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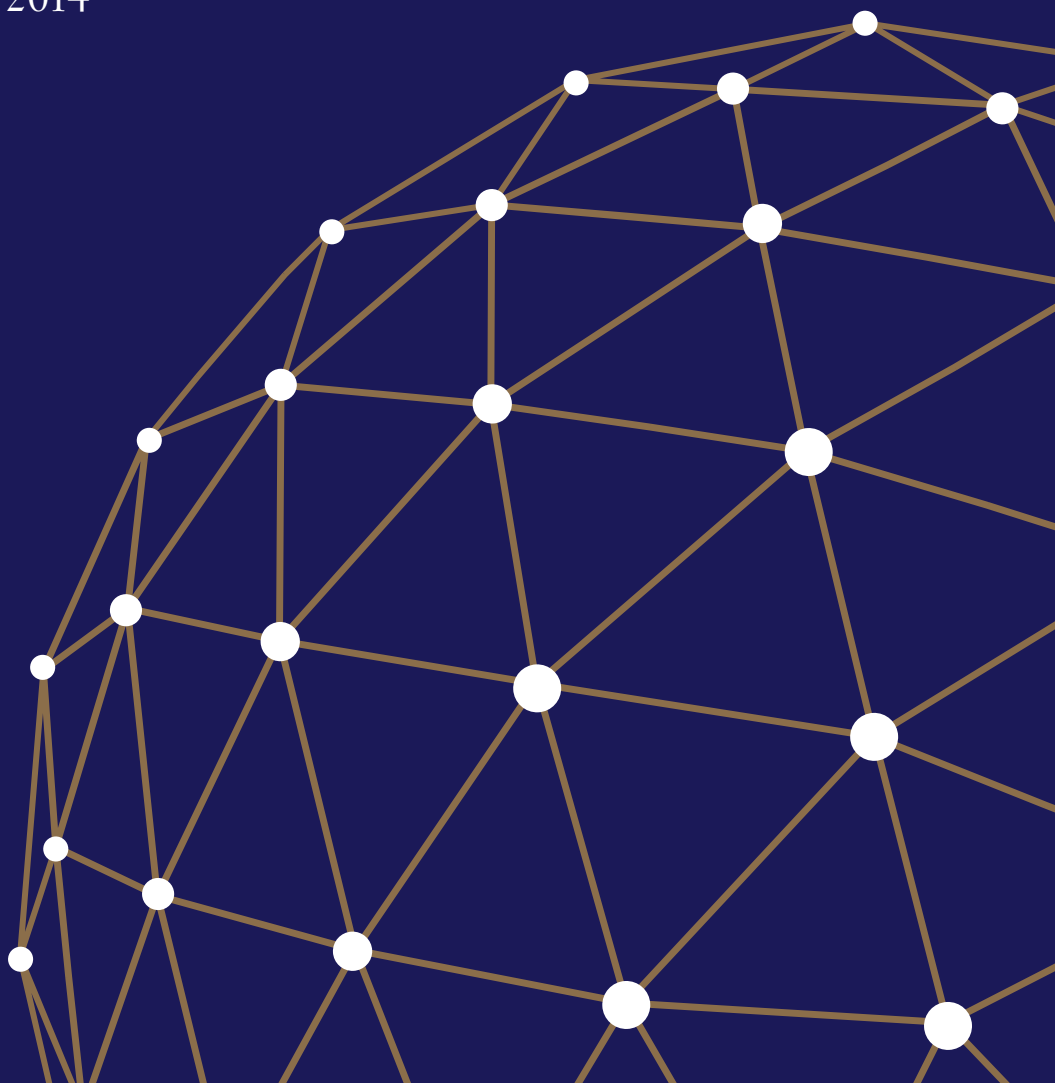

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(Stressztesztek a Magyar Nemzeti Bank gyakorlatában)

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Contents

Abstract

Our study presents the top-down stress testing framework currently used by the Magyar Nemzeti Bank. We run separate solvency and liquidity stress tests to analyse the ability of the banking system to absorb shocks and we present their results in our *Report on Financial Stability.* In the former, we focus mostly on credit risk but also take into account losses due to market risks. Our study explains in detail the method we apply to quantify the impact of a negative two-year macroeconomic shock on the capital adequacy ratio. We explain the models we use for calculating profit before loan losses, PDs and LGD. We also demonstrate how we measure the impact of an intensive 30-day liquidity shock on the banking system. Finally, we use the stress test completed in the spring of 2013 to explain in detail how the results should be interpreted and what conclusions we can draw from them.

JEL: E44, E47, G21.
Keywords: stress test, liquidity risk, credit risk.

Összefoglaló

Tanulmányunk célja bemutatni a Magyar Nemzeti Bankban jelenleg alkalmazott top-down stresszteszt keretrendszerét. A bankrendszer sokkellenálló képességének vizsgálatakor külön készítünk szolvencia- és likviditási stressztesztet, amelyek eredményét a *Jelentés a pénzügyi stabilitásról* című kiadványban mutatjuk be. Előbbi esetében elsősorban a hitelkockázatra fokuszálunk, de a piaci kockázatokból származó veszteségeket is figyelembe vesszük. A tanulmányban részletesen bemutatjuk, hogyan számszerűsítjük egy kedvezőtlen, kétéves makrogazdasági sokk hatását a tőkemegfelelési mutatóra. Bemutatjuk azokat a modelleket, amelyekkel a hitelezési veszteségek előtti eredményt, a PD-ket és az LGD-t számítjuk. Bemutatjuk továbbá, hogyan mérjük egy intenzív, 30 napos likviditási sokk hatását a bankrendszerben. Végül pedig a 2013 tavaszán készült stressztesztet felhasználva részletezzük, hogy a kapott eredményeket hogyan kell értelmezni, és milyen következtetéseket vonhatunk le belőle.

1 Introduction

'The MNB shall establish the macro-prudential policy for the stability of the entire system of financial intermediation, with the objective to enhance the resilience of the system of financial intermediation and to ensure its sustainable contribution to economic growth. To that end and within the limits specified in this Act, the MNB shall explore the business and economic risks threatening the system of financial intermediation as a whole, promote the prevention of the development of systemic risks and the reduction or elimination of the evolved systemic risks.'[1] It relies on a series of analytical tools to fulfil this responsibility. One of these tools is stress testing, which has become especially important during the crisis. Stress tests have gained prominence not only in Hungary but in all neighbouring countries. Examples of countries where stress testing now forms a part of the stability reports include Austria, the Czech Republic, Slovakia and Romania. It is also crucial in the work of major central banks such as the Bank of England and the European Central Bank.

In stress testing, we aim to discover whether the capital surplus and liquidity buffer of the banking system would be sufficient to allow it to retain stable operations under adverse macroeconomic conditions. We quantify the impacts of different macroeconomic scenarios for the individual institutions. Based on this, we attempt to identify the impact of a series of potential adverse events on the banking system. Besides measuring the shock-absorbing capacity of the banking system, we offer guidelines for identifying risks and preparing for adverse events. The fundamental objective of this methodology is sensitivity analysis, and therefore the results should not be seen as forecasts even if their starting point is an actual macroeconomic projection. This should be remembered as we evaluate the assumptions used.

The most fundamental feature of a stress test is the risk itself that is being tested. Accordingly, we run separate liquidity stress tests and credit risk stress tests supplemented with market risk. Although in designing the tests we try to keep the range of risks analysed together as wide as possible, there are several reasons why stress testing liquidity and solvency together is not practical (e.g.: different time horizons, impact mechanism, the necessary regulatory measures etc.). Separating the tests is received practice in other countries too. Capital stress tests tend to focus on credit and market risks (e.g.: Geršl et al., 2012; ECB, 2013), whereas liquidity stress tests form a separate entity (e.g.: Komárková et al., 2011; Van den End, 2010). Solvency stress tests tend to focus mainly on the quantification of losses from credit risks. In Slovakia, the primary objective of testing is to determine the default rate of loans and their impact on profits. Less attention is given to quantifying interest and exchange rate shifts (Zeman and Jurca, 2008). Similarly, stress testing in the Czech Republic assigns less importance to market risk than to credit risk. The revaluation of the portfolio is calculated on the basis of the currency structure and the maturity structure. The tests also look at potential contagion impacts and sovereign risks (Geršl et al., 2012) .

As in the examples cited, solvency and liquidity stress testing is separated in Hungarian practice as well. We will therefore present the methodologies and interpretations of the stress tests separately. In Chapter 2 we address liquidity stress testing. We present the risk scenario we surmise, the results we get at the end of stress testing and how the results are interpreted. Chapter 3 focuses on the same features in respect of credit risk stress testing. We demonstrate the interpretation of the results in our study by using the stress tests published in May 2013.

[1] Article 4 (7) of Act CXXXIX of 2013 on the Magyar Nemzeti Bank.

2 The liquidity stress test

In liquidity stress testing we aim to answer the question of how the liquidity surplus of individual banks and thus the banking system as a whole would change in a stress situation. It is defined as an extreme case of liquidity deficit when one or more banks become illiquid in the stress test; in other words, their liquid assets and their revenues are not enough to meet their obligations. In such a case, without the banks' adjustment or in the lack of a government or central bank intervention, the bank concerned becomes insolvent. In the stress test we investigate how much of a shortfall there is compared to the regulatory minimum liquidity at the level of the individual banks and across the banking system as a whole.

In the following we describe in detail the structure of the MNB's liquidity stress tests. In addition to a description of the methodology, we present an interpretation of the results using the stress tests from our *Report on Financial Stability* published in May 2013.

2.1 REGULATORY MINIMUM OF LIQUIDITY SURPLUS

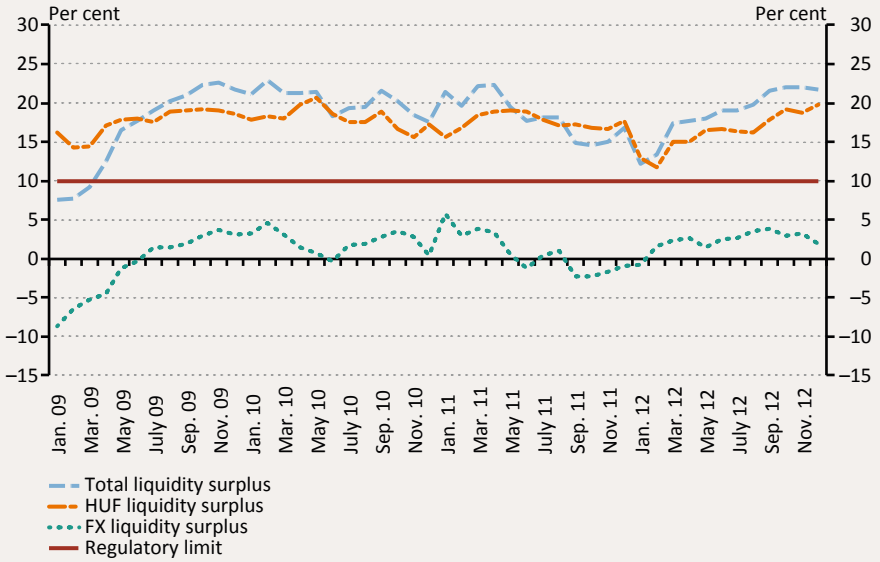
Before 2012, there had been a lack of precise liquidity rules for banks to comply with, which caused some difficulty in determining the stress testing target variable. The minimum liquidity requirement for banks is currently stipulated by Government Decree no. 366/2011 on the level of liquidity for credit institutions and the regulating of maturity matching of currency positions. The Decree[2] has been in effect since 16 January 2012 and prescribes the liquidity surplus banks must have looking ahead 30 days, as a ratio to the balance sheet total (balance sheet coverage ratio) or as a proportion of the deposits by households and non-financial corporations placed with the credit institution (deposit coverage ratio). This requirement must be complied every day; the Supervisory Authority verifies compliance based on daily reports. It also provides an appropriate benchmark for determining when a bank is considered liquid.

The literature differentiates balance sheet-based and maturity-based liquidity ratios. The balance sheet-based ratios are static and compare, for instance, the liquid assets in the balance sheet to the balance sheet total or the level of liquid assets to the level of funds that might be easily withdrawn. The purely maturity-based ratios stipulate, looking forward mostly one month, the positive balance of outgoing versus incoming items on the basis of the cash flow or the cash flow adjusted according to predefined rules. Combinations of balance sheet-based and maturity-based requirements also exist. The Hungarian regulatory requirements represent such a combination. Accordingly, the liquidity surplus comprises liquid items on the asset side (and their foreseeable changes) plus a 30-day cash flow, i.e. it includes liquid assets as well as a 30-day maturity gap.

The numerator is the same in the deposit coverage ratio and the balance sheet coverage ratio because the rules stipulate a single way of calculating liquidity surplus. Liquidity surplus, as mentioned above, comprises two main parts: (i) a 30-day financing position and (ii) liquid assets. The 30-day financing position is a cash flow calculated from treasury transactions, which includes the cash flows generated by incoming and outgoing on-balance sheet and off-balance sheet items foreseen by the Treasury. Liquid assets comprise the foreign currency nostro account balance, the 30-day accumulated balance of MNB-eligible securities at acceptance value, the 30-day accumulated value of collaterals accepted by the European Central Bank and the central banks in the euro area for monetary policy transactions, own-issued debt securities maturing within 30 days (as negative figures), deviations from the required level of the mandatory central bank reserve (with the appropriate sign) and cash held by the credit institution. The thus calculated liquidity surplus must reach 10 per cent of the balance sheet total or 20 per cent of the total deposits placed with the credit institution by households and non-financial corporations.

[2] The rules do not apply to home savings funds, MFB Zrt., Magyar Export-Import Bank Zrt., Keler Zrt., and cooperatives.

Chart 1
30-day liquidity surplus as a proportion of balance sheet total by currencies



Source: MNB.

The rules changed as of 1 July 2012 in that the balance sheet coverage ratio expected from mortgage banks was cut from the overall 10 per cent to 5 per cent.

Of the balance sheet coverage ratio and the deposit coverage ratio, we opt for the balance sheet coverage ratio to serve as a point of reference in our calculations, since the different funding structure of the different banks means that this is the ratio that allows creating a uniform process of liquidity monitoring across the banking system that relies on data from individual banks. The liquidity surplus figure is also available in a breakdown by currency, and therefore we can analyse potential asymmetries even if the liquidity is sufficient at the level of the system as a whole. Or, to put it differently, we can analyse whether there is a risk that banks' foreign currency liquidity is in fact tight but this is offset by ample HUF liquidity, making the banks highly dependent on the seamless operation of the swap market (Chart 1).

Based on the minimum regulatory requirement, a bank is considered liquid if its balance sheet coverage ratio is at least 10 per cent. Banks with a ratio below the regulatory requirement have a liquidity shortage. The greater this deviation from the regulatory limit, the more serious the deficit is considered to be. If the liquidity surplus falls below zero, the bank may not be able to meet its obligations in the lack of an external intervention, or if it is unable to adapt quickly.

2.2 THE STRESS ASSUMPTIONS USED

Short-term liquidity stress testing measures the impact of the assumed simultaneous occurrence of financial market disturbances, a withdrawal of deposits and an exchange rate shock. Our starting point for the stress test is the liquidity surplus figures of individual banks derived from the aforementioned daily reports. We have looked at the impact of five different shocks occurring at the same time with a low degree of probability:

1. a significant degree of default on interbank loans;
2. the revaluation of the swap portfolio due to a devaluation of the currency;[3]
3. the unexpected and steep devaluation of central bank eligible securities due to interest rate movements;
4. withdrawal of deposits by households (HUF and foreign currencies);
5. withdrawal of deposits by corporates (HUF and foreign currencies);

[3] For the purposes of exchange rate devaluation, we considered only the prompt liquidity impact reflected in the increased deposit (margin) demand in currency swaps. The potential longer-term secondary impacts of a weakening exchange rate (late repayments, withdrawal/conversion of deposits) have been disregarded as they do not affect the short-term liquidity position considerably.

Table 1
Key parameters in liquidity stress testing

Assets			Liabilities		
Item	**Degree (per cent)**	**Currencies affected**	**Item**	**Degree (per cent)**	**Currencies affected**
Default on interbank assets	20	HUF	Withdrawals in household deposits	10	HUF/FX
Exchange rate shock on swaps	15	FX	Withdrawals in corporate deposits	15	HUF/FX
Depreciation of assets eligible at the central bank	10	HUF			

Source: MNB.

Shock events fall into three categories: 1) *market risk* (exchange rate devaluation, interest rate changes); 2) *reputational risk* (withdrawal of deposits); 3) *counterparty risk* (default on interbank loans) (Table 1). We used Hungarian and international crisis experiences as a basis for the rest of the stress measures. It is important to note that the balance sheet coverage ratio already incorporates a kind of stress. This is due to the fact that the forward-looking maturity gap does not include adjustment by the bank, and it thus fundamentally expresses the failure to renew maturing interbank and foreign funding.

2.2.1 The different shocks

Asset-side items

1. Default on interbank HUF assets: a failure to repay a HUF loan granted by one credit institution to another. Default by a bank due to liquidity problems may give rise to contagion to the rest of the credit institutions. The spread of the contagion is difficult to grasp and quantify; we assumed a uniform ratio of 20 per cent for the default of interbank HUF loans maturing within thirty days. This assumption is consistent with the default of a hypothetical market player to which all other players have a 20 per cent exposure as a percentage of their respective interbank assets.

2. Exchange rate shock on the swap portfolio: swap transactions are important means for ensuring interoperability between HUF and foreign currency liquidity. If the HUF weakens and a bank's net swap portfolio against the HUF is positive, this may generate a need for surplus liquidity at the bank, since it must either increase the collateral for the transaction (margin call) or it will need additional HUF if it renews the deal. In line with the credit risk stress test, we assumed a 15 per cent devaluation in the HUF exchange rate, and quantified its impact on the entire net portfolio against the HUF.

3. Exchange loss on eligible securities (government securities, mortgage bonds, municipal bonds): our estimate based on bond market information is that in the event of a shock the value at which the central bank would accept the eligible assets could decrease by a uniform rate of 10 per cent, reducing the bank's liquidity reserves.

Liability-side items

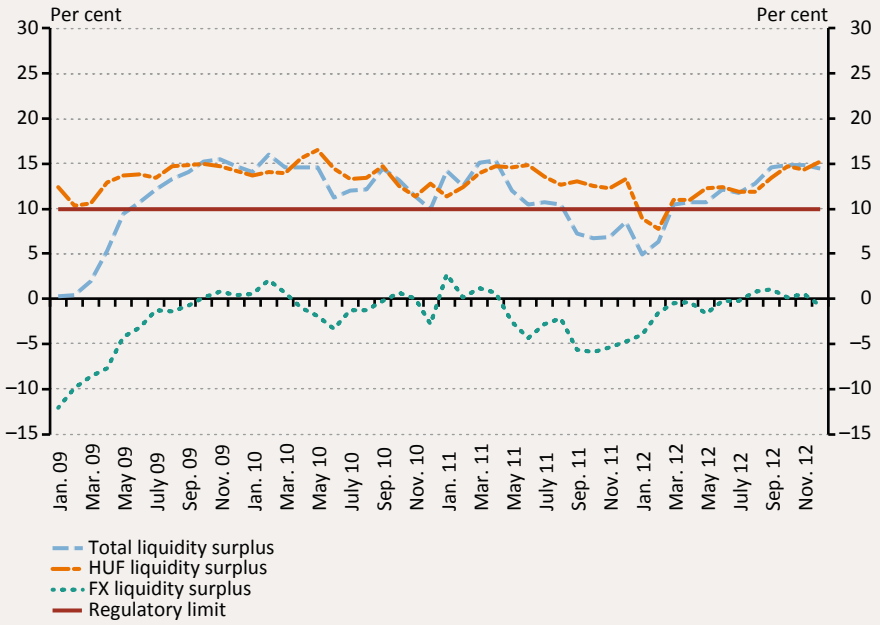
4. Households withdrawing their deposits: household deposits represent a rather stable source of funds for the banks. Extreme bank runs are rare in advanced financial systems today, thanks to the deposit insurance schemes. The most extreme monthly rate of deposit withdrawal by households is 10 per cent. We identified this ratio through an estimate based on historic figures, in which we relied on the banks' daily reports.

5. Deposits withdrawn by corporations: non-financial corporations manage their deposits dynamically, and they would respond faster to a shock than households, which is why corporate deposits are a more uncertain source of funds for the banks. Similarly to household deposits, we worked with the extreme deposit withdrawal ratio calculated on the daily data series; the rate in this case is 15 per cent.

2.3 POST-STRESS LIQUIDITY

Taking the above shocks into account, we calculated how the stressed liquidity surplus would have developed since early 2009 in a breakdown of HUF versus FX. We found that the banks' stressed liquidity surplus consistently exceeded the required level from June 2009 onward, and it was temporarily below the required level between September 2011 and March 2012, although the liquidity situation strengthened gradually thereafter. Even the previously mostly negative foreign currency liquidity surplus improved and approached zero by the end of the period under review. This shows that the uninterrupted operation of the FX swap market is a fundamental precondition for the stability of the liquidity situation in a protracted stress environment (Chart 2).

Chart 2
30-day stress liquidity surplus as a proportion of balance sheet total by currencies



Source: MNB.

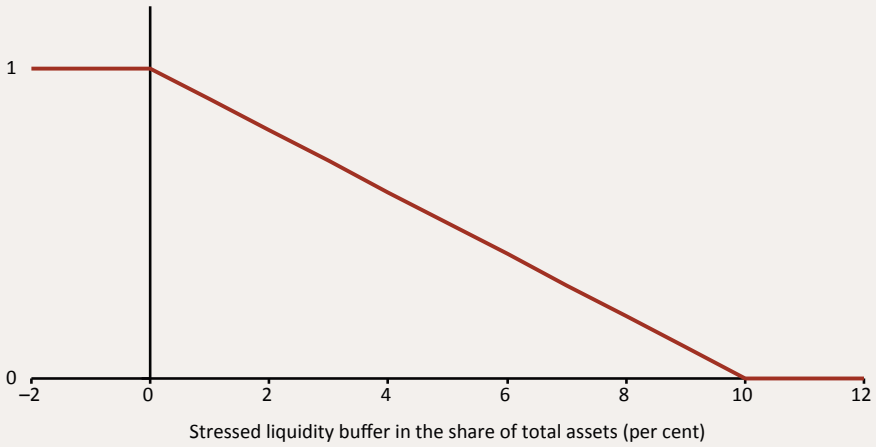
2.4 SPECIFIC BANKS' ASYMMETRIES, LIQUIDITY STRESS INDEX

Although the consolidated figures applicable to the banking system as a whole are derived from the data of individual banks, it is nevertheless important to investigate whether the banking system figures conceal potential specific, severe liquidity risks. We perform the stress test on the data of the specific banks,[4] and check whether there is liquidity surplus at the individual level, i.e. whether the risk of insolvency exists. No such result was observed at the end of the review period, even when we assumed the unlikely simultaneous occurrence of shocks.

We developed the Liquidity Stress Index (LSI) to measure stressed liquidity risk and to demonstrate the specific bank risks. After calculating the specific bank stress liquidity surpluses, we assign an indicator of 0 to 1 to each bank depending on the percentage of the balance sheet total the stressed liquidity surplus represents. If the liquidity is equal to or higher than the 10 per cent required by the regulator, a value of 0 is assigned, whereas if the ratio is 0 per cent, we assign a value of 1 to the bank concerned (Chart 3). The indicator is calculated linearly between these two thresholds. We weight the calculated specific indicators with the market shares of the banks as expressed in balance sheet total, then we total the figures and arrive at the LSI. If the index is equal to or above 30 per cent, the liquidity risk is critical. An LSI of 30 per cent is equivalent

[4] Each bank and specialised credit institution subject to the liquidity regulation is included as from March 2012, while prior to that date, the data of the seven major banks are included in the time series, which is due to data access issues.

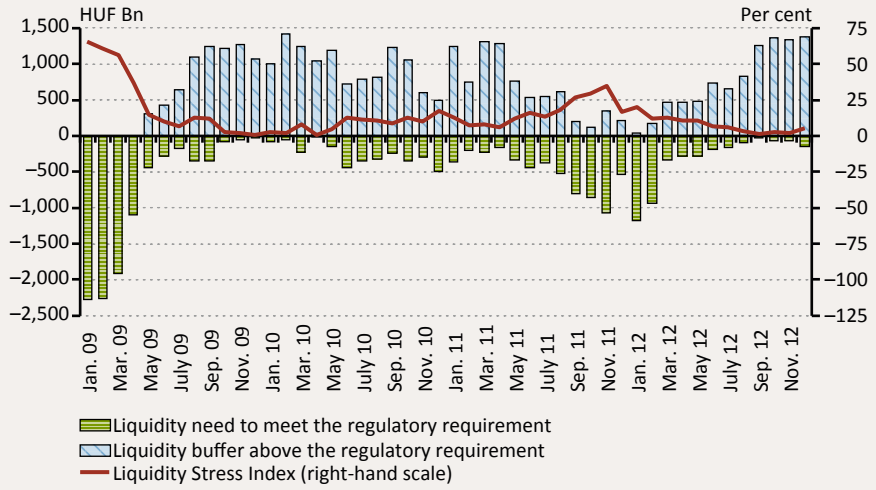
Chart 3
Calculation of specific liquidity indicators



to a bank with 30 per cent market share becoming illiquid and all other banks satisfying the regulatory minimum, or to a situation wherein each bank is 3 percentage points short of the 10 per cent balance sheet coverage ratio in the stress scenario.[5]

Using the above methodology, the balance sheet total weighted with the specific bank indicators returns a result showing a low Liquidity Stress Index of 5.3 per cent at the end of the period, which means that the banking system would be only slightly below the regulatory minimum in the event of a stress scenario, and no bank would become illiquid. We also found that the shortfall from the regulatory limit decreased and the surpluses above the limit increased as we approached the end of the review period (Chart 4).

Chart 4
Liquidity Stess Index, and banks' liquidity surplus or deficit relative to the regulatory level in the stress scenario



Note: The LSI is the sum of normalised liquidity deficits relative to the 10 per cent level, weighted by the balance sheet total. The higher the value of the index, the higher the liquidity risk in the stress scenario.
Source: MNB.

[5] The liquidity stress index calculation is included in the section 'Methodological description of main financial stability indices' in MNB (2012), as well as it will be available in a future study dedicated to financial stability indicators, Holló et al. (2013).

3 Credit risk stress testing with market risk

3.1 ANTECEDENTS, DEVELOPMENT AND APPLICATIONS

The Magyar Nemzeti Bank had regularly monitored credit risk in the banking system even before developing the stress testing framework applied today. Credit risk scenario analysis and sensitivity analysis were already included in the *Report on Financial Stability* in 2007, and subsequently in studies by Holló and Papp (2007) and also Valentinyi-Endrész and Vásáry (2008). These studies still focused on specific credit markets, analysing the credit risk of either corporate or household loans. The first tests encompassing both areas at the same time were completed in 2008, but they were not publicly available as yet. Stress test results have been published in the *Report on Financial Stability* since 2009. The stress test methodology published in April 2009 was rather different from the current one, as at the onset of the crisis practice focused on the quantification of unexpected losses. Efforts to develop a framework based on expected losses started in the summer of 2009, and its first publicly available version was included in the November 2009 report.

While the underlying philosophy of stress testing has remained unchanged since the summer of 2009, its methodology has been subject to substantive updates from time to time. These modifications were focused on increasing the level of detail and incorporating an ever expanding pool of information in the time series used in estimating the models. Occasionally, the latter implied a mere re-estimation of the models but at other times even the econometric models themselves changed. Our primary objective below is to describe the structure and the assumptions. The models used for determining the individual parameters give a snapshot of the prevailing methodology. The methodology should not be considered absolutely final; after all, our goal is to have a stress testing practice that is based on as wide an information base and as precise a methodology as possible.

New elements have been added to our practice in recent years: in spring 2011, we also quantified market risk in the tests and also quantified additional loss on the non-performing loans. Furthermore, we had to make lesser or greater adjustments due to a number of economic policy measures: the bank levy, the early repayment scheme and the exchange rate cap were all unavoidable factors in the analysis of the capacity of the banking system to absorb shocks.

Besides the usual publication of the results, the framework can be put to other uses as well. It can be equally used for estimating the effects of the economic policy measures and regulatory proposals on the banking system and for identifying critical points. The latter is referred to in the literature as reverse stress testing, and in our practice it means that instead of the usual two scenarios, we calculated far more, 100 to 150 scenarios, which allows us to identify the scenarios in which a predefined event, loss measure or other criterion would occur. We also use the stress test results to quantify, based on assumptions, the impact of shocks on the real economy. Tamási and Világi (2011) use a SVAR model that identifies the GDP impact of a credit supply shock. The capital deficit calculated from the stress test serves as a basis for assuming the degree of adjustment on the credit side at the individual credit institutions, which we can also translate into a GDP impact.

Introduced in the autumn of 2012, the Capital Stress Index is primarily a tool that helps evaluate stress test results and compare them chronologically, and it should therefore been seen as an application of, rather than an enhancement to, the framework. The new index is part of a family of indices that allow us to condense into a few figures the most important developments affecting the financial intermediary system.[6]

[6] The description of indices is included in the section 'Methodological description of main financial stability indices' in MNB (2012), as well as it will be available in a future study dedicated to financial stability indicators, Holló et al. (2013).

3.2 KEY FEATURES AND ASSUMPTIONS

Our credit risk stress test uses a top-down approach. This means that we apply the same methods and uniform parameters in the calculations for each bank. In this approach, for modelling purposes the individual banks differ from one another only in their balance sheet and income statement figures. This uniform methodology facilitates comparability among the banks, and allows the MNB to complete the test without contributions from the banks themselves, since the calculation relies solely on information available in the statistical reports. The disadvantage of the approach is its inability to fully reflect the unique *modus operandi* of each bank. If a bank disbursed its loans by applying a much more stringent credit approval system compared to the rest of the banks, its loan portfolio may be of higher quality than the banking sector average. A uniform application of the parameters would thus return for this bank results that are more negative than the actual fact. A more detailed look at products may allow grasping the differences reflected in the product structure, but not the substantive differences in quality among loans of the same type granted by different banks.

To demonstrate the advantages and disadvantages of assumptions, we need to provide a brief description of the bottom-up approach as well. According to this approach, while the authorities organise the testing process and set the rules and uniform scenarios, the calculations are performed by the banks themselves. To do so, they may use any internal information and models they have developed in-house. This would mean that comparing the banks' results would be much more difficult, despite the fact that the information base used is much wider than in the top-down approach and even the specificities of individual banks can be taken into account. The authorities participating in or organising the testing process verify the quality of the calculations and ensure that the results are credible. Thus overall, testing in a bottom-up approach requires considerably more time, energy and participants. In view of the fact that bottom-up tests are extremely resource-intensive, usually they are not expected to be comprehensive. In general, only the key players participate in the exercise unlike in top-down stress testing, which typically have full coverage. Bank groups participate in the stress testing organised by EBA at the consolidated level and accordingly, the affiliates and financial enterprises in different countries are treated uniformly. The published results thus reflect the situation of the bank groups and do not give an assessment of the banking systems of individual countries. In theory, the bottom-up approach allows us to take into account the future strategies of the bank. Since this makes the verification process and inter-bank comparability much more difficult, the organising authorities clearly define the future plans and measures that can be taken into account.

Central bank tests are conducted at the level of individual banks without performing regular consolidation. However, we do incorporate the potential negative effects from group members owned by the individual banks. The test encompasses all credit institutions operating in Hungary and all of the financial enterprises owned by Hungarian banks. Banks belonging to the same banking group are treated as separate banks in our calculations, and are consolidated into a single bank group only after the individual results have been calculated, and the capital deficits and capital buffers have been identified. Not only the profits/losses of a financial enterprise owned by a bank are included in the shareholder bank's result, but the bank will also inject capital in its financial enterprise if its initial capital is negative. Thus we assume that the shareholder bank fully settles the capital position of the affiliate across the entire review horizon. As regards the foreign affiliates of Hungarian credit institutions, we take into account their need for additional capital only.[7] Capital injections requested by foreign affiliates are satisfied by the parent bank itself, without reliance on the profitable foreign banking affiliates in the group. In the test, the profitable foreign affiliates do not pay dividends to their parent bank.

Currently, the time horizon of the stress test is two years. In the past, there have been shorter time horizons in the autumn stress tests, with the end of the following year serving as the closing date for the exercise. We moved to a uniform time horizon in 2012 in order to allow better comparability for stress tests taken at different points in time. Calculations are currently made with a quarterly frequency, aligned to the frequency of the scenarios. The test disregards seasonal impacts both in the macroeconomic scenario and in the operations of the banks.

We work with a static balance sheet assumption in the test, i.e. we assume that maturing assets will be replaced by assets with corresponding risk and that there is no lending activity apart from this. We also assume that non-performing loans will remain in the balance sheet until the end of the test, i.e. there is no opportunity for balance sheet cleaning either in the initial balance sheet or in relation to the loans becoming overdue during the time horizon of the test. The credit trends in recent

[7] Only OTP Bank has foreign affiliates at the moment, but MKB Bank has also owned foreign credit institutions in the past.

years have rendered the static balance sheet assumption rather conservative. However, since our test is not a forecast but a sensitivity analysis, a moderate distortion in this respect is acceptable.

It is safe to say that the Hungarian framework is common in international practice, as most central banks analyse changes in capital adequacy and its reactions to various shocks on the basis of banking revenues and expected losses. Analyses taking a different approach are additional items at best; an example is the analysis of the CDS figures of Danish banks. The differences between the sub-models of different central bank stress tests can be primarily attributed to the data available, whereas the differences in the assumptions used reflect the specificities of the banking systems. Notably, however, testing is performed with a dynamic credit scenario in countries where loan portfolios have been on the rise since the onset of the crisis, as this returns results that better approximate actual facts; although it is also true that this approach is stricter than the constant balance sheet assumption. There are differences in the capitalisation of the result as well: wherever the banks generate substantive profits, the central bank incorporates dividend payments in its calculation, which also represents a move from sensitivity analysis toward a more realistic outcome. Besides taking into account specificities, past findings and the familiar sensitivity channels, the additional elements to be incorporated in the framework are selected on the basis of the modellers' judgement.

3.3 THE STRUCTURE OF THE STRESS TEST

The solvency stress testing framework presented in our study focuses on credit risk, which we supplemented with market risk. Our current framework is based on the calculation of expected losses; therefore, separate estimates are made for the banks' profits before loan losses and the expected loan losses. Expected loss (EL) is calculated as a product of exposure at default (EAD), probability of default and loss given default (LGD).

While the exposures of individual institutions are available in the statistical reports, we can forecast the probabilities of default for corporate and retail loans with econometric models along the individual scenarios. We determine the LGD parameters on the basis of the information provided by the banks in earlier bottom-up stress tests and the market indicators most likely to affect LGD (changes to real estate prices and the HUF exchange rate).

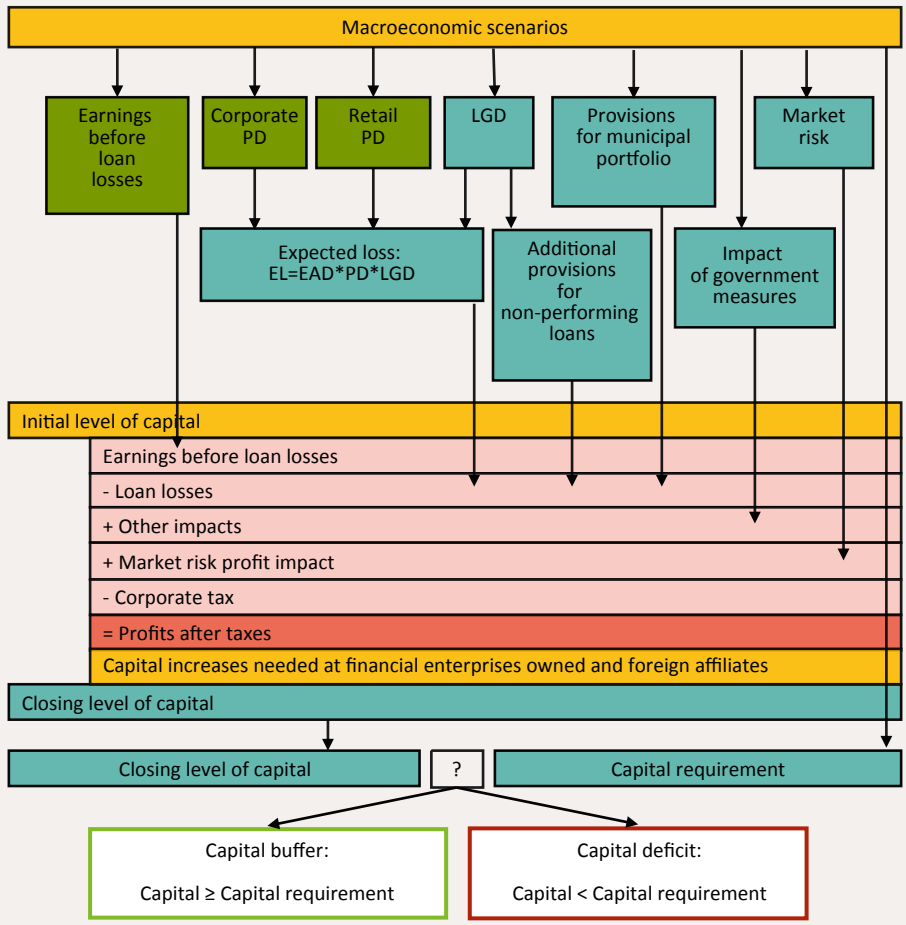
We determine municipal exposure parameters by expert judgement; this is a highly specialised segment where risks cannot be estimated with econometric methods. The significant growth of the municipal portfolio took place very fast, and most loans and municipal bonds paid only interest and did not repay the principal in the first few years under the contract terms. As a result, there have been no losses relevant for statistical purposes. However, as the grace periods expire, this segment may also encounter severe problems in respect of loan repayments; therefore, we have determined the segment parameters by expert judgement instead of projections based on past observations.

During the crisis, banks accumulated major non-performing portfolios in their balance sheets. And while the banks have raised provisions to cover them, a significant deterioration in the macroeconomic situation may require additional provisioning. We calculated this on the basis of the differences in LGD parameters estimated for the different scenarios. Therefore if a less favourable situation on the real estate market and a weaker HUF exchange rate cause higher LGD values in a stress scenario compared to the baseline scenario, this would result in higher losses from non-performing loans and the need for additional provisions.

Several government measures in recent years have affected the income of banks fundamentally. The bank levy, the early repayment scheme and the exchange rate cap scheme all exerted a considerable impact on the shock absorption capacity of the banking system. The latest effects have been incorporated in the framework. These measures have tended to result in an additional expenditure item, although the early repayment and the exchange rate cap schemes also affected portfolio size and PD parameters.

In the stress scenario, there is a significant exchange rate and interest rate shock in the macroeconomic scenarios. As a result, banks achieve losses or gains on their total open currency positions and open interest positions due to the revaluation. Banks' after-tax profits can be calculated including this item and subtracting taxes. For the purposes of our stress test, this is the equivalent of retained earnings, because we do not assume dividend payments by the banks to their shareholders.

Chart 5
Solvency stress testing framework



We then measure the final level of capital calculated from retained earnings against the capital requirement appropriate to the macroeconomic scenario: if the level of capital is lower than the capital requirement, the bank has failed the test and the difference between the two values appears as a capital deficit. The capital deficit or, if they satisfy the requirement, the capital buffer of bank groups is determined by consolidating the results of the individual members, as described above. Chart 5 summarises the key parts of the exercise.

3.3.1 Scenarios

Within the macroeconomic scenarios, the baseline scenario is always the one corresponding to the most recent forecast published in the *Quarterly Report on Inflation.* In the stress scenario we assume that serious but plausible shock will occur early in the second quarter of the forecast horizon, pushing up the Hungarian risk premium, reducing external demand for our products and weakening the HUF exchange rate. All this would reduce growth in the Hungarian economy, deteriorate employment and cause a sudden fall in real estate prices.

The stress scenario was prepared on the basis of the model originally used for constructing the baseline scenario. In order to facilitate the comparison of stress tests over time, in the autumn of 2012 we fixed the shock impact, i.e. the deviation of the stress scenario from the baseline scenario, using the stress scenarios created with the earlier model (Table 2). Full comparability would be possible only if the scenarios analysed were equally likely to occur; however, we are unable to measure the probability of scenarios. The latest information available to us suggests that the baseline scenario is always the most probable, whereas the stress scenario deviates from it to a fixed degree.

Table 2 Fixed stress measures	
Percentage point changes in GDP in 8 quarters (percentage points)	–4.3
Percentage point changes in employment in 8 quarters (percentage points)	–2.7
One-off permanent depreciation of the exchange rate of the forint (per cent)	15
One-off permanent interest rate shock (basis points)	300
Change in the prices of real estates for residential use – one-off, permanent (per cent)	–10
One-off permanent shock on CDS spread (basis points)	300

3.3.2 Profitability

Earnings before loan losses includes numerous items such as profits from various banking operations, operating expenses and taxes payable. It would be impossible to forecast each of these items separately; moreover, many of them depend on one-off events and are independent of the macroeconomic environment. Profitability is therefore forecast in two steps: a linear regression model with fixed effects is used for forecasting interest and fee and commission income (which we believe to be more closely tied to the macroeconomic outlook), whereas the other items are determined by expert judgement based on historical data.

We compiled a panel database for the estimation exercise with a cross-section of the nine largest banks and, as a 10th bank, the rest of the banking system. We used quarterly average figures, with the sample starting in 2004 Q1. The sources for the database were the banks' balance sheets and income statements, their interest rate statistics and the macro variables. The variables used in the estimate were interest and commission income, balance sheet total, foreign funds, CDS, Euribor, HUF and FX mortgage loans of households, HUF and CHF interest rates on households' mortgage loans, corporate HUF loan portfolio and interest rate, households' HUF deposit portfolio and interest rate, the corporate HUF deposit portfolio and interest rate, and the performing corporate loan portfolio.[8] As far as information about interest rate is concerned, we used the portfolio interest figures wherever available, otherwise we used the interest rates on newly issued loans.

The dependent variable in the estimate was the interest and commission income as a ratio of assets, and the estimation sample was 2004 Q1 to 2012 Q2. As the ten banks apply highly differing business models, the different explanatory variables may affect the banks differently. Consequently, we divided the banks into two groups to ensure that the estimated model matches the consolidated sample as closely as possible. We thus created sub-samples of 4 and 6 banks, and executed on the two sub-samples linear regression estimation containing the same explanatory variables and also incorporating 'fixed effects' (Table 3).

Table 3 Estimate results				
Variable	Estimation with 4 banks		Estimation with 6 banks	
	Coefficient	Significance	Coefficient	Significance
(CDS/100+EURIBOR)*(external funds/total assets)	–0.0004	0.33	–0.0009	0.00
Household sector's deposit rate*(household sector's HUF-deposits/total assets)	–0.0017	0.00	–0.0001	0.84
Household sector's HUF-lending rate*(outstanding amount of households' HUF-loans/total assets)+household sector's FX-lending rate*(outstanding amount of households' FX-loans/total assets)	0.0039	0.00	0.0015	0.00
Corporate HUF-lending rate*(outstanding amount of corporate HUF-loans/total assets)*(performing outstanding amount of corporate loans/total assets)	0.0134	0.00	0.0035	0.00
Corporate HUF-deposit rate*(corporate HUF-deposits/total assets)	–0.0038	0.00	–0.0032	0.00
Constant	0.0091	0.00	0.0084	0.00

[8] During the estimation exercise, we found the aforementioned variables were significant and explicable in economic terms.

The estimate results can be considered rational from an economic perspective: the increase in the cost of external and internal funds (corporate and household deposits) and in their ratio to assets has a negative impact on profitability, whereas the increase in loan interest and loan portfolio and the performing loan portfolio as a ratio of assets has a positive impact on the same. The coefficients and significance levels suggest that the grouping may have been based on the proportion of external and internal funds within the structure of financing on which a given bank relies.

In making the forecast we assumed that the ratio of the balance sheet items to assets and the deposit interest spreads compared to short-term interest rates would remain unchanged over the forecast horizon. In loans, interest spreads over short-term rates have reached historical peaks in recent quarters. Since our expert projection is that the existing spreads can only be sustainable over the short term, we expect them to return to the historical average over the forecast horizon, whereas in the stress scenario we assume a further, prompt and lasting decrease by 100 basis points in the interest premium. Since forecasts are prepared for the performing loan portfolio, the CDS and the short-term interest rates irrespective of the model, the forecast of earnings was created with a simple substitution by using these forecasts and the estimated coefficients.

3.3.3 Probability of default on corporate loans

The deteriorating macroeconomic outlook worsened the income position of borrowers. For corporations, such deterioration may be brought about by a decline in demand on the goods markets (and thus in their sales revenues) or by an increase in costs, which increase the probability of loan repayment problems. Corporate probability of default is estimated using quarterly macro-level data and a linear regression model with distributed lag.

Contract-level micro data are not available in sufficiently long time series regarding corporate loans. We therefore made the assumption that the probability of default for corporations will be equal to their probability of bankruptcy, and applied the model to the seasonally adjusted corporate bankruptcy rate figures (companies in bankruptcy/all companies). These indicators are available in a sectoral breakdown as well. Construction industry figures behave very differently from the rest of the sectors; therefore, we selected the corporate bankruptcy rate excluding the construction industry as our dependent variable. We applied the quarterly percentage of growth in GDP, its lags and the logarithm of the quarterly average of the Swiss franc and the euro as explanatory variables.

Our dependent variable expresses a probability, and as such, it may take values in the fixed range of 0 to 100 per cent. As a result, the estimate for the period between the first quarter of 1995 and the second quarter of 2012 is not for the bankruptcy rate itself but its logistic transformation[9] (Table 4).

The explanatory variables are significant and their signs meaningful in an economic sense: higher past and contemporary GDP growth, i.e. more dynamic economic activity, will reduce PD. The weakening of the HUF/EUR exchange rate helps the export sector and thus reduces PD, whereas the weakening of the HUF/CHF exchange rate increases it due to the higher repayments payable. Since there are GDP and exchange rate forecasts available, the PD forecast is a simple substitution exercise.

Table 4
The estimated coefficients of the model for the logistic transformation of the bankruptcy rate

Variable	Coefficient	Significance
Constant	–6.41	0.000
GDP	–6.78	0.000
GDP(–3)	–5.13	0.020
GDP(–4)	–6.19	0.005
HUF/EUR	–0.92	0.013
HUF/CHF	1.57	0.000

Note: We used the transformations of the variables as we mentioned before in the estimate; the figures in brackets after the variables indicate the lags used.

[9] The logistic transformation of variable X: $ln(X/(1–X))$.

A particular group of corporate loans is given special attention in the stress testing exercise, as we deemed loans financing real estate development and purchasing to be higher risk than average in corporate. This is due to the sensitivity of the real estate market and the construction industry to a crisis and also the scheduling of principal repayments under these loans. Since we do not have at our disposal direct information to gauge the level of risk accurately, we will use a probability of default based on the bankruptcy rate in the construction industry, a PD that is higher than for other corporate loans.

3.3.4 Probability of default of retail loans

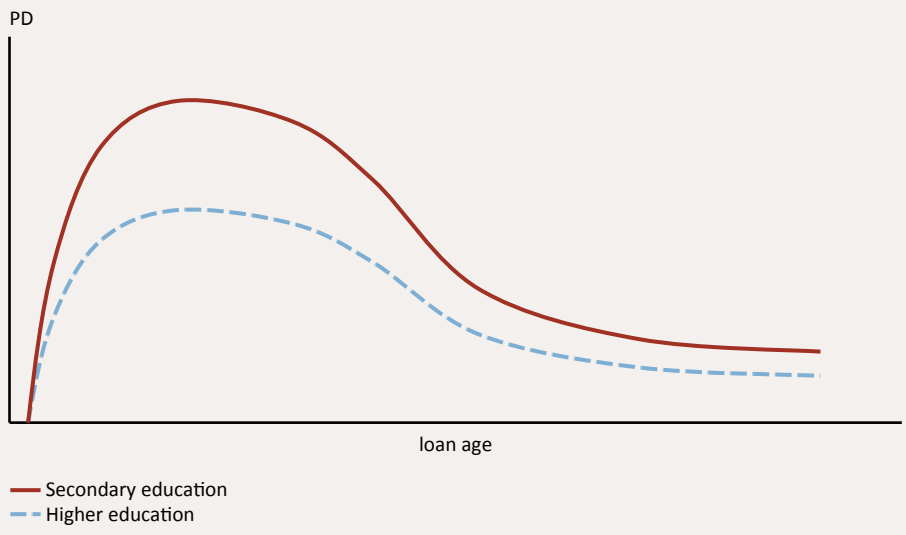
We used the econometric model to combine the macroeconomic variables with the expected rates of loan default also in the household sector. Although there are examples in Hungarian practice as well (Holló and Papp, 2007; Gáspár and Varga, 2011) of approaching this issue with a simulation methodology from the revenues and the expenditures of households, the availability and substantive features of the databases used in the aforementioned articles convinced us that it would be more appropriate to use a database focusing on retail loans for our purposes.

Our database contains the retail loans of several major commercial banks at the level of individual transactions and it covers one third of the entire retail loan portfolio in the banking system. The banks provide these figures, anonymised, to the MNB under a cooperation agreement. The database contains the characteristics of the primary debtor of the loan (for example education and marital status), the initial parameters of the loan (for example loan type, disbursement date, currency, maturity, the initial loan-to-value ratio if it is a mortgage loan) and the performance history of the loan. The database has loan histories available from 2003 onwards, which was well before the boom in foreign currency lending.

Our model depicts probability of default as a factor of the age of the loan. This is based on the observation that loans have a higher probability of default in the first few years after disbursement under normal economic conditions and the probability decreases significantly thereafter. This initial high-risk period reveals the debtor's payment discipline (whether it is willing to make payments or observe the deadlines) and the soundness of credit approval. Under normal economic conditions, it becomes clear within the first few years whether the debtor has considerably over-exposed itself or its labour market position is more uncertain than it should be.

Besides loan age, probability of default is also influenced by the characteristics of the loan and the debtor, as well as the macroeconomic environment. These are incorporated rather simply: using the Cox proportional hazards[10] function, we estimate probability of default as $h(t)=h_0(t)*exp(\alpha X+\beta Z(t))$. The name proportional hazard originates from the fact that, in the

Chart 6
PD over time for two notional loans differing only in the debtor's educational qualification



[10] The hazard function is the mathematical expression of PD. It shows the probability of a loan history ending in default at age *t* if the debtor had performed on schedule up until *t* point in time.

function form above, the proportion of the *h(t)* functions of two loans of different characteristics will be dependent only on the differing characteristics of the loans and independent of the level of their identical characteristics. For instance, if two borrowers whose main characteristics differ only in education level (one has secondary education and the other higher education) take out loans with the same conditions at the same time, the assumption is that their probability of default will be constant across the entire term of the loans: $PD_{secondary}/PD_{degree-level} = exp(\alpha(X_{secondary} - X_{degree-level}))$, where X is the variable denoting level of education and α is the relevant estimated coefficient. Representing in a loan age graph the evolution of the PDs of two loans that differ in only one characteristic which is constant over time, the model returns curves of the same shape and their quotient is constant over time (Chart 6).

Characteristics that change over time, such as the macroeconomic variables, are represented in the model according to a similar principle: if a shock raises PD by a given per cent compared to a scenario in a normal macroeconomic environment, this will have a different impact, expressed in percentage points, on loans in different lifecycles. Chart 7 demonstrates that the PD of a loan approaching the end of its term does not change significantly when the macro-scenario is unfavourable. On the contrary, the probability of default of a loan in the critical period of its term rises dramatically as a result of the same shock.

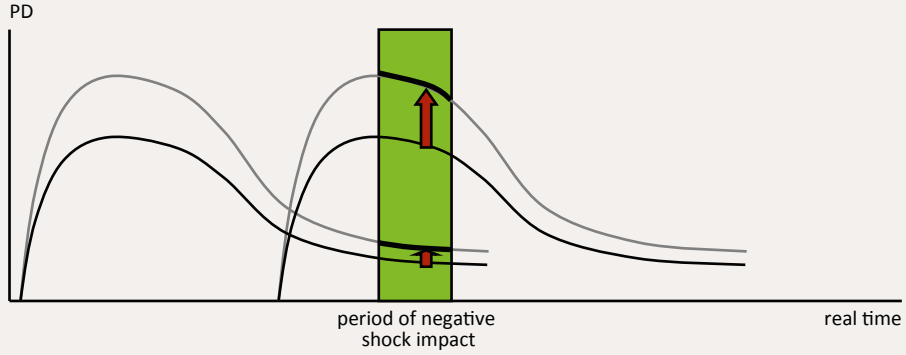
We calculate retail loan PDs in detailed product breakdown: we model HUF housing loans, foreign currency denominated housing loans, home equity loans and the HUF and FX denominated unsecured loans separately. The explanatory variables for these five loan types vary at most in the transformation used. Of the macroeconomic variables, we have included in the model employment, HUF and EUR three-month interbank interest rates and, for foreign currency denominated loans, the HUF/CHF exchange rate. Of the loan characteristics, the explanatory variables include the half year in which the loan was disbursed, the currency if the product group is of mixed denomination, the HUF/CHF exchange rate at the disbursement of foreign currency loans and the initial loan-to-value ratio for mortgage loans. Of the characteristics of the principal debtor, age recorded at the time of disbursement, education and marital status are considered.

Employment growth is a macroeconomic variable that reduces PD, whereas a rise in domestic interest rates and a weakening of the HUF exchange rate both increase it. In this case, the three-month EURIBOR does not behave as an interest rate but reflects the external economic and money market situation: its decrease is simultaneous with the intensification of the signs of the crisis, resulting in higher retail PD.

The most interesting characteristic of the loan is the half year in which it is issued: these dummy variables confirm the periods known from the lending survey as those when credit approval conditions were eased or tightened significantly. The initial real estate coverage ratio of mortgages is another important characteristic: the loan-to-value ratio (LTV) simultaneously reflects the amount of the instalment and the debtor's savings before borrowing, i.e. the debtor's over-exposure. If all else is unchanged, a higher LTV will always return a higher PD.

The most noteworthy debtor characteristic is education. The estimated PD is markedly lower among debtors with a higher education degree. This is the variable in our system that reflects the heterogeneity of the labour market. It is therefore

Chart 7
PDs of loans in different lifecycle stages in the event of a negative economic shock



clearly not a coincidence that it reflects the fact known from employment statistics that those with higher education qualifications not only have higher income levels, but also a more secure position in the labour market. They were less likely to lose their jobs in the crisis, or they have found new employment more easily than those without a degree.

3.3.5 Loss given default (LGD)

As shown above, we calculate expected losses by taking into account not only the exposure figures but also the probability of default (PD) and the amount of loss a default on the loan would generate. The latter is embodied in LGD, which demonstrates via the present value of the cash flows of a loan after default (disposal of the collateral, handling costs) the bank's loss versus its receivable. LGD is therefore determined primarily by the value of the collateral securing the loan. The higher it is, the lower the ensuing losses will be. Changes in the macroeconomic environment influence LGD through a number of channels. Firstly, through changes in collateral value: future growth in asset prices may motivate the bank to keep the defaulting loans in their portfolio longer and sell off the underlying collaterals later. Secondly, through changes in the exchange rate in case of foreign currency denominated loans: the growth in the outstanding debt due to a weakening exchange rate will, *ceteris paribus,* decrease the value of the collateral versus the loan amount. Thirdly, the change in interest rates may affect LGD through the present value: the later a bank sells the collateral, the later it will be able to use the cash flows from the same. Since the aforementioned factors may differ greatly from one loan type to another (especially in terms of coverage), we create time series by product type in our LGD forecast. There is relatively little information available to us in this respect and therefore, we develop the forecasts on the basis of our experts' view, taking real estate prices and exchange rates into account.

The LGD data are not available either in a cross-section or in a time-series dimension. Our most important sources of data in this respect are the results of the bottom-up stress test carried out by the Hungarian Financial Supervisory Authority (HFSA) in late 2011; in the course of that test, banks calculated LGD for each credit product. We also monitor the loan losses incurred by the banks. We use the FHB house price index and exchange rate change information to reflect changes in collateral values.

We calculate the LGD time series for eight loan types: unsecured HUF and FX denominated and secured HUF and FX denominated household loans, corporate HUF and FX denominated project loans, and other corporate HUF and FX-denominated loans. We also assume that the LGD of municipal loans is the same as that of other corporate loans. We match the LGD forecast to house price changes in the case of secured loans and to the changes in the exchange rate for foreign currency denominated loans. We assume house prices to remain unchanged over the forecast horizon in the baseline scenario and to depreciate by 10 per cent in the stress scenario. The exchange rate follows the stress test scenarios. All other potential impacts are quantified by expert judgement.

3.3.6 Government measures

Several countries introduced different government programmes and new measures during the crisis, affecting the profitability and capital position of the banking system considerably. Likewise in Hungary, government measures in recent years have exerted a considerable impact on the profitability and portfolios of banks. We incorporate these impacts in our stress tests as from the time of their announcement. In recent years, the bank levy has been a key high-impact measure, which we incorporate in our stress testing simply as an expense. The early repayment scheme and the exchange rate cap scheme implied a more difficult task, since besides direct costs, they also affected portfolio risk. Invariably, we needed to make a number of assumptions for the preliminary quantification of the effects. Such assumptions include the participation rates in specific schemes. When publishing the results, we consistently indicated our participation rate assumptions.

The impact of the measures on the portfolios and their risks was somewhat harder to quantify than the costs of the measures. To do so, we needed to return to the level of individual loans in the PD forecast. Regarding the early repayment scheme, we assumed that the loans with the lowest risk would be repaid, and the probability of default in the remaining portfolio would therefore grow. The method for considering the exchange rate cap was similar in the first step: we assumed like that these contracts would have got out from the portfolio. Since we work with the technical assumption that those not eligible will be the ones not taking advantage of the exchange rate cap, we left only the contracts with the highest loan amounts in the original portfolio. As for new loans entering the exchange rate cap scheme, we recalculated the probability

of default by applying the exchange rate limit, as a result of which the risk on these contracts decreased at the contract level. We then aggregated the PDs at the portfolio level once again. It should be noted that the two-year time horizon of the stress test is shorter than the time horizon of the exchange rate cap scheme, and therefore the stress test does not reflect the credit risks rising at the expiry of the scheme.

3.3.7 Market risks considered

Besides influencing the performance of the loan portfolio, the long-term exchange rate and interest rate shock in the stress scenario leads to the re-pricing of banks' balance sheet items and certain off-balance sheet items. While our testing focuses on credit risk, we should not disregard the positive or negative effects of revaluations. A much more suitable means of identifying market risks is available in the surveys by the HFSA, which take into account a large number of possible scenarios in the framework of bottom-up market stress testing.

A HUF exchange rate shock leads to the revaluation of banks' assets, liabilities and off-balance sheet items. This tends to have a relatively small impact on profits, as most banks try to keep their overall currency positions closed[11], in line with the incentive of the relevant government decree[12]. However, Hungarian banks are entitled to keep their currency positions according to the Hungarian Accounting Standards open to a certain degree, within the limits set forth in the aforementioned Government Decree. The direction of the total open currency position may differ from bank to bank, and although the Hungarian banking system holds a long currency position overall, some banks take a short currency position from time to time. An interest rate shock causes the revaluation of banks' interest-bearing assets and liabilities. The most important impact is generated by the re-pricing of the portfolio of government securities, which causes a loss due to higher yields.

We account for the losses and profits arising from market risks spread over the time horizon. This (i) serves the purpose of smoothing out after-tax profits and (ii) assumes that banks will start re-pricing their assets and liabilities not registered at market prices only after they have ascertained the lasting nature of the shock.

3.3.8 Capital level and capital requirement

The starting point for determining the capital level is the end-of-quarter data selected for the starting date of the exercise. Added to this is the positive or negative after-tax profit calculated during the exercise and the negative effect of the capital infusion needs of foreign affiliates and financial enterprises owned. In order for our stress test to reflect actual risks, we take into account the significant capital injections announced since the start date. As to what classifies as significant depends not only on the amount of capital in HUF billion but also the extent to which this will change the given bank's chances of passing the stress test. The objective of the capital injection is also important when we decide on whether to consider it as a factor. In the wake of the early repayment scheme, several banks have announced their intention to raise capital. It would have been impossible to disregard the effects of the early repayment scheme and similarly, the outcome would have been distorted if we had disregarded the capital injections announced to cover the losses incurred from early repayments. Thus our overall understanding of the banking system now incorporates the negative effect of the government measure and the contributions of parent banks alike.

Capital requirement is forecast in a simple mechanism aligned to the static balance sheet assumption: it changes in proportion to the size of the gross portfolio. This assumption is closer to the standard method of capital calculation. This may result in a slightly more favourable view of the banks operating with more advanced capital calculation methods, because it does not include the impact of risk parameter changes in increasing the capital requirement. To incorporate this effect, we would need to know more details about the capital calculation methods of the banks applying internal models. Indeed, the momentary increase in risk parameters is not reflected directly in the capital calculation parameters compiled in a through-the-cycle approach taking the view across economic cycles.

[11] In our stress test we define the total currency position as the difference between the FX assets and liabilities on and off the balance sheet. This is different from the cumulative open position defined in the Government Decree, which is calculated on the basis of the net open positions in each currency and thus also penalises cross-rate exposure.
[12] Government Decree no. 244/2000. (XII. 24.).

In bottom-up stress testing, the banks using more advanced stress techniques will obviously have all this information regarding their own operations at their disposal and will rely on this information during the exercise. Therefore, the comparison of the capital requirements in a test conducted on the basis of the two approaches can provide insight into the distorting effect of the calculation used in top-down testing. However, the specific information available in bottom-up tests has a price tag: we must bear in mind throughout the comparison of the banks, which banks had used an advanced, and which a standard method in the exercise.

3.3.9 The test results

Since 2009 we have published the latest stress test results in our *Report on Financial Stability* every half year. The Report also explains the latest changes to the methodology and the key assumptions. Since the central bank is responsible for analysing the status of the banking system rather than the situation of individual banks, we publish aggregated figures only. Our main purpose in publishing loan losses and other loss items (Table 5) is to demonstrate the effects of the parameters and assumptions applied in the testing, along with their level of rigidity.

Table 5
Impact of main risks on banking system profits in the stress test of spring 2013, over a two-year time horizon

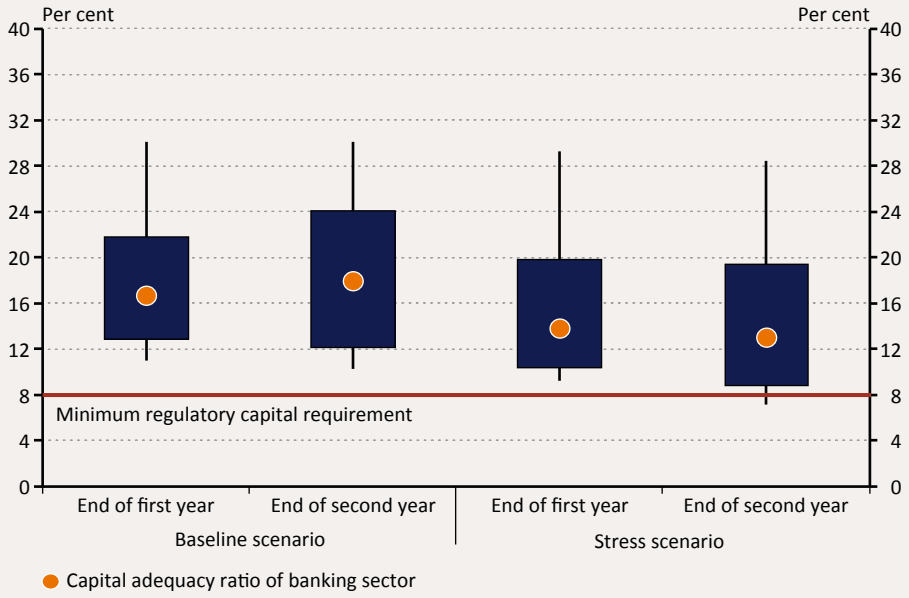
	Main components of losses of banking system in eight quarter horizon (HUF Bn)	
	Baseline scenario	**Stress scenario**
Loan losses on corporate and household portfolio	**498**	**875**
Loan losses on new non-performing corporate loans	264	382
Loan losses on new non-performing household loans	234	368
Additional loan losses on the already non-performing loans		125
Loan losses on local government portfolio	10	23
Exchange rate risk of open position		–63
Interest rate risk		60
Bank levy	234	234
Interest cost of the exchange rate cap scheme	28	45

Of all loss items in the spring of 2013, loan losses represented the highest losses both in the baseline and the stress scenario. The expected losses incurred on the corporate and the household portfolios are similar in size. The difference between the baseline and the stress scenario originates not only from the risks of the portfolios still performing; there are also major additional losses from the non-performing loans that have remained behind in the balance sheet in the stress scenario. The losses charged to the municipal portfolio on an experts' view basis are significantly lower than the losses in the private segment. The exchange rate shock has earned the banking system a profit on its open currency position overall, even as it incurs losses on interest risk, primarily due to the re-pricing of government bonds. The profits/losses from the two market risks are similar in magnitude, but the two kinds of risks are distributed very unevenly among the banks; accordingly, substantial losses or profits from market risk may occur at the level of individual banks.

We also present the lump-sum impacts of the government measures separately. In line with the announcement in spring 2013, we took the bank levy into account at full value throughout the two-year time horizon. The exchange rate cap will represent an expense due to the interest part payable by the bank, but the impact of the scheme is not limited to this, since we have incorporated its positive impact in reducing credit risk under loan losses.

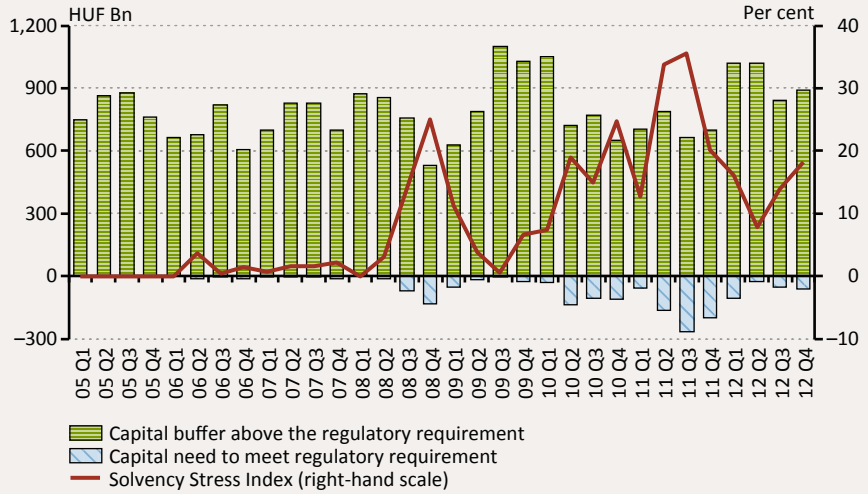
We present the sum of the aggregated capital requirement and the positive capital buffer as a target variable. Besides the banking system average TMM that relies on the above items, we also publish the distribution of TMMs by number of items (Chart 8) in order to demonstrate the heterogeneity prevailing among the banks. This is important because it makes a difference whether the stated need for capital injection applies to a sole bank or there are more than one institutions in

Chart 8
Distribution of the capital adequacy ratio based on number of banks



Note: Vertical line: 10–90 per cent range, rectangle: 25–75 per cent range.

Chart 9
Capital Stress Index, banks' capital surplus over the regulatory limit or the lack of the same in the stress scenario



Note: The indicator is the sum of normalised capital deficits weighted by the capital requirement and compared to 8 per cent. The higher the indicator, the greater the solvency risk in the stress scenario.

distress. The Capital Stress Index calculated from the results (Chart 9) is an indicator that also reflects heterogeneity: it combines the extent of the loss with the sizes of the banks struggling with the need for capitalisation.

Our chart of capital adequacy ratios in the banking system demonstrates that we expected a strengthening capital position in the baseline scenario in spring 2013, on the assumption that the banks would capitalise their profits in full. By contrast, in the stress scenario we found weakening capital adequacy. This suggested that it was not only the banking system as a whole that would be loss-making in a stress scenario, but the majority of the specific credit institutions would also have to face a decline in their capital levels. In analysing the distribution of capital levels, we found significant heterogeneity: while some

banks have very good indicators, the capital adequacy of most banks ranges within a narrow band, with far more banks clustering around lower capital adequacy levels (Chart 9). Since the distribution is presented on the basis of the number of items, we should note that it is smaller banks that tend to be characterised by extremely high capital adequacy, as it would be very costly for larger banks to hold multiples of the amount required. It is no coincidence therefore, that average capital adequacy in the banking system, which takes into account the sizes of the banks, reflects the relatively high spread of the values in the top quartile.

The Capital Stress Index chart offers comparisons over time and demonstrates events of a major impact clearly: the acute stage of the crisis in 2008–2009, the capital injections by parent banks in 2009, the introduction of the bank levy in the third quarter of 2010 and the launch of the early repayment scheme in the second half of 2011. In the subsequent period, the index decreased due to the bank levy discounts in the context of the early repayment scheme and the continued capital injection. The index returned to growth in the last quarters owing to the finalisation of the credit institution special levies at their full sum on the one hand, and the loan losses of some major banks on the other hand, which exceeded the banking system average significantly, nevertheless were not offset by capital increases, resulting in a weaker initial capital position.

4 Conclusion

It is a key role of the Magyar Nemzeti Bank to facilitate the continued, stable operation of the financial intermediary system. As the crisis escalated in Hungary from the autumn of 2008, the regular analysis of the banking system's shock absorption capacity has come into focus. Stress testing is an important tool in this effort, as its results support decision-making at all times, and it contributes to the evaluation of the processes in the financial intermediary system through our *Report on Financial Stability.*

Our study offers a snapshot of the methodology. As seen above, we quantify several factors on the basis of simple assumptions and estimates in our current framework. In our view, it would be important to use models for these factors in the future. Improvements in international practice also prompts regular enhancements. Moreover, as our information base grows over time, our current models will need to be regularly reviewed. One key feature in the solvency stress testing is the calculation of loan losses. Currently we rely on models to quantify PDs only; therefore, it is important to enhance the LGD calculation methodology. The introduction of CRD IV also necessitates development, primarily in quantifying stressed capital. Regulatory changes also affect liquidity stress testing, as credit institutions are required to satisfy a new kind of liquidity requirements. Finally, changes in the economic environment may also call for development. Since the recovery is gradual, our current static balance sheet assumption will not represent a prudent approach. We will need to reconsider in the future how we take into account capital requirement, which changes in line with the increasing loan portfolio.

In the above, we have sought to offer a detailed overview of the objectives and the operation of our existing stress tests and the interpretation of their results. In our stress testing, we analyse the liquidity and solvency positions of banks separately. In the liquidity stress test we attempt to find out the extent to which the Hungarian banking system would be able to absorb a complex liquidity shock. To define liquidity, we apply the balance sheet coverage ratio used in Hungarian practice and the 10 per cent minimum requirement for the same. We incorporate the effects of a complex liquidity shock into this indicator. In our results, we identify the additional liquidity needed across the entire system to ensure that all banks can comply with the requirement, even in a stress scenario. Besides the system-level demand, we monitor the performance and foreign currency liquidity positions of individual banks.

In the solvency stress test, on the other hand, we aim to identify the extent of losses a strong macroeconomic shock would generate in the banking system due to credit and market risks, and the impact of this on banks' capital adequacy. For this purpose, we quantify the adjusted income before loan losses expected of the banking system over a two-year time horizon in the event that they are forced to operate under very difficult macroeconomic circumstances. Similarly, we model the losses banks would suffer in their loan portfolios and the income consequences a revaluation of the securities portfolio and the foreign currency denominated items would have. Taking all of the above into account, we can quantify the demands for capital injection after stresses. Besides system-level results, we also note the asymmetries existing among banks in our stress testing. This means that, beyond identifying systemic issues, we can name the specific institutions representing the greatest threat to the system as a whole.

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