6. MACROPRUDENTIAL LIQUIDITY STRESS TEST: HOW TO COPE WITH LIQUIDITY DRAINS[1]

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Abstract

This paper develops a macroprudential liquidity stress-testing tool to seize possible consequences of a liquidity drain that manifests during a systemic crisis tailored to an emerging economy. The tool novelty resides in including feedback from the real economy also affected by a liquidity shock, quantifying the impact of the drop in the support from the banking group through foreign funding and the link between liquidity and solvency that matches emerging market features. The stress-testing tool aims to: (i) test the capacity of the banking sector to withstand liquidity drain and to gauge consequences to liquidity and solvency ratio, (ii) assess the impact on credit supply when the liquidity shock occurs, and (iii) evaluate some policy options, including liquidity deficit a central bank should accommodate. We apply the tool to the Romanian economy using two scenarios with different risk severity and discuss possible policy measures.

Keyword: banks; capital flows; systemic liquidity; stress-testing tool; policy measures; emerging markets;

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1. Introduction

Liquidity drain is usually the first wave of shock during a systemic crisis. International experiences of the 2007-2008 Global Financial Crisis (GFC) and COVID-19 crisis underpin

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this pattern. Liquidity drain may result from several causes, like high uncertainty about economic developments, foreign capital outflows, panic or run on deposits, credit crunch, etc. and it impacts both the real economy and the financial system. Improper management of liquidity stress might become solvency problems, as many debtors would encounter difficulties repaying their debts.

Financial distress impairs banks from fulfilling their financial intermediation role in the economy and might also trigger high economic costs. Preventing financial crises and ensuring a high resiliency for the banking sector is part of the mandate of policymakers in the financial stability field. After the GFC, the regulatory and supervisory framework became more oriented toward achieving these goals, with preventing systemic liquidity risk as one of the main objectives. To fulfil their financial stability goals, central banks and supervisory authorities developed new tools for evaluating the systemic dimension of liquidity risk. Given the complex nature of this risk, supervisors targeted efforts toward stress testing as these tools are more flexible in terms of types of transmission and contagion channels examined. However, these instruments demand highly granular data on banks' exposures and a good understanding of the critical vulnerabilities of the banking sector.

Most of the existing literature on liquidity stress-testing models looks at developed economies with advanced banking sectors and substantial market-based funding (Schmieder et al., 2012; Van den End, 2012; Cont et al., 2020; Bakoush et al., 2022). Emerging economies distinguish themselves through specific characteristics that make the design of stress-testing tools more challenging. In European emerging markets, the banks rely less on market funding and more on foreign funding provided by the group. Fewer banks have public ratings and instruments issued on the capital market (either shares or bonds). In this paper, we construct a liquidity stress-testing tool with features specific to an emerging European economy with the macroprudential purpose of exploring the potential systemic consequences of heightened liquidity constraints. The model is similar to the one used by the National Bank of Romania[4].

Several features stand out compared with other stress-test methodologies described in the literature. First, we emphasise the macroprudential pattern of systemic liquidity shocks. We assess the impact of a liquidity strain on both banks and nonfinancial companies and capture the feedback effects between these sectors. Second, we tailor the methodology to better deal with specific issues of the banking sectors of the European emerging economies, especially the relatively high dependency on foreign funding. We focus on *the funding liquidity channel* (i.e. inability to rollover funds or to borrow additional funding without significantly increasing the cost and/or collateral requirements) instead of *the market liquidity channel* (i.e. the difficulty of selling assets without a substantial price discount). The European emerging banking sectors hold a lower volume of marketable securities than the advanced ones and have less developed domestic capital markets. Third, we incorporate the link from liquidity to solvency risk through *loss and cost channels*. Designing transmission channels from liquidity to solvency is constrained by certain conditions of the domestic banking sector. The lack of development of the fixed-income market and the low number of banks with ratings puts a restraint on the funding received from the central bank[5].

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[4] *The instrument was initially designed in late 2007 to test the banking sector's resilience to a foreign funding shock.*

[5] *For a different approach, see Schmieder et al. (2012). The authors use market-intensive information to infer the impact of liquidity on solvency through funding costs. Their approach*

The liquidity stress-testing tool developed in this paper aims to: (i) test the capacity of the banking sector to withstand liquidity drains and to gauge the consequences of the liquidity stress to the solvency ratio; (ii) quantify the liquidity deficit a central bank should accommodate (for both total and FX positions); (iii) assess the impact on the banks' credit supply (new credit and rolling-over credit lines) when the sudden stop occurs; and (iv) evaluate policy options.

We apply the stress-testing tool to the Romanian economy using scenarios based on the best practices and choosing the magnitude of shocks similar to those during the Global Financial Crisis.

We discuss different possible policy measures given the systemic dimension of liquidity strains that might occur. The ex-ante solutions (e.g. early call for additional capital, improvement in loan-to-deposit ratio, and increase of the outstanding amount of eligible collateral in the bank's portfolio) targeted banks that could face difficulties. However, these measures have to be in place beforehand. Regarding the ex-post solutions, the most efficient, according to our simulations, is the unconventional one (e. g. the macroprudential authority acting as an intermediary for an orderly asset sale of a bank with a liquidity deficit to a bank with more than sufficient liquidity).

The paper is structured as follows: Section 2 is the literature review, Section 3 describes the methodology, assumptions and data used, Section 4 presents some results with a numerical example, and the last chapter contains the main conclusions.

2. Literature Review

Under the financial stability mandate, the authorities seek to preserve the functioning of the banking sector during adverse economic and financial conditions. Therefore, assessing its resilience to liquidity shocks is critical. The literature on banks' liquidity is diverse but less developed compared with the literature on banks' solvency and even less so for stress testing models. Possible explanations could be the difficulties in evaluating the impact of a liquidity shock, the variety of channels through which it propagates and the complexity of feedback responses. In addition, this type of research requires excellent and detailed supervision and banks balance sheet data.

Understanding the correct causes of liquidity shock, though the manifestation might be similar, helps to design the proper measures from the policymaker's point of view, as Barnhill and Schumacher (2011) also note. The central bank's function as a lender of last resort may be efficient in the event of a pure liquidity shock. However, it may be less efficient in a liquidity crisis triggered by a solvency event. Khan and Wagner (2012) show that characteristics of the liquidity supply (elasticity, the relative cost of raising additional liquidity) play an essential role in banks' behaviour in both pre- and post-crisis periods. This factor should be taken into account when designing policy measures.

The literature on banks' liquidity identifies several types of triggers of a liquidity crisis: (i) pure liquidity shock – even banks with strong solvency positions can suffer a deposit run-off as the withdrawals decisions are based on the expectations of all the other depositors' behaviour (Diamond and Dybvig, 1983); (ii) solvency triggered shock – the depositors try to

assumes the existence of a direct or implied bank rating. Also, the importance of market funding in banks' balance sheets is material and generates additional risk channels (such as the potential impact of market concentration).

distinguish between good and bad banks in the context of asymmetric information (Allen and Gale, 2000); (iii) funding structure shock – the distribution of leverage in the financial sector and the position in the business cycle are crucial in determining the severity of crises (Acharya and Viswanathan, 2011).

There are several liquidity tools and models for assessing banks' liquidity risk. Acharya and Skeie (2011) develop a theoretical model that evaluates rollover risk in the interbank market, showing that heightening the banks' precautionary liquidity demand leads to higher interest rates and lower transaction volume, increasing banks' liquidity pressures during a crisis. Anand *et al.* (2013) analyse systemic risk using a network approach with three agent types: domestic banks, international finance institutions and companies. The authors measure the financial sector resilience by examining the interconnectedness between these three types of agents. They evaluate the effect of asset fire-sales externalities and the impact on lending to the real sector. Another model is Pagratis *et al*. (2017), which estimates the liquidity shortfall for the US banking sector during the GFC.

Many of the most recent models for assessing banks' liquidity are stress-testing tools. Van den End (2012) simulates banks' responses to different exogenous shocks using a macro stress-testing model, with the bank's liquidity position constructed using a Liquidity Coverage Ratio approach. Schmieder *et al*. (2012) present a framework for system-wide balance sheet-based liquidity stress tests. Their framework includes three modules assessing different aspects of liquidity risk: bank runs, maturity transformation and rollover risks, and links from liquidity to solvency risk. Schmitz *et al.* (2019) also assess the importance of the interaction between solvency and funding risks. Nguyen *et al*. (2020) evaluated how liquidity stress-testing exercises conducted for supervisory purposes might affect banks' liquidity creation in the economy.

The stress-testing methodology for prudential purposes advanced significantly (Ong *et al.,* 2017; ECB, 2019) and became even more relevant after the COVID-19 crisis. The newly developed tools include more granular data to capture all relevant cash flows and multiple channels like off-balance sheet derivatives funding or counterparty risk. Still, these new developments based on advanced economies are not well-fitted for emerging banking systems like Romania. Our contribution to this literature resides in including features specific to an emerging European economy, like the impact of the drop in the support from the banking group through foreign funding and different transmission channels from liquidity to solvency.

A more novel part of the literature looks at the banks' liquidity for macroprudential policy purposes. Van den End (2016) analyses the loan-to-deposits indicator as a macroprudential tool, while Jobst (2014) looks at the Basel Committee indicators (BCBS, 2019a and 2019b) - Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NFSR). Cont *et al*. (2020) construct a joint stress testing framework for liquidity and solvency risks. The liquidity shock is endogenously determined by the solvency shock, while the solvency shock is exogenous. Authors show that banks' credit risk can be underestimated if the stress-testing tool does not account for the interactions between solvency and liquidity risks. In our framework, in addition to solvency and liquidity interactions on both banks and companies, we include an endogenous liquidity shock that banks transmit to the real sector by not rolling over credit lines and reducing the volume of new credit. Bakoush *et al.* (2022) developed an integrated stress test for liquidity and solvency risks using a banking system network approach for macroprudential purposes. Their framework uses a new measure for systemic financial distress that allows the supervisors to assess the current state of a banking system's stability. Our paper also contributes to this literature by including feedback from the real economy to the banking sector and assessing a systemic liquidity shock. The paper also discusses different policy options that can be used to contain such a systemic shock.

3. Methodology and Data

Our model uses a balance sheet approach with three sectors: banks, non-financial companies and households. We present the general framework of the model in Figure 1. The liquidity stress test consists of five steps: (i) calculating banks' liquidity positions after the initial liquidity shock (Λ); (ii) assessing banks' response actions through lending activity, dL (i.e. delivering a second-round effect of the liquidity shock to the economy); (iii) computing the non-financial companies' liquidity position (λ) and their response to banks' decisions (the credit lines reimbursed, x); (iv) quantifying the demand for money (by major currencies) and the liquidity deficit a central bank might accommodate; and (v) computing the consequences for banks' solvency.

The liquidity shock tested consists of (i) foreign capital outflows affecting banks (including not rolling over the FX swap transactions) and non-financial companies; and (ii) the run of domestic households and companies' deposits[6]. Banks incurring liquidity deficits after the initial liquidity shock trigger a second-round shock. Banks with liquidity strains will reduce their credit activity and/or not roll over credit lines to the real sector. In addition, debtors face difficulties due to new macroeconomic and financial conditions. If debtors cannot fully service their debts, a further liquidity shock is sent to the banking sector, along with additional pressure on the bank's solvency ratio. Both first and second-round effects of the liquidity shock are added up, and the banks' liquidity position is recalculated.

To compute the banks' liquidity position, we need some ex-ante assumptions regarding the banks' behaviour and the interbank market. First, we consider that banks cannot borrow additional funds from the money market. Therefore, banks resort to Central Bank for their liquidity needs. Second, banks' balance sheet positions remain unchanged during the stress-test horizon except for the ones affected by cash outflows and inflows. These assumptions are important and need to be evaluated carefully. In what concerns the Romanian banking sector, the GFC crisis generated a substantial reduction of the interbank market, with daily average volume dropping by 50% in the aftermath and remaining at this low value in the subsequent three years.

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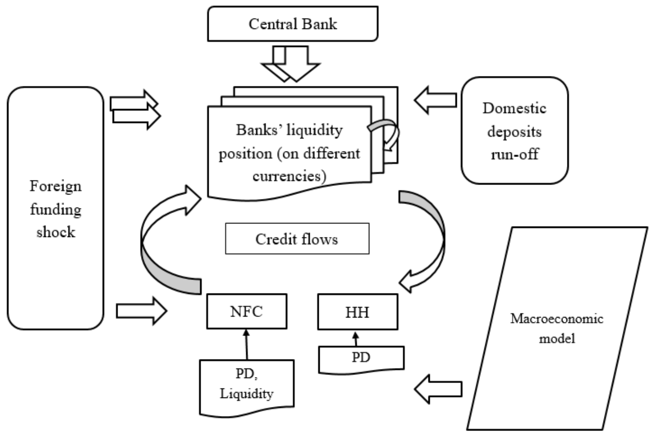
[6] *We do not model the link between these two types of shocks under review.*

Figure 1. Model general framework



The stress-test exercise can accommodate different time horizons. However, one-month tenure is better suited for our needs[7], also constrained by data availability. Shocks are computed separately by currency (domestic and FX) and aggregated across currencies[8].

For the first step, each bank liquidity position at time t (Λ_t^i) is computed as

$$\Lambda_t^i = \sum_q A_{q,t}^i (1 - H_q) + \sum_p CFI_{p,t}^i - \sum_m CFO_{m,t}^i \, , for \ \forall \ bank \ \ i = \overline{1, N}$$

where: A_q represents the stock of liquid assets and H_q the haircuts applied (from best practices and Romanian experience); CFI_p represents the cash flows received by the bank from its outstanding loan repayments, and CFO_m reflects the cash outflows from new lending or due to the run of domestic deposits and parent funding withdrawals, according to the scenario under review (the initial liquidity shock).

The cash inflows and outflows are computed for customer-driven flows only (deposit and credit activity). For comparison, the items used to calculate banks' cash inflows (CFI) and

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[7] For three-month and higher horizons, the impact of the post-shock macroeconomic indicators (economic growth, interest rate and foreign exchange rate) must also be considered. In this latter case, new channels should be envisaged: (i) the quality of banks' credit portfolios could deteriorate at a faster pace leading to lower inflows for credit activity; and (ii) the effort in local currency of due FX liabilities could be higher in the most likely context of local currency depreciation. In addition, higher risk aversion on the part of banks would trigger a higher liquidity threshold buffer, leading to higher deleveraging consequences.

[8] The total result is not a simple sum of the currency positions, as additional effects are taken into account. If a bank registers a liquidity deficit, the bank will stop granting new loans in any currency. Also, the bank will enter the forex market to transform the liquidity from one currency (in which it has additional resources) to another (in which the liability is denominated). This additional demand for foreign currency will be added to the total new demand on the FX swap market.

outflows (CFO) in the model represent around 80% of total assets (without central bank exposures, which represent the liquid assets) and, respectively, 80% of total liabilities. These results are calculated as average values on aggregate balance sheet data for Romanian banks.

The cash inflows (CFI) are derived from payments received from credits granted to companies and households. For credit lines, the initial assumption is that they are automatically rolled over. The cash inflows from credit granted to companies are computed as follows:

$$\sum_j \left(1 - PD_{j,t} * LGD\right) * DS_{j,t}^{i} \ ,$$

for $\forall$ j = $\overline{1, \mathrm{M}}$ companies from bank's portfolio$\forall$ i = $\overline{1, \mathrm{N}}$ loans granted to company j

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where: $LGD = 1$[9], PD$_j$ is the default probability for company j[10] and DS_j^i is the credit annuity of company j for each of its loans i (the debt service for exposures with more than 90 days past due has not been included).

The cash outflows due to parent funding withdrawals and run of deposits are calculated as:

$$S = \alpha(1 - r_{MRR})$$

where: α represents the percentage that is withdrawn, r_{MRR} is the rate of minimum required reserves.

To quantify new credit activity (also part of cash outflows for the bank, CFO), we assume banks will display two types of behaviour based on their funding structure relative to their credit portfolio: (i) banks with a loan-to-deposit ratio (LTD) lower than the banking sector average would supply new credit in a similar amount as that of the previous 12 months (no change in the business model); (ii) banks with higher than average loan-to-deposit ratio would only lend to keep their current stock of credit unchanged (banks are no longer active in the credit market, but they are maintaining their status quo). The LTD pattern mirrors, to a large extent, the liquidity coverage ratio envisaged in the Basel III rules (BCBS, 2019a).

$$\begin{cases} \underset{t-12<\theta\leq t}{\text{avg}} \left(dL_{i,\theta}\right), & LTD_{i,t} \leq \overline{LTD}_t \\ 0, & LTD_{i,t} > \overline{LTD}_t \end{cases} \qquad for\ \forall\ bank\ i = \overline{1, N}$$

The banks with structural liquidity (LTD) higher than the banking sector average are able to continue their lending

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[9] LGD (loss given default) is the estimated loss in case of default, and 1-LGD is the recovery rate or the percentage of the loan that the bank estimates to recover after the debtor enters default. We use the value of one for LGD because banks, most likely, cannot recover the loan's value by seizing the collateral over the stress test horizon (i.e. one month).

[10] We used the methodology from Costeiu and Neagu (2013) to calculate the default probability for each company. Their model is a logit estimation that uses receivables turnover ratio, sales-to-total assets ratio, short-term bank debt-to-total assets and debt-to-equity as explanatory variables for computing idiosyncratic PDs, and this result is adjusted with macroeconomic factors affecting corporate default rate (annual GDP growth, change in the real effective exchange rate, CORE1 annual inflation rate and FX interest rate spread).

activity after a liquidity shock. The banks' cash outflows (CFO) due to new lending are defined as:

$$\begin{cases} \underset{t-12<\theta\leq t}{\text{avg}}\left(dL_{i,\theta}\right), & LTD_{i,t} \leq \overline{LTD}_t \\ 0, & LTD_{i,t} > \overline{LTD}_t \end{cases} \quad for\ \forall\ bank\ i = \overline{1,N}$$

where: LTD_i is the loan-to-deposit ratio for bank i, $\overline{LTD}_t$ is the average loan-to-deposit ratio for the banking sector at time t, L is the outstanding loan portfolio, dL is the amount of new credit granted, t is the current month for which the stress test is run.

$S = \alpha(1 - r_{MRR})$In the second step, the total new credit is adjusted based on the bank's liquidity needs. If a bank cannot obtain sufficient resources to cover its liquidity needs after the withdrawals of deposits and foreign funds[11], it will decide to restrain from new lending.

In the third step, we assess the response of non-financial companies to banks' decisions. The non-financial companies finance themselves from abroad (from foreign financial institutions and from parent entities) and from domestic banks (where an important part of borrowing is for treasury purposes, in the form of revolving credit lines). The empirical literature on credit lines (Ippolito *et al*., 2016; Acharya *et al*., 2020) shows that during crises, companies typically use large parts of the undrawn amounts to obtain additional liquidity, putting more constraints on the financial institutions[12].

When a company must deal with simultaneous shock from abroad and from the domestic financial market, we consider that foreign creditors would be paid first[13]. A company that is required to pay back the credit lines would also experience a deterioration in the ability to service the debt vis-à-vis other creditors if there are insufficient liquid assets on its balance sheet to deal with the initial shock.

A company faces the following liquidity constraint:

$$\lambda_{j,t} \geq 0$$

$$for\ \forall\ j = \overline{1,M}\ \ non - financial\ companies$$

where:

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[11] Some banks could decide to reduce their credit activity, even if they succeed in covering the liquidity needs, owing to uncertainties regarding the future (banks are more precautionary, they are more risk averse). To capture this effect, the model should incorporate a threshold higher than zero of the liquidity position (Λ). A similar approach can be found in van den End (2012). The value of this threshold will depend on banks' risk tolerance. During crisis periods, we expect to see an increase in this threshold, as banks tend to exhibit greater risk aversion, thus increasing the effect of the liquidity shock on the credit supply (this feature is not implemented in our model).

[12] During the Global Financial Crisis, Romanian banks reduced the volume of credit lines and the number of companies to which they granted loans, while companies reduced their volumes of credit drawn from such credit line agreements.

[13] Domestic companies from emerging Europe increased their funding from abroad significantly to borrow in FX, owing to better lending conditions provided by the foreign banks (lower interest rates, larger exposures available, etc.). If a negative development were to occur, it is more probable that domestic firms would pay the external creditor first in order not to cut off this channel of funding which has better lending conditions.

$$\lambda_{j,t} = Deposits_{j,t} + OCF_{j,t} - STED_{j,t}$$

$$OCF_{j,t} = NetProfit_{j,t} + Amo_{j,t} - NI_{j,t} + dP_{j,t} + dSTD_{j,t} - dCA_{j,t} + dIA_{j,t}$$

Deposits are inferred from the company's balance sheet position, OCF[14] is the operational cash flows, STED represents the short-term external debt that is not rolled over by foreign creditors, d stands for change in stock, Amo is amortisation, NI is non-cash income arising from the re-evaluation of real estate assets, P reflects provisions, STD represents short-term debt other than from banks, CA stands for current assets and IA for income in advance.

How a bank chooses which companies will not be rolled over is difficult to assess. One option is to select the companies with a lower PD on the assumption that such companies would be able to service the debt and provide liquidity for the relevant bank. The main drawback of such an option is that the bank reduces its market share of good clients. The other option is to sacrifice companies with higher PD, but such a choice might deliver a higher increase in credit risk provisions. These firms have a lower ability to service their debt; therefore, the liquidity problem would remain unsolved. To determine how much companies can repay their debt, we compute the bilateral exposure matrix using a maximum entropy algorithm based on Mistrulli (2007). The results of the bilateral exposures are compiled as follows:

$$\min_{x} ln \frac{x_{j,i}}{x_{j,i}^{0}}$$

with the following restrictions:

$$\begin{cases} \sum_{j} \mathrm{x_{j,i}} = \min\left(|\Lambda_i|, \sum_{j} \mathrm{CL_{j,i}}\right) \text{ where } \mathrm{i} = \overline{1,\mathrm{n}} \text{ banks for which } \Lambda_i < 0 \\ \sum_{i} \mathrm{x_{j,i}} = \min\left(\lambda_{j,} \sum_{i} \mathrm{CL_{j,i}}\right) \text{ where } \mathrm{j} = \overline{1,\mathrm{M}} \text{ non} - \text{financial companies} \\ x_{j,i} > 0, \forall i, j \end{cases}$$

where:

$$\langle x_{j,i} \rangle_{j=\overline{1,M},\ i=\overline{1,N}}$$

is the matrix of companies/banks cross-exposures, CL represents credit lines, λ is the companies' liquidity position, and $X^0=\{x^0_{j,i}, i = 1,N, j = 1,M\}$ is the initial matrix used as a reference.

The volume of reimbursed credit lines is added to the bank's liquidity position, while the requested but unpaid amounts are recorded as losses. The non-financial companies that are more than 90 days past due on their payments are not included, even if the credit line matures (as the probability of servicing the debt is low). In these cases, banks usually try to mitigate the loss by implementing different temporary solutions (credit restructuring, bridge loans, etc.).

In step four, we evaluate the demand for money (both in domestic and foreign currency) and the liquidity deficit that a central bank should accommodate. An important emerging market feature is that the stress test is run for all the major currencies, given that emerging

[14] *We computed companies' operational cash flows on a similar basis to that recommended by the IFRS.*

economies depend highly on foreign flows. Banks' demand for FX currency is constrained by their available resources in local currency and is triggered by either of the following: (i) the bank has a liquidity surplus in local currency but has a deficit in foreign currency (if a bank does not have sufficient resources in local currency to cover the need in foreign currency, it will decide to reduce the credit activity in local currency in a similar manner as if it had a deficit in local currency); (ii) the parent bank decides not to roll over total or part of the outstanding FX swap transactions that mature within the following month (the stress-test horizon).

In step five, we compute the impact on the solvency position of banks. The liquidity shock is transmitted to the solvency position through two channels:

- *credit risk channel*: (i) bank's decision not to roll over maturing credit lines will affect the debtor's ability to meet its payment obligations (the loss is computed as the difference between the due amount of credit and the liquidity position of non-financial companies); and (ii) new unfavourable macroeconomic fundamentals (FX rate, interest rate, etc.) will shift upwards the probability of default in the corporate sector;
- *funding cost channel*, bank's loss resulting by summing: (i) cost of new domestic currency funding from the central bank credit facility and/or open market operations; (ii) cost of euro-denominated funding (such as FX swap operations).

The main limitations of the model reside in the assumptions used to compute the banks' liquidity positions, such as the dynamics of balance sheet items and the banks' and non-financial companies' behaviour after the liquidity shock. However, the stress test methodology is flexible enough and can accommodate different setups and assumptions. Moreover, this is a macroprudential stress test and looks at banks' structural vulnerabilities. Therefore, in practice, banks that experience large liquidity deficits in one scenario are very likely to witness liquidity deficits under multiple setups. Similarly, a policy measure that is efficient under one scenario is usually efficient in other setups too.

To feed our tool, we use microdata for banks' and non-financial companies' positions. This approach has the advantage of (i) capturing the asymmetries that exist both in the banking sector and the real economy in terms of liquidity positions and shock developments, (ii) tailoring specific scenarios (e.g. according to the country or area of the origin of the shock), and (iii) limiting model uncertainty. The main drawback of this approach is the material resources of information that need to be plugged into the model.

For banks, multiple databases are used: required minimum reserves for each observation period; central securities depositories to assess the eligible collateral for central bank refinancing; balance sheet information for credit institutions; and external funding (residual maturity). For non-financial companies and households, credit information is obtained from the Central Credit Bureau. For companies' credit lines, we use treasury loans as a proxy. Databases on companies' balance sheets, profit and loss statements, and long and short-term external debt positions are also used.

We test our tool using data for 2007-2011 period, as this tenure is representative of liquidity strains delivered by the Global Financial Crisis. We selected this tenure for testing the tool because the other recent systemic period (the COVID-19 crisis) delivered marginal liquidity strains due to extraordinary policy measures implemented worldwide to supply banks and economies with sufficient liquidity.

4. Results

We run the stress-testing tool on the Romanian economy and consider two potential general scenarios (the shocks for each scenario are applied to all banks and are considered to occur simultaneously): (i) domestic deposits' run-off by 10%, short-term (i.e. up to one year) parent funding withdrawals of 25%, short-term external debt for non-financial companies that is not rolled over by 25%, banks' FX swap position maturing within one month and not rolled over by 25% (the scenario S1); (ii) domestic deposits' run-off by 20%, short-term (i.e. up to one year) parent funding withdrawals of 50%, short-term external debt for non-financial companies that is not rolled over by 50%, banks' FX swap position maturing within one month and not rolled over by 50% (the scenario S2).

The magnitude of the shocks is motivated by the international and domestic episodes of liquidity drain. For example, amid the Global Financial Crisis, Romanian banks recorded net deposit withdrawals ranging between 1.2% and 15.3% at the 25th percentile and between 7.6% and 64.8% at the 5th percentile, depending on the counterparty and the currency (Tabel 1, Annex). The design of the tool also allows us to test specific events when constructing a certain scenario. Establishing the exact value and the combination of shocks to be modelled in the stress-test exercise is a difficult task, particularly given the limitations of the data (liquidity shocks are low frequency and highly heterogeneous events).

Liquidity is asymmetrically allotted across banks, and this pattern persists after the shock. Because the money market is frozen during periods of financial stress, there would be no lending from banks with excess liquidity to banks with a deficit. This gap should be covered by the central bank provided that an adequate amount of eligible collateral is in place.

Based on the scenarios presented above, the main results of the stress-testing tool are: (i) liquidity injections by the central bank can be significant (ranging from 3.9% to 7.8% of total banks' assets), and additional FX demand on the FX market can be material (2.7% to 5.1% of total banks' assets); (ii) impact of the liquidity shock on solvency ratios is rather limited (the loss incurred by banks after the liquidity shock over a one-month horizon is between 0,1% and 0,25% of banks' own funds). However, banks tend to be highly dependent on central bank liquidity for several months, with a greater potential impact on banks' profitability (and capital) in the ensuing period, especially if the interest rate rises in order to accommodate a liquidity crunch; (iii) supply of credit to the economy can be affected to a moderate or high degree, even in the context of significant liquidity injections by the central bank (-0.2% of banks' credit in the adverse scenario); and (iv) some companies may not be able to pay their external creditors; the importance of these companies for the domestic economy range from low to moderate (depending on the specific stress scenario). The companies with foreign liquidity deficits are responsible for 4% to 10% of the gross value added generated by non-financial companies.

The shock is manageable at the aggregate level in both scenarios but with some burden. The liquidity deficit is relatively low in the first scenario and moderate in the second (Figure 2). Although the second scenario entails shocks double in size compared to those used in the first scenario, the impact on the banking sector liquidity position is not twice the magnitude, owing to various non-linear features, such as asymmetries within the banking sector (some banks might be using the entire excess reserves in both scenarios, while others might take recourse to this resource only partially or totally in the second scenario). Another non-linear effect is that a deficit in one currency (such as the euro) can trigger a complete discontinuation of new lending for the other currencies as well.

New instruments and policy measures should be implemented in order to cover the deficits. There are two options:

(i) ex-ante solutions targeted to banks that could face difficulties in meeting liquidity obligations in times of stress (e.g. early call for additional capital, improvement in loan-to-deposit ratio, increase of the outstanding amount of eligible collateral in bank's portfolio, etc.). The magnitude of these solutions is based on the results derived from the stress-testing tool.

(ii) ex-post solutions can be divided into two groups: conventional measures (e.g. broadening the eligible collateral, decreasing the required reserves ratio, etc.) and unconventional measures (e.g. a macroprudential authority acting as an intermediary for an orderly asset sale of the bank with a liquidity deficit to a bank with sufficient liquidity). The main disadvantage of conventional measures is that they provide liquidity to the entire banking sector and are, therefore, not targeted for the most needy entities. Also, empirical evidence and current simulations show that, in many cases, the effect on banks with deficits is rather marginal. The above-mentioned unconventional measure proved to be the most efficient in our simulations, but its implementation requires some prerequisites (*e.g.* detailed information about banks' credit portfolios, exploratory discussions with the liquid banks before the deal, if required, etc.).

Figure 2. Stress-testing scenarios results (change in total banking sector assets)

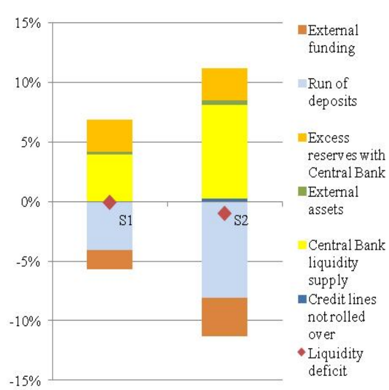
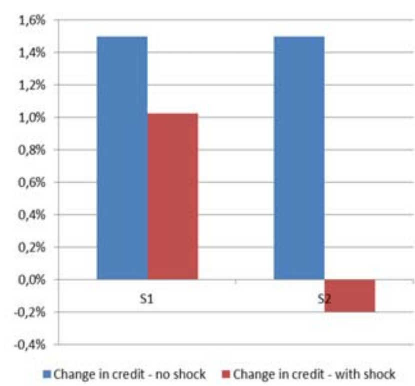


Figure 3. The impact of the liquidity shock on the new lending activity (change in outstanding loans)



It is crucial to run stress tests by currency (domestic and FX) when assessing the liquidity deficit. If banks do not feel comfortable accessing the forex market owing to disequilibrium between FX demand and supply during a liquidity shortage, the overall liquidity deficit could increase considerably. Central bank interventions to provide FX swaps could be a solution. The central bank could engage in FX swaps with other central banks to provide liquidity funding in foreign currencies.

Depending on the scenario, the consequences of a capital outflow on lending activity range from moderate to adverse material effects (Figure 3). In the first scenario, credit growth dynamics is nearly two-thirds of the credit growth in the no-shock scenario[15]. In the second scenario, the credit dynamic enters the negative territory. The decrease in credit is highly concentrated (three banks contribute to over 80%). If access to central bank funding (in exchange for eligible collateral) and the forex market are adversely affected, the adverse outcomes displayed above will increase accordingly.

We conduct different robustness tests by changing the values of shocks and dropping the assumption regarding the money market. The stress test methodology proves to be robust in the sense that banks with significant liquidity deficits (over 10% of minimum reserves held with the central bank) also experience deficits in other stress test setups. A possible explanation for this result is that the model looks at banks' structural vulnerabilities. Indeed, banks with significant liquidity deficits have structural weaknesses like a high share of foreign funds or a low level of liquid assets.

5. Conclusions

Liquidity stress-test tools are valuable for macroprudential purposes in order to assess how the overall banking sector can withstand liquidity shocks and how adverse developments are transmitted between the real economy and the banking sector. However, predicting outcomes of severe liquidity drains remains challenging, owing to different trigger events, multiple transmission channels, and feedback responses.

We construct our macroprudential tool using microdata and the balance sheet approach. The novelty of our tool resides in the specific features that characterize an emerging European market. We include feedback from the real economy also affected by a liquidity shock, quantify the impact of the drop in the support from the banking group through foreign funding and the link between liquidity and solvency that matches emerging market features. The tool tests the capacity of the banking sector to withstand liquidity stress, assesses the impact on banks' credit supply, and evaluates the most suitable policy options, including the estimation of the liquidity deficit a central bank should accommodate.

We apply our macroprudential stress-testing tool to the Romanian economy. Our results suggest that stressed scenarios with magnitudes similar to those registered during the Global Financial Crisis are manageable, but with some burden. Liquidity injections by the central bank might be significant. However, the impact of the liquidity shock on solvency ratios is somewhat limited to a one-month horizon, and the supply of credit to the economy could be affected to a medium-high degree level.

According to our simulations, unconventional ex-post solutions (e.g. macroprudential authority acting as an intermediary for an orderly asset sale from banks with liquidity deficit to banks with sufficient liquidity) are the most efficient for dealing with severe liquidity shocks. Ex-ante solutions (e.g. early call for additional capital, improvement in loan-to-deposit ratio, ensuring the adequate outstanding amount of eligible collateral in the bank's portfolio) might play an important role, but are not always sufficient to cope with severe scenarios. Liquidity crises can develop very rapidly. Therefore, authorities need to implement sound and operational macroprudential policies beforehand.

[15] *For the baseline (non-shock scenario), we use the assumption that banks will continue to lend according to their funding position, as presented in Section 2, in which we discuss the new credit activity.*

While the stress test model is able to properly identify banks that would register liquidity strains during a crisis and to evaluate possible policy options, it does not fully capture the magnitude of the liquidity drain on the economy. Further developments of this tool could be to include a more reasonable assessment of the implications of a liquidity shock to the real economy.

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Annex – Data Statistics

Table 1. Romanian bank deposits - monthly changes for individual banks; by counterparties and currencies; 2007-2011

		Mean	Median	Standard deviation	5% percentile	25% percentile
Non-financial companies	local currency	2.7	1.0	22.4	-17.2	-5.1
	euro	4.8	-0.2	36.2	-27.3	-7.6
	other foreign currencies	28.4	-0.8	715.9	-44.0	-15.3
Households	local currency	2.5	1.3	11.5	-7.6	-1.2
	euro	9.0	1.1	276.7	-7.6	-1.6
	other foreign currencies	6.3	-0.3	189.0	-13.1	-3.8
Domestic financial institutions	local currency	13.7	0.3	151.1	-35.2	-9.3
	euro	89.7	0.0	1357.1	-61.0	-14.6
	other foreign currencies	73.4	0.3	1031.1	-64.8	-15.3
Foreign financial institutions	local currency	23.5	0.3	249.5	-33.1	-3.1
	euro	12.8	0.4	121.3	-31.7	-3.9
	other foreign currencies	47.4	0.1	673.0	-56.4	-8.3

Source: National Bank of Romania, authors' calculations.