627</b>	<b>2,020,730</b>
(23) = (10) - (22) <b>Total short-term assets available less total short-term liabilities redeemed (assuming full redemption of deposits)</b>	<b>196,881</b>	<b>174,019</b>	<b>137,184</b>	<b>-820,265</b>	<b>87,591</b>	<b>20,992</b>	<b>20,992</b>	<b>20,992</b>	<b>-161,615</b>
(24) = (11) - (22) <b>Total liquid short-term assets available less total short-term liabilities redeemed, (assuming full redemption of deposits)</b>	<b>-41,575</b>	<b>-132,694</b>	<b>32,005</b>	<b>-1,067,244</b>	<b>-9,349</b>	<b>-21,899</b>	<b>-21,899</b>	<b>-21,899</b>	<b>-1,284,555</b>
(25) = (23) + (13) <b>Total short-term assets available less total short-term liabilities redeemed (assuming stability of deposits)</b>	<b>488,210</b>	<b>397,429</b>	<b>161,005</b>	<b>223,912</b>	<b>89,179</b>	<b>24,776</b>	<b>24,776</b>	<b>24,776</b>	<b>1,434,065</b>
(26) = (24) + (13) <b>Total liquid short-term assets available less total short-term liabilities redeemed (assuming stability of deposits)</b>	<b>249,754</b>	<b>90,715</b>	<b>55,827</b>	<b>-23,066</b>	<b>-7,761</b>	<b>-18,115</b>	<b>-18,115</b>	<b>-18,115</b>	<b>311,125</b>

Sources: Landsbanki 2007 Annual Report; and authors' calculations.

### *Stress test combining FME and Seðlabanki liquidity shocks*

Under the scenario where the combined FME and Seðlabanki liquidity shocks are applied, both the asset and liability sides of Landsbanki's balance sheet are affected (Table 5):

- This time, the value of the bank's obligations is also directly shocked using the magnitudes described in the Seðlabanki's rule No. 317/2006 on the Liquidity Ratio for Credit Institutions.<sup>19</sup> In sum, the items in rows 2–5 are directly shocked, as are those in rows 12–14 and 21. Where FME and Seðlabanki shocks overlap, the larger shock is applied.
- The remaining liabilities, which are relatively small, are assumed to be redeemed in full.
- The exchange rate shock would impact both foreign currency assets and liabilities (all items in columns two to eight, which are reported in króna).

The stress test results suggest that:

- There would be sufficient short-term assets to cover the outflows.
  - Short-term assets available for liquidation less the redemptions on the short-term liabilities show an aggregate surplus of 960 billion króna (row 23, column 9).
  - The short-term assets in each currency would also be adequate to cover the corresponding short-term liabilities (row 23).
- Liquid short-term assets, in aggregate, would be sufficient to repay short-term liabilities (row 24, column 9).
  - Liquid short-term assets less redemptions of short-term liabilities result in an aggregate surplus of 12 billion króna (row 24, column 9).
  - On a currency-by-currency basis, however, the surpluses in króna and U.S. dollars (row 24, columns 1 and 3) may be required to cover the deficits in the other currencies.

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<sup>19</sup> The Seðlabanki's rule No. 317/2006 assigns a weighting of 5 percent to time deposits and 10 percent to other deposits in its calculation of liquid liabilities. In other words, it assumes that only 5 percent of time deposits and 10 percent of other deposits would be withdrawn. In the months leading up to the crisis, the Seðlabanki had applied greater shocks to banks' deposits, in stress tests of liquidity risk (see earlier discussion).



Table 5. Landsbanki: 12-Month Liquidity Situation as at December 31, 2007 After a Combination of FME and Seðlabanki Shocks are Applied  
(In millions of króna)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ISK	EUR	USD	GBP	CHF	DKK	NOK	SEK	Total
<b>Short-term assets available for liquidation</b>									
(1) Cash and cash balances with Central Bank	69,285	10,212	0	1,374	0	1,048	1,048	1,048	84,014
(2) Loans and advances to financial institutions	19,860	70,054	17,922	68,418	1,421	2,738	2,738	2,738	185,888
(3) Loans and advances to customers	169,691	164,044	68,084	115,957	76,414	32,096	32,096	32,096	690,478
(4) Bonds	58,083	102,043	35,950	7,038	494	782	782	782	205,954
(5) Equities	7,371	17,090	1,151	6,164	7	6,183	6,183	6,183	50,332
(6) Hedged securities	92,931	40,169	23,157	11,440	399	2,695	2,695	2,695	176,181
(7) Derivatives held for trading	6,751	6,140	4,165	1,128	265	903	903	903	21,160
(8) Derivatives held for hedging	131	81	1,193	36	1	5	5	5	1,457
(9) Unsettled securities trading	3,724	31,524	959	33,578	0	28	28	28	69,869
(10) <b>Total short-term assets available for liquidation</b>	<b>427,826</b>	<b>441,357</b>	<b>152,581</b>	<b>245,134</b>	<b>79,001</b>	<b>46,478</b>	<b>46,478</b>	<b>46,478</b>	<b>1,485,332</b>
(11) <b>Total liquid short-term assets available for liquidation</b>	<b>234,421</b>	<b>175,655</b>	<b>64,423</b>	<b>27,144</b>	<b>1,165</b>	<b>11,611</b>	<b>11,611</b>	<b>11,611</b>	<b>537,640</b>
<b>Less: Short-term liabilities that are redeemed</b>									
(12) Deposits from financial institutions	6,171	35,096	7,871	9,691	2,318	22,722	22,722	22,722	129,311
(13) Deposits from customers	22,420	22,341	2,382	104,418	159	378	378	378	152,855
(14) Borrowings	14,731	82,016	28,657	1,099	3,107	1,788	1,788	1,788	134,975
(15) Financial liabilities designated at fair value	0	2,156	51	0	0	431	431	431	3,502
(16) Subordinated loans	453	6,153	2,346	0	0	74	74	74	9,175
(17) Trading liabilities	843	2,864	1,697	2,532	80	114	114	114	8,357
(18) Derivatives held for hedging	0	765	0	0	12	5	5	5	792
(19) Tax liabilities	5,255	0	0	0	0	0	0	0	5,255
(20) Unsettled securities trading	0	26,546	532	28,219	2,742	13	13	13	58,079
(21) Derivatives held for trading	9,119	6,722	80	6,746	394	8	8	8	23,084
(22) <b>Total short-term liabilities that are redeemed</b>	<b>58,992</b>	<b>184,660</b>	<b>43,615</b>	<b>152,705</b>	<b>8,811</b>	<b>25,534</b>	<b>25,534</b>	<b>25,534</b>	<b>525,384</b>
(23) = (10) - (22) <b>Total short-term assets available less total short-term liabilities redeemed</b>	<b>368,833</b>	<b>256,696</b>	<b>108,966</b>	<b>92,429</b>	<b>70,190</b>	<b>20,944</b>	<b>20,944</b>	<b>20,944</b>	<b>959,948</b>
(24) = (11) - (22) <b>Total liquid short-term assets available less total short-term liabilities redeemed</b>	<b>175,428</b>	<b>-9,006</b>	<b>20,809</b>	<b>-125,560</b>	<b>-7,646</b>	<b>-13,923</b>	<b>-13,923</b>	<b>-13,923</b>	<b>12,256</b>

Sources: Landsbanki 2007 Annual Report; Seðlabanki; and authors' calculations.

## *Stress test with actual shocks*

### *Liquidity situation*

Under the scenario where the *actual* shocks are replicated, the impact on the liability side of the balance sheet is especially marked (Table 6). As before, the items in rows 2–5 are shocked, and the items in columns 2–8 are adjusted by the actual changes in the króna exchange rate. Additionally, the funding (liability) side of the balance sheet is significantly affected, with counterparties demanding repayment as a result of Landsbanki's sharply rising counterparty risk:

- Some 43 percent of deposits in the United Kingdom, in Landsbanki's Icesave accounts, were withdrawn during the crisis. In the absence of information, we conservatively assume runs of a similar magnitude on the rest of the deposits at Landsbanki.<sup>20</sup>
- Short-term market funding, through deposits from other credit institutions, and borrowings through securities issuances and syndicated loans, became inaccessible as lenders refused to roll over these loans or to make new ones, and the bank was required to repay maturing liabilities (rows 12 and 14).

As actually happened, the impact of the actual shocks to Iceland's financial system on Landsbanki's overall liquidity situation was quite severe. At the point where deposit withdrawals at branches abroad were suspended by Landsbanki:

- The bank's net short-term liquidity position remained in surplus of 776 billion króna (row 23, column 9).
- However, its liquid short-term assets would have been insufficient to cover demands for the repayment of its short-term liabilities, by 367 trillion króna (row 24, column 9).
- Additionally, the shutdown of the payment system would have significantly affected its ability to sell off its traditionally more liquid assets.
- On a by-currency basis:
  - Landsbanki would have had sufficient assets to cover its króna, euro and U.S. dollar liabilities (rows 23 and 24, columns 1–3) at the point when repayments were halted.

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<sup>20</sup> The extent of the runs was likely to have been smaller as the outflow of deposits from banks in Iceland subsided following the government's announcement of an unlimited guarantee.

- The largest deficits were in the bank's pound sterling operations—its high reliance on retail deposit funding from its United Kingdom Icesave accounts meant that the run on deposits significantly affected its liquidity position (rows 23 and 24, column 4).
- Furthermore, the shutdown in the international payment system would have prevented any transfer of surpluses by the bank to meet its other foreign currency liabilities, even if it had wanted to do so.

### *Funding gap*

The key question then is to what extent Landsbanki's estimated funding gap would have been at the time of the actual shocks. If we assume that the bank would have been able to realize its short-term assets in the market, and that all its short-term creditors would have demanded repayment of their maturing claims from the bank (Table 7), we find the following:

- Short-term assets less short-term liabilities would have shown a funding gap of 231 billion króna (row 23, column 9); liquid short-term assets less short-term liabilities would have resulted in a funding shortfall of about 1.37 trillion króna (row 24, column 9).
- The funding gap in pound sterling would have been the most severe, at between 868 billion króna, if all short-term assets could be realized, and 1.12 trillion króna, if only liquid short-term assets could be realized (rows 23 and 24, column 4). Indeed, the surplus net assets in all other currencies would have been insufficient to cover the funding gap in pound sterling (row 23).

If the bank would not have been able to sell its securities assets, such as bonds and equities, as a result of the closure of the payment system, then the funding gap would have widened considerably.

Table 6. Landsbanki: 12-Month Liquidity Situation as at December 31, 2007 after Actual Shocks and Freezing of Deposit Withdrawals are Applied  
(In millions of króna)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ISK	EUR	USD	GBP	CHF	DKK	NOK	SEK	Total
<b>Short-term assets available for liquidation</b>									
(1) Cash and cash balances with Central Bank	69,285	11,077	0	1,443	0	1,136	1,099	1,116	81,559
(2) Loans and advances to financial institutions	21,404	73,710	19,552	69,697	1,547	2,879	1,640	2,830	193,258
(3) Loans and advances to customers	205,750	215,758	92,845	147,654	103,932	42,197	24,031	41,474	873,641
(4) Bonds	108,826	222,884	82,090	14,894	1,087	1,706	1,648	1,673	434,807
(5) Equities	9,469	15,298	1,098	5,771	7	5,940	4,568	5,386	47,538
(6) Hedged securities	92,931	40,169	23,157	11,440	399	2,695	2,695	2,695	176,181
(7) Derivatives held for trading	10,944	12,689	9,067	2,330	591	1,920	1,698	1,824	41,064
(8) Derivatives held for hedging	131	81	1,193	36	1	5	5	5	1,457
(9) Unsettled securities trading	3,724	34,195	1,078	35,264	0	30	29	30	74,351
(10) <b>Total short-term assets available for liquidation</b>	<b>522,465</b>	<b>625,861</b>	<b>230,080</b>	<b>288,528</b>	<b>107,564</b>	<b>58,508</b>	<b>37,415</b>	<b>57,034</b>	<b>1,923,857</b>
(11) <b>Total liquid short-term assets available for liquidation</b>	<b>291,456</b>	<b>302,117</b>	<b>115,412</b>	<b>35,878</b>	<b>2,084</b>	<b>13,396</b>	<b>11,709</b>	<b>12,696</b>	<b>781,150</b>
<b>Less: Short-term liabilities that are redeemed</b>									
(12) Deposits from financial institutions	7,713	47,587	11,065	12,721	24,977	30,797	29,799	30,269	194,927
(13) Deposits from customers	124,345	103,435	11,435	426,946	760	1,752	1,695	1,722	672,089
(14) Borrowings	14,731	88,966	32,230	1,154	3,485	1,939	1,876	1,906	146,287
(15) Financial liabilities designated at fair value	0	2,339	58	0	0	468	453	460	3,777
(16) Subordinated loans	453	6,675	2,638	0	0	80	78	79	10,003
(17) Trading liabilities	843	3,107	1,908	2,659	90	123	119	121	8,971
(18) Derivatives held for hedging	0	765	0	0	12	5	5	5	792
(19) Tax liabilities	5,255	0	0	0	0	0	0	0	5,255
(20) Unsettled securities trading	0	28,796	598	29,635	3,076	14	14	14	62,147
(21) Derivatives held for trading	14,784	13,891	175	13,933	878	16	14	14	43,705
(22) <b>Total short-term liabilities that are redeemed</b>	<b>168,124</b>	<b>295,561</b>	<b>60,106</b>	<b>487,048</b>	<b>33,277</b>	<b>35,194</b>	<b>34,052</b>	<b>34,589</b>	<b>1,147,953</b>
(23) = (10) - (22) <b>Total short-term assets available less total short-term liabilities redeemed</b>	<b>354,340</b>	<b>330,300</b>	<b>169,974</b>	<b>-198,521</b>	<b>74,287</b>	<b>23,314</b>	<b>3,363</b>	<b>22,445</b>	<b>775,904</b>
(24) = (11) - (22) <b>Total liquid short-term assets available less total short-term liabilities redeemed</b>	<b>123,331</b>	<b>6,555</b>	<b>55,306</b>	<b>-451,170</b>	<b>-31,193</b>	<b>-21,798</b>	<b>-22,343</b>	<b>-21,894</b>	<b>-366,803</b>

Sources: Landsbanki 2007 Annual Report; various media reports; and authors' calculations.

Table 7. Landsbanki: Estimated Short-Term Funding Gap as at December 31, 2007 after Actual Shocks are Applied  
(In millions of króna)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ISK	EUR	USD	GBP	CHF	DKK	NOK	SEK	Total
<b>Short-term assets</b>									
(1) Cash and cash balances with Central Bank	69,285	11,077	0	1,443	0	1,136	1,099	1,116	85,157
(2) Loans and advances to financial institutions	21,404	73,710	19,552	69,697	1,547	2,879	1,640	2,830	193,258
(3) Loans and advances to customers	205,750	215,758	92,845	147,654	103,932	42,197	24,031	41,474	873,641
(4) Bonds	108,826	222,884	82,090	14,894	1,087	1,706	1,648	1,673	434,807
(5) Equities	9,469	15,298	1,098	5,771	7	5,940	4,568	5,386	47,538
(6) Hedged securities	92,931	40,169	23,157	11,440	399	2,695	2,695	2,695	176,181
(7) Derivatives held for trading	10,944	12,689	9,067	2,330	591	1,920	1,698	1,721	40,960
(8) Derivatives held for hedging	131	81	1,193	36	1	5	5	5	1,457
(9) Unsettled securities trading	3,724	34,195	1,078	35,264	0	30	29	30	74,351
(10) <b>Total short-term assets</b>	<b>522,465</b>	<b>625,861</b>	<b>230,080</b>	<b>288,528</b>	<b>107,564</b>	<b>58,508</b>	<b>37,415</b>	<b>56,931</b>	<b>1,927,351</b>
(11) <b>Total liquid short-term assets</b>	<b>291,456</b>	<b>302,117</b>	<b>115,412</b>	<b>35,878</b>	<b>2,084</b>	<b>13,396</b>	<b>11,709</b>	<b>12,592</b>	<b>784,644</b>
<b>Short-term liabilities</b>									
(12) Deposits from financial institutions	19,202	47,587	11,065	12,721	24,977	30,797	29,799	30,269	206,415
(13) Deposits from customers	291,329	242,340	26,791	1,096,582	1,782	4,104	3,971	4,033	1,670,933
(14) Borrowings	14,731	88,966	32,230	1,154	3,485	1,939	1,876	1,906	146,287
(15) Financial liabilities designated at fair value	0	2,339	58	0	0	468	453	460	3,777
(16) Subordinated loans	453	6,675	2,638	0	0	80	78	79	10,003
(17) Trading liabilities	843	3,107	1,908	2,659	90	123	119	121	8,971
(18) Derivatives held for hedging	0	996	0	0	16	6	6	6	1,031
(19) Tax liabilities	5,255	0	0	0	0	0	0	0	5,255
(20) Unsettled securities trading	0	28,796	598	29,635	3,076	14	14	14	62,147
(21) Derivatives held for trading	14,784	13,891	175	13,933	878	16	14	14	43,705
(22) <b>Total short-term liabilities</b>	<b>346,598</b>	<b>434,697</b>	<b>75,463</b>	<b>1,156,684</b>	<b>34,303</b>	<b>37,548</b>	<b>36,329</b>	<b>36,903</b>	<b>2,158,524</b>
(23) = (10) - (22) <b>Total short-term assets less total short-term liabilities</b>	<b>175,867</b>	<b>191,164</b>	<b>154,618</b>	<b>-868,157</b>	<b>73,261</b>	<b>20,960</b>	<b>1,085</b>	<b>20,028</b>	<b>-231,173</b>
(24) = (11) - (22) <b>Total liquid short-term assets less total liabilities</b>	<b>-55,142</b>	<b>-132,581</b>	<b>39,950</b>	<b>-1,120,806</b>	<b>-32,218</b>	<b>-24,152</b>	<b>-24,620</b>	<b>-24,311</b>	<b>-1,373,881</b>

Sources: Landsbanki 2007 Annual Report; various financial press; and authors' calculations.

## Summary of results

Our exercise illustrates that Landsbanki's liquidity position worsens when more realistic shocks are introduced to include the funding (liability) side of the balance sheet (Table 8). In particular, we find that:

- (1) The short-term balance sheet of the bank is more than 1.5 times the country's GDP.
- (2) Under the FME shocks, the bank would still be able to comfortably meet its short-term obligations with its short-term assets, if deposits remain stable.
- (3) The bank's liquidity position worsens somewhat when the Seðlabanki liquidity shocks are added, although it would still be able to cover its obligations.
- (4) The introduction of the actual shocks to the bank's deposit funding further reduces the availability of liquidity. At the point where the withdrawal of deposits is frozen, the bank would not have been able to cover a large portion of its short-term liabilities with its liquid assets alone.
- (5) With the actual shocks, Landsbanki's funding gap amounts to an estimated 18 percent of Iceland's 2007 GDP, assuming all short-term assets are recoverable. The gap would have widened to more than 100 percent of GDP if liquid short-term assets only are taken into account; the funding gap would have worsened if liquid assets such as bonds and equities could not have been sold down following the closure of the international payment system.

## III. LESSONS LEARNED

The global financial crisis provided an opportunity to assess stress testing efforts by country authorities and others, including international financial institutions. Many stress tests have failed to capture the key shocks that subsequently materialized during the crisis, as a result of the emphasis on solvency risk, instead of taking a more comprehensive view which includes a perspective on the liquidity situation. Using the example of a particular (failed) bank in Iceland, we demonstrate the basic weaknesses of stress tests that have been applied in many countries, and provide suggestions for improvement.

In the case of Iceland, it has been posited that the problems that beset the country's banking sector was largely attributable to its unviable banking model (e.g., Buiters and Sibert, 2008b; Danielsson, 2008; and Jackson, 2008). Iceland is a small, open economy, with its own currency and an internationally integrated financial sector that was very large relative to its GDP and the government's fiscal capacity. Thus, the central bank could not act as an effective foreign currency lender of last resort, nor did the government have the capacity to provide credible guarantees, either explicit or implicit, to the banks to back up their assets. In other words, the banks were "too big to save." It has also been contended that the Icelandic

Table 8. Landsbanki: Summary of Stress Test Results

Shock	Outcome
Iceland 4-quarter GDP to 30 September 2008 (in millions of krona)	1,301,409
(1) <u>Initial liquidity position, assuming no crisis</u>	
Total short-term assets	
In millions of krona	1,702,965
As a percentage of GDP	131
Total liquid short-term assets	
In millions of krona	727,640
As a percentage of GDP	56
Total short-term liabilities	
In millions of krona	1,951,385
As a percentage of GDP	150
(2) <u>FME shocks, assuming stability of deposits</u>	
Total short-term assets available less total short-term liabilities redeemed	
In millions of krona	1,434,065
As a percentage of GDP	110
Total liquid short-term assets available less total short-term liabilities redeemed	
In millions of krona	311,125
As a percentage of GDP	24
(3) <u>Combined FME and Seðlabanki liquidity shocks</u>	
Total short-term assets available less total short-term liabilities redeemed	
In millions of krona	959,948
As a percentage of GDP	74
Total liquid short-term assets available less total short-term liabilities redeemed	
In millions of krona	12,256
As a percentage of GDP	1
(4) <u>Actual shocks, with deposit freeze</u>	
Total short-term assets available less total short-term liabilities redeemed	
In millions of krona	775,904
As a percentage of GDP	60
Total liquid short-term assets available less total short-term liabilities redeemed	
In millions of krona	-366,803
As a percentage of GDP	-28
(5) <u>Funding gap, following actual shocks</u>	
Total short-term assets less total short-term liabilities	
In millions of krona	-231,173
As a percentage of GDP	-18
Total liquid short-term assets less total liabilities	
In millions of krona	-1,373,881
As a percentage of GDP	-106

Sources: Tables 2, 4–7; International Financial Statistics, IMF; and authors' calculations.

banks might not have been brought down by illiquidity alone, if Iceland had been a full member of the Euro Area, with the full liquidity facilities of the Eurosystem at its disposal.

Our observations on the design of stress tests are broadly applicable, notwithstanding the relatively unique situation of Iceland's banking sector. Many countries around the globe are not members of a common currency area, and their governments may still need to provide backing to the banking system in the event of a crisis. Even if those governments have the capacity to do so, liquidity crises in the banking sector could still cause significant stress for the stability of a financial system while the problem is being addressed by the authorities (e.g., the Northern Rock incident in the United Kingdom). Thus, stress tests that are able to capture key risks early on could contribute towards the design of or improvements in crises mitigation and resolution frameworks.

The stress testing exercise presented in this paper highlights several salient points about the design of stress tests in general. These are as follows:

- Stress testing for solvency risk alone is insufficient. Even solvent financial institutions, when faced with severe liquidity shortages, could rapidly become insolvent as demonstrated by the recent global financial crisis. As noted in BCBS (2008a), *“Even though strong capital positions reduce the likelihood of liquidity pressure, apparently solvent banks can suffer liquidity problems.”* Conversely, financial institutions that may be insufficiently capitalized would be able to “survive” for some time if they have sufficient liquidity to service their short-term debts.<sup>21</sup>
- There is a need to look beyond the consolidated numbers in profit and loss statements and balance sheets. Ideally, one would need to have access to supervisory information with detailed breakdowns of the various off-balance sheet positions, identifying more precisely their impact on liquidity. However, the analysis in this paper shows that the publicly available Notes to the Consolidated Accounts already provide a substantial amount of detail (e.g., claims and obligations by currencies; spot and derivatives positions; and maturities), as well as information on off-balance sheet items, which enable closer focus on the key risk areas.
- Stress tests should consider “unthinkable” developments. BCBS (2008a) observes that, regardless of how strong a bank's current liquidity situation may seem, it should consider the potential impact of severe stress scenarios, and not discount those severe scenarios as “implausible.” They may need to take into account sensitive issues, such as a sustained run on deposits (typically considered a stable source of funding), a

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<sup>21</sup> In the case of Landsbanki, the short-term funding problems eventually revealed the bank to be badly insolvent as asset quality deteriorated sharply and quickly amid the unprecedented magnitude of the financial crisis, exacerbated by the bank's weak lending practices.



refusal by lenders in wholesale capital markets to roll over their loans, or the possibility of a shutdown in the payment and settlement infrastructure, paralyzing the transfer of funds to meet maturing obligations and the trading of securities. Indeed, performing such exercises on a routine basis could make them more acceptable.

- A useful way of performing and presenting extreme shocks is to “stress test till it breaks.” This means that, instead of focusing on identifying an “extreme but plausible” scenario, the focus would be on identifying a set of scenarios under which the system reaches a pre-defined threshold, such as a low capitalization ratio or a low level of liquidity (Čihák, 2007). If such tests are performed regularly, their results can be used for discussing how vulnerabilities in the system evolve over time.

Within the specific framework of a liquidity stress test, there is a need to focus on key vulnerabilities in terms of asset recovery and funding sources. For instance, tail risks should be taken into account when shocking key liquid short-term assets that may have to be realized quickly (e.g., the impact from a closure of the payment system on securities trading), or the main funding sources on which significant reliance is placed (e.g., withdrawals of deposits or wholesale funding). For the items described above, shocks could be focused on particularly risky items/currencies, where such breakdown is available. Ultimately, stress test models do not need to be overly complex. Basic stress tests, using appropriate assumptions and shocks, could reveal important vulnerabilities well ahead of time.

#### IV. CONCLUDING REMARKS

Clearly, our findings in this paper have benefitted from hindsight. Thinking the unthinkable or unpalatable is easier said than done, *ex ante*. For instance, few banks can survive a sustained deposit run, which could make the specification of that particular stress difficult. That said, well-designed stress tests—ones that assess risks holistically, rather than each one in isolation—could help identify key areas where risks may be concentrated.

Once identified, supervisory authorities and banks themselves could take some actions, *ex ante*, to mitigate potential risks. For instance, BCBS (2008b) notes that in the lead-up to the global financial crisis, many banks had failed to take account of a number of basic principles of liquidity risk management. In particular, many of the most exposed banks did not have an adequate framework that satisfactorily accounted for the liquidity risks posed by individual products and business lines; many had not considered the amount of liquidity they might need to satisfy contingent obligations. Numerous banks also viewed severe and prolonged liquidity disruptions as implausible and did not conduct stress tests that factored in the possibility of market wide strain or the severity or duration of the disruptions. And finally, contingency funding plans were not always properly linked to stress test results and sometimes failed to take account of the potential closure of some funding sources.

Stress testing and contingency planning should be closely intertwined. The results of stress tests should also play a key role in shaping the contingency planning by banks and the authorities, and in determining the appropriate strategies and tactics to deal with events of stress, or, ideally, to forestall significant problems from developing. In the Iceland example presented here, the banks were simply too big to save; appropriate prudential measures should have been implemented and risk management strategies should have been strictly enforced while those banks were expanding rapidly.

## APPENDIX I. GLOSSARY

Appendix Table 1. Landsbanki: Composition of Balance Sheet Items

Item	Composition
<b>Assets</b>	
Cash and cash balances with Central Bank	n.a.
Loans and advances to financial institutions	n.a.
Loans and advances to customers	Customers include public entities, corporates and individuals; net of provisions for credit losses.
Bonds	Domestic and foreign, listed and unlisted.
Equities	Domestic and foreign, listed and unlisted.
Hedged securities	Bonds and equities
Derivatives held for trading	Foreign exchange, interest rate, equity and commodity derivatives.
Derivatives held for hedging	Interest rate and cross currency swaps.
Unsettled securities trading	n.a.
<b>Liabilities</b>	
Deposits from financial institutions	Loans from Central bank and repurchase agreements; loans from other credit institutions.
Deposits from customers	Demand and time deposits.
Borrowings	Securities issued (MTNs, CPs, other); syndicated loans and other borrowings.
Financial liabilities designated at fair value	Unit-linked investment contracts; with matched interest rate swaps; with embedded derivatives.
Subordinated loans	Tier I (non-innovative and innovative hybrid capital); Tier II
Trading liabilities	n.a.
Derivatives held for hedging	Interest rate and cross currency swaps.
Tax liabilities	n.a.
Unsettled securities trading	n.a.
Derivatives held for trading	Foreign exchange, interest rate, equity and credit derivatives.

Source: Landsbanki.

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