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Banks as Liquidity Providers in the Interbank Market

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Abstract. *The paper analyzes structural differences in banks' ability and willingness to supply liquidity in the interbank market given the existing prudential regulation using a partial equilibrium model. The results show differences in the Liquidity Coverage Ratio (LCR) effectiveness for two types of banks' business models. First, for the more traditional one (with structural liquidity surplus), the LCR measure enables banks to lend more in the interbank market (by letting them subtract possible cash inflows from the expected outflows under a liquidity stress scenario) but at the cost of allowing them to maintain lower default limits (thresholds on the maximum liquidity shock the banks can withstand without entering default). Second, banks with structural liquidity deficits that need other funding sources than retail deposits, like subsidiaries that receive finance from their parent banks, face tighter requirements on high-quality liquid assets, keep higher default limits and lend less in the interbank market. For this business model, often seen in emerging markets, including Romania, the LCR measure fosters banks' resilience to liquidity shocks. However, this LCR functionality might encourage them to overlook contagion risk from their parent and parent banks' economies, especially under favorable financial conditions. Prudential authorities should complement the LCR measure with other instruments (like liquidity stress test) that better assess banks' liquidity risk due to maturity mismatch. Banks' liquidity risk management can partially mitigate the differences in LCR effectiveness through precautionary holdings of additional liquidity buffers. Banks with higher risk aversion prefer maintaining a higher no-penalty limit (the maximum liquidity shock the bank can accommodate without a penalty fee) and an increased default threshold and are less willing to lend in the interbank market.*

Keywords: Liquidity Coverage Ratio, liquidity risk, banking sector.

Introduction

Banks play an essential role in the economy by providing liquidity to other banks and to the real sector - Kashyap et al. (2002), Acharya and Steffen (2020), Acharya et al. (2021). After the Global Financial Crisis, the regulatory authorities started paying more attention to liquidity risk and extended the regulatory framework. The main reason for liquidity regulation, according to Diamond and Kashyap (2016), is the process of maturity transformation of banks acting as liquidity providers to the economy. The ability and willingness of banks to fulfill this role are determined by the level of banks' risks and market financial conditions. Acharya and Skeie (2011) show in a theoretical set-up that, during normal times, banks lend in the interbank market, but the volume supplied varies with their level of risk.

The literature on liquidity risk prudential regulation started to develop relatively recently. Allen and Gale (2018) argued that while the literature on capital regulation is vast, the one on liquidity is almost nonexistent. Moreover, the topics discussed in this literature are diverse. Bech and Keister (2017) studied the impact of LCR regulation on interbank interest rates. The authors look at the implications of the liquidity needs of banks to restore the LCR liquidity buffers on the overnight and long-term interest rates. They find that the additional needs by banks triggered by an LCR shortfall decrease short-term interest rates while increasing the regulatory premium on long-term rates. Another paper, De Haan and van den End (2013), analyzes the implications of liquidity prudential regulation from a financial stability perspective. The authors evaluate the impact of

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banks' maturity transformation on banks' asset holdings and banks' liquidity management using data from the Netherlands' banking sector. Their empirical findings show variation in banks' liquidity buffers on banks' size and ownership. They also discuss the impact of the Global Financial Crisis (GFC).

This paper contributes to this strand of literature - the implications of liquidity regulation from the financial stability perspective. More specifically, it assesses how the LCR measure[1] helps banks increase their resilience to shocks while preserving their ability to provide liquidity to the economy.

The partial equilibrium model builds on the existing literature like Kashyap et al. (2002), Acharya and Skeie (2011) and Bech and Keister (2017). The main finding is that LCR regulation acts differently for two main types of banks' business models. First, for banks with structural liquidity surplus (L/D < 100%) - the more traditional business model, the LCR measure enables them to lend more in the interbank market. It does that by considering the possible cash inflows from lending (the estimated cash inflows are subtracted from the expected outflows under a liquidity stress scenario). However, this comes at the cost of allowing banks to maintain lower default limits (the thresholds on the maximum liquidity shock the banks can withstand without entering default). Second, banks with structural liquidity deficits that need other funding sources than retail deposits (L/D > 100%) - a second type of business model, face tighter requirements on high-quality liquid assets (HQLA) and, thus, keep higher default limits. These banks lend less in the interbank market. For this business model, often seen in emerging markets, including Romania, the LCR measure fosters banks' resilience to liquidity shocks as they receive finance from their parents or banking group, not directly from the market. Still, this LCR functionality might encourage them to overlook contagion risk from parent and parent banks' economies, especially under favorable financial conditions.

Prudential authorities should complement the LCR measure with other instruments (like liquidity stress test) that better assess banks' liquidity risk due to maturity mismatch. Banks' liquidity risk management can partially mitigate the differences in LCR effectiveness through precautionary holdings of additional liquidity buffers. Banks with higher risk aversion prefer maintaining a higher no-penalty limit (the maximum liquidity shock the bank can accommodate without a penalty fee) and an increased default threshold and are less willing to lend in the interbank market.

The paper is structured as follows. I describe the model in the following section, while in section three, I discuss the main results. In section four, I formulate the main conclusion and show a possible extension of the model. A detailed presentation of the model is in the Appendix.

Model

I construct a simple partial equilibrium model to study structural differences in banks' ability and willingness to supply liquidity in the interbank market. The model considers a bank's balance sheet, profit and prudential requirements at three moments (t0, t1 and t2). At t0, the bank decides its funding and liquidity strategy for the period until t2, as well as the amount of lending it wants to supply in the interbank market (B). At t1, a liquidity shock can occur as deposit withdrawals. The bank's decisions depend on its risk tolerance, assessment of deposit dynamics, and the prudential

[1] The model includes only the Liquidity Coverage Ratio (LCR) indicator as it assesses the implication of liquidity regulation on short-term interbank lending as part of banks liquidity providing function. The other Basel III measure for liquidity risk, Net Stable Funding Ratio (NSFR), refers to banks' funding profile on a one-year horizon.

requirements it must comply with. At t2, the bank collects loan payments and pays interest rates on deposits and other fundings.

At t0, the bank holds high-quality liquid assets (reserves held at the central bank - Res_0 and government securities - S_0), lends to the real sector the amount L of loans, has capital E_L that complies with the prudential requirements on the minimum level of capital on the real sector lending, and capital E_B for the interbank lending[2]. The bank can access funds from the central bank (CB_0) and the wholesale market (F_0).

Therefore, at t0, the bank's balance sheet identity is:

$$S_0 + Res_0 + L + B = E_L + E_B + D_0 + CB_0 + F_0 \quad (1)$$

subject to regulatory constraints:

- the minimum reserves requirements (the Minimum Reserve Requirements - MRR):

$$Res_0 \geq r_{MRR} D_0 \quad (2)$$

- the capital requirements (the Capital Adequacy Ratio - CAR):

$$\frac{E_i}{w_i V_i} \geq \kappa \quad (3)$$

where V_i is L for lending to the real sector and B for interbank lending;

- the liquidity requirements (the Liquidity Coverage Ratio - LCR):

$$\frac{Res_0 + S_0(1 - h_{LCR})(1 - \eta_0)}{outflows - min\{75\% outflows, inflows\}} \geq \lambda \quad (4)$$

where[3]

$outflows = \theta_D D_0 + \theta_F F_0$

$inflows = \theta_B B$

The banks have different levels of risk tolerance that affect both their lending activity and the level of capital and liquidity buffers held. A bank with a lower level of risk tolerance will hold more liquid assets than the level required by prudential regulations (LCR). To assess how the level of risk tolerance affects the bank's decision regarding liquidity risk, I add a term ($\xi_D \sigma_D$) to the level of high-quality liquid assets (HQLA) held by the bank as well as to the level of bank's reserves at the central bank. The higher the value of the $\xi_D \sigma_D$ term, the higher the bank's risk aversion regarding liquidity risk. Therefore, the bank decides to hold at t0 a level of HQLA as follows[4]:

$$(1 - h_{LCR})(1 - \eta_0) S_0 = \lambda \theta_D (25\% + \xi_D \sigma_D) D_0 + 25\% \lambda \theta_F F_0 - r_{MRR}(1 + \xi_D \sigma_D) D_0 \quad (5)$$

The level of reserves held with the central bank is:

$$Res_0 = (1 + \xi_D \sigma_D) D_0 \quad (6)$$

At t1, the bank's balance sheet identity changes to:

$$S_0 + Res_1 + L + B = E_L + E_B + (1 - x) D_0 + CB_0 + F_0 + CB_1 \quad (7)$$

[2] As I study the banks' behavior regarding supplying funds in the interbank market, I do not include the possibility of borrowing from the interbank market. The model can be extended easily to allow banks to borrow from the interbank market.

[3] I assume that banks receive payments from loans (L) only at t2.

[4] If the level of bank's inflow is high enough, the inflows are capped at 75% outflows and the denominator becomes 25% outflows.

where $Res_1 = r_{MRR}(1-x)D_0$.

At t1, the bank is confronted with a liquidity need due to deposit withdrawals[5]. If the bank borrows from the central bank (CB_1) to obtain additional funds, it has to pledge part of its government securities portfolio as collateral. The maximum amount a bank can receive from the central bank is $(1-h_{CB})(1-\eta_0)S_0$, where h_{CB} is the haircut the central bank applies to its lending operations and η_0 is the rate of encumbered assets at t0[6]. However, the bank has to comply with liquidity regulation (LCR) at t2. If it uses the entire portfolio of unencumbered government securities, it will pay a penalty fee. The bank might hold a larger amount of government securities to avoid this if it fears such a scenario (in the model, this is captured by a higher $\xi_D \sigma_D$ term).

When a liquidity shock occurs, the bank will first use the existing resources like excess reserves at the central bank and the additional portfolio of government securities it can pledge as collateral at the central bank. If the bank has higher liquidity needs ($x > lim_1$), it can use the reserves from the minimum reserve requirements but at the cost of having to pay a penalty fee at the end of the MRR maintenance period. If the shock is even bigger ($lim_1 > x > lim_2$), the bank can use its government securities portfolio held for the LCR regulation to request additional funding from the central bank at a higher interest rate ($r_{Lombard}$) and taking into account the central bank haircut rate (h_{CB})[7]. If the shock is higher than the bank's liquidity buffer ($x > lim_3$), it will default. If a bank experiences such a shock, the central bank will not allow the bank to borrow at the Lombard rate, and the bank is liquidated.

The bank decides to lend at t0 a volume B in the interbank market that will maximize the expected profit conditional on fulfilling the prudential requirements[8].

$$\begin{aligned}\Pi_{t2} = {} & (r_f - \tau)S_0 + r_L(1 - pd_L lgd_L)L + r_B(1 - pd_B lgd_B)B - dE_L - dE_B \\ & - r_{CB}CB_0 - r_F F_0 - r_D\left(1 - \int_0^1 xg(x)dx\right)D_0 \\ & - \int_0^1 r_{CB}CB_1(x)g(x)dx \\ & - \int_{lim_1}^1 r_{pMRR}\eta_{1,res}(x)Res_1(x)g(x)dx \\ & - \int_{lim_2}^{lim_3} r_{Lombard}\eta_{1,s}(x)(1-h_{CB})S_1(x)g(x)dx \\ & - \int_{lim_3}^1 Cost_{default}(x)g(x)dx\end{aligned} \tag{8}$$

where τ is the cost of holding government securities, similar to Kashyap et al. (2002), g(x) is the probability distribution function of the liquidity shock.

[5] If the F_0 funding is provided by the parent bank or the banking group of the bank and it is not obtained directly from the market, the bank will most probably not consider shocks on this type of funding when deciding the amount of lending it will offer in the interbank market. This assumption is more appropriate for Central Eastern European countries like Romania. The model can be extended to include shocks on market funding.

[6] The bank used at t0 a part η_0 of its government securities portfolio to obtain CB_0 finance from the central bank.

[7] While the haircut rate for the government securities portfolio is $h_{LCR}=0$ in the LCR regulation, the ECB haircut is different from 0.

[8] See the Appendix for a detailed solution of the model and the descriptions of limits.

The different shock limits are as follows:

- *no-penalty limit:*

$$lim_1 = \frac{\xi_D \sigma_D \left(r_{MRR} + \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} \right)}{1 - r_{MRR} - 25\% \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} + r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}}} \quad (9)$$

- *no default with penalty limit:*

$$lim_2 = \frac{\xi_D \sigma_D \left(r_{MRR} + \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} \right) + r_{MRR}}{1 - 25\% \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} + r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}}} \quad (10)$$

- *default limit:*

$$\begin{aligned} lim_3 = {} & \xi_D \sigma_D \left(r_{MRR} + \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} \right) + r_{MRR} \\ & - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} + 25\% \lambda \theta_D \frac{1-h_{CB}}{1-h_{LCR}} \\ & + 25\% \lambda \theta_F \frac{1-h_{CB}}{1-h_{LCR}} \frac{F_0}{D_0} \end{aligned} \quad (11)$$

The optimal level of a bank's interbank lending results from solving the following nonlinear equation:

$$\begin{aligned} \frac{\partial \Pi_{t2}}{\partial B} = 0 \iff {} & \gamma_0 (1 - pd_B lgd_B) - \gamma_1 (1 - pd_B lgd_B) B - d\kappa w_B - r_F \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \\ & + 25\% \left[(r_f - \tau) - r_{CB} \eta_0 (1 - h_{CB}) \right] \frac{\lambda \theta_F}{(1-h_{LCR})(1-\eta_0)} \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \\ & - 25\% r_{Lombard} (1 \\ & - h_{CB}) S_1(lim_3) g(lim_3) \lambda \theta_F \frac{1-h_{CB}}{1-h_{LCR}} \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \frac{1}{D_0} = 0 \end{aligned} \quad (12)$$

where $b_0 = \frac{\lambda \theta_F}{(1-h_{LCR})(1-\eta_0)}$ and $e_0 = \eta_0 (1 - h_{CB})$.

The model shows that the optimal volume of lending supply in the interbank market (B) for a bank depends on three factors (equation 12). First, it varies with the spread the bank earns in the interbank market relative to the costs of funds from the financial market (including the additional capital required by the prudential authority for the interbank exposure). Second, it is determined, but to a lesser degree, by the return on the government securities portfolio after subtracting the cost of central bank funding the bank needs at t0. Third, the optimal lending supply depends on the cost incurred on additional funding if the liquidity shock is near the bank's default limit[9]. The default limit (lim_3) is the level of the maximum liquidity shock that the bank can withstand without entering default, although at a cost[10].

[9] A fourth factor can be added if we consider the cost of entering default to be proportional to the level of interbank lending.

[10] If the liquidity shock is near the default limit, the bank will use all of its reserves held at the central bank and almost the entire portfolio of government securities to obtain funding from the central bank at a higher interest rate (Lombard rate).

Table 1. Model parameters

Parameter	Value	Description	Source
		Prudential regulation	
λ	1	LCR weight on stable retail deposits	EBA
κ	0.08	minimum capital requirement	EBA
w_L	0.45	risk weight for loans to real sector	EBA
w_B	0.2	risk weight for interbank loans	EBA
h_{CB}	0.014	central bank haircut	ECB
h_{LCR}	0	LCR haircut on hig-quality liquid assets	ECB
θ_D	0.05	LCR weight on stable retail deposits	EBA
θ_F	1	LCR weight on wholesale funding	EBA
r_{MRR}	0.01	minimum reserve requirement rate	ECB
p_{MRR}	0.0475	minimum reserve requirement penalty fee	ECB
		Interest rates and cost of funding	
r_{CB}	0.03	central bank interest rate	ECB
$r_{Lombard}$	0.035	central bank interest rate on marginal lending facility	ECB
r_f	0.026	government bond yield	ECB
r_L	0.025	interest rate on loans to real sector	ECB
r_d	0.007	interest rate on deposits from real sector	ECB
r_F	0.030	interest rate on wholesale funding	ECB
d	0.01	composite cost of banks' capital	ECB
γ_0	0.035	interbank interest rate parameter	
γ_1	0.001	interbank interest rate parameter	
		Banks' additional parameters	
η_0	0.2	rate of encumbered assets at t_0	
τ	0.0045	cost of holding government securities	Kashyap et al. (2002)
ξ_D	1	risk aversion parameter	
σ_D	0.01	risk aversion parameter	
p_B	0.035	probability of default on interbank loans	
l_B	0.45	loss given default on interbank loans	
p_L	0.055	probability of default on loans to real sector	
l_L	0.45	loss given default on loans to real sector	

Source: EBA, ECB, Kashyap et al. (2002), authors' own research.

To understand how the default limit changes, I rewrite equation 11 in terms of the bank's risk aversion toward liquidity risk ($\xi_D \sigma_D$) and the bank's structural liquidity condition (L/D_0):

$$\begin{aligned} lim_3 = \; & r_{MRR}\frac{h_{CB}-h_{LCR}}{1-h_{LCR}} + 25\%\lambda\frac{1-h_{CB}}{1-h_{LCR}}\left\{\theta_D + \theta_F\frac{a_0^* + c_0^* - e_0 a_0^* - 1}{1-b_0+e_0 b_0}\right\} \\ & + \xi_D\sigma_D\left(r_{MRR}\frac{h_{CB}-h_{LCR}}{1-h_{LCR}} + \lambda\theta_D\frac{1-h_{CB}}{1-h_{LCR}} + 25\%\lambda\theta_F r_{MRR}\frac{1-h_{CB}}{1-h_{LCR}}\right. \\ & \left. + 25\%\lambda^2\theta_D\theta_F\frac{1-h_{CB}}{1-h_{LCR}}\frac{1-e_0}{1-b_0+e_0 b_0}\right) \\ & + 25\%\lambda\theta_F\frac{1-h_{CB}}{1-h_{LCR}}\frac{1-\kappa w_L}{1-b_0+e_0 b_0}\frac{L}{D_0} \\ & + 25\%\lambda\theta_F\frac{1-h_{CB}}{1-h_{LCR}}\frac{1-\kappa w_B}{1-b_0+e_0 b_0}\frac{B}{D_0} \end{aligned} \quad (13)$$

The default limit increases with the structural liquidity position (the L/D_0 term) and with the interbank lending (the B/D_0 term)[11]. Both terms result from the LCR requirements on market funding. The default limit also expands with the level of banks' risk aversion. The LCR requirements add to the contribution of this term as well. Therefore, the stricter the LCR requirements on deposits (θ_D) and market funding (θ_F), the higher the bank's default limit.

These results are somewhat similar to the ones obtained by Acharya and Skeie (2011) in that the level of the funds supplied to the interbank market depends on lender bank risk. There are a few differences. First, this model includes the bank's perception of risk. Banks with higher risk aversion will be less willing to lend in the interbank market and prefer hoarding liquidity. Second, the model takes into account liquidity regulation (LCR). Banks with structural liquidity deficits will face higher funding costs and tighter requirements regarding high-quality liquid assets and will be less able to provide liquidity in the interbank market.

I calibrate the model using the eurozone data for risk parameters and the European Union's prudential regulation for parameters on prudential requirements. The description of the parameters, the values used and the data sources, where available, are presented in Table 1.

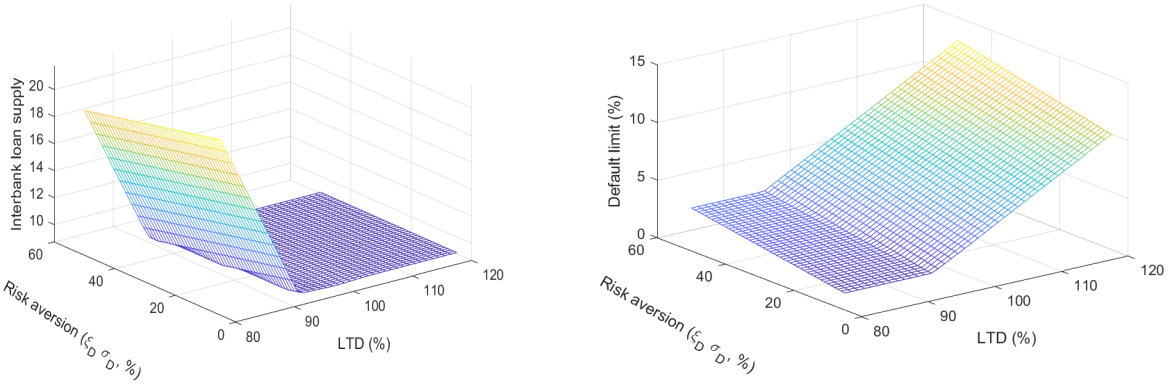
Results and discussions

During normal times, banks supply loans in the interbank market to other banks. The volume of loans varies not only with financial conditions but also with lenders' level of risks and perception of risks. In this section, I discuss only the last two types of factors. For the first one, please take a look at the previous section. The results on the optimal level of banks' loan supply in the interbank market for different levels of banks' structural liquidity and risk aversion are presented in Figure 1 (a).

As expected, the banks with higher structural liquidity surplus lend more in the interbank market. However, these banks are more prone to liquidity risk as they face lower prudential requirements on liquidity buffers. The Liquidity Coverage Ratio (LCR) measure is intended to increase banks' resilience to shocks while preserving their ability to provide liquidity to the economy. This objective is obtained by requiring banks to hold high-quality liquid assets (HQLA) sufficient enough to allow them to fund net outflows for 30 days under a liquidity stress scenario. The LCR measure allows banks to subtract the value of estimated credit inflows from the estimated outflows (equation 4). If these inflows are large enough, the LCR denominator will shrink to 25% of possible outflows over 30 days (equation 5) and, thus, the required liquidity buffers will be

[11] The contribution of the LTD term is the most important as $1-\kappa w_{LL} > 1-\kappa w_{BB}$.

lower. If a shock occurs before the bank receives the expected inflows, it will face higher difficulties covering the additional liquidity needs. Therefore, a bank with a similar deposit withdrawal risk but without significant interbank lending or other inflows has a stricter HQLA requirement (due to a higher denominator value - equation 4) than a bank with a significant volume of lending in the interbank market. The latter has a lower default limit - Figure 1 (b). This LCR measure limitation is also briefly discussed by De Haan and van den End (2013) using empirical data on the Netherlands' banking sector. The authors also find that banks must hold lower liquid buffers while recording higher cash inflows. However, these banks tend to act more prudently than required and do not reduce the level of their high-quality liquid assets with the entire amount allowed by the LCR measure.



(a) Banks' loan supply in the interbank market

(b) Banks' default limit

Figure 1. The banks' lending supply in the interbank market and default limit given the structural liquidity ($\frac{L}{D_0}$, LTD) and the level of risk aversion ($\xi_D \sigma_D$)

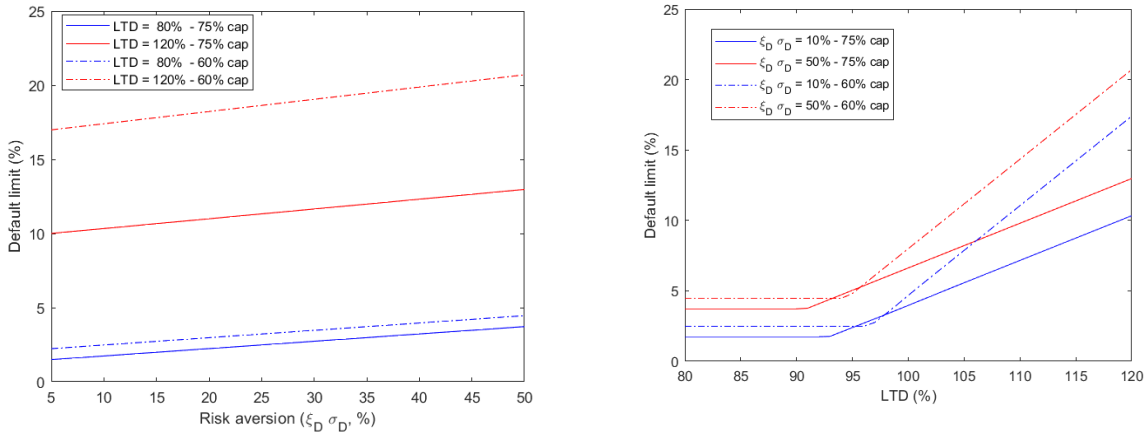
Source: Authors' own research.

Contrary to the more traditional business model presented above, the banks with high structural liquidity deficit must hold more considerable levels of HQLA as they widely use market funding. Suppose these banks receive funds from their parents and not directly from the market and thus are less prone to funding risk. In that case, they can provide liquidity in the interbank market (thanks to additional finance provided by the parent banks) and have higher default limits - Figure 1 (b).

To understand the differences in LCR requirements for the two types of banks' business models, I present an example of the HQLA calculation. First, for a bank with a structural liquidity surplus that does not use market funding (the first business model type) but lends in the interbank market so that the 75% cap on inflows applies, the HQLA requirement will be $25\%\theta_D D_0$. If we look only at retail deposits, $\theta_D = 5\%$ - banks should be able to withstand a 5% withdrawal rate on deposits. Nevertheless, the LCR requirement is to hold liquidity buffers in the amount of $25\%\theta_D D_0 = 1.25\%D_0$. For the banks with the second business model type, considering that the 75% cap also applies, the HQLA requirement will be $25\%\theta_D D_0 + 25\%\theta_F F_0 = 1.25\%D_0 + 25\%F_0$, where $\theta_F = 1$.

Increasing the cap on cash inflows will improve all banks' resilience to a liquidity shock for all banks. Still, the effect will be strongly asymmetric, with only an incremental strengthening

of the default limit for banks with a more traditional business model and a substantial upward change for banks using market funding (the second business model type). Continuing the above example, lowering the cap from 75% to 60%, the HQLA requirements will be $40\%\theta_D D_0 = 2\%D_0$ $(+0.75\%D_0)$ for banks with the first type of business models and $40\%\theta_D D_0 + 40\%\theta_F F_0 = 2\%D_0 + 40\%F_0$ $(+0.75\%D_0 + 15\%F_0)$ for banks part of a banking group that receive funds from their parent, the second type of business model - Figure 2[12]. Therefore, reducing the cap limit might not produce the needed effect of improving the resilience of banks with the more traditional business model. It might even negatively affect other banks by reducing their ability to lend to the real sector.



(a) The impact for different banks' business model

(b) The impact for different banks' risk aversion $(\xi_D \sigma_D)$

Figure 2. The impact of a lower cap for cash inflows (continuous lines for 75% cap, dashed lines for 60%cap) on bank's default limit (the maximum liquidity shock the banks can withstand without entering default) given the structural liquidity ($\frac{L}{D_0}$, LTD) and the level of risk aversion ($\xi_D \sigma_D$)

Source: Authors' own research.

These results imply that the LCR measure might be more advantageous for banks such as subsidiaries financed through parent banks' funding. For this business model, which we frequently find in emerging markets (including Romania), the LCR measure fosters these banks' resilience to liquidity shocks due to tighter requirements on market funding. Still, it might encourage them to overlook contagion risk from parent and parent banks' economies, especially under favorable financial conditions. If the portfolio of government securities and interbank loans pay a meaningful margin over the cost of their funding, this business model is also profitable and quick to implement without the need for substantial deposits collected to finance the lending activity. Therefore, prudential authorities should complement the LCR measure with other instruments (like liquidity stress test) that better assess banks' liquidity risk due to maturity mismatch.

Another factor determining the volume of loans supplied in the interbank market is the bank's level of risk aversion. The banks can act more prudently and hold higher liquidity buffers than the level required by the LCR regulation. Banks can, therefore, mitigate the reduced LCR effectiveness in the case of structural liquidity surplus by holding a higher level of HQLA. These

[12] In the calculations and Figure 2 (a) I considered the banks with a more traditional business model, the ones with L/D=80% and the ones reliant on parent banks' finance, the banks with L/D=120%.

banks will maintain a higher no-penalty limit (the maximum liquidity shock the bank can accommodate without a penalty fee) and an increased default threshold. In the example presented in Figure 2 (a), for a bank using a more traditional business model, the default limit more than doubles: from 1.5% (low-risk aversion) to 3.7% (high-risk aversion).

Conclusion and further extension of the model

I construct a partial equilibrium model to examine the banks' ability and willingness to provide liquidity in the interbank market. The model assesses the banks' decision to lend in the interbank market by maximizing their profit subject to the balance sheet and prudential regulation constraints.

The model shows that the optimal volume of interbank lending depends on the market financial conditions (the spread on interbank lending compared to the cost of different funding sources and the return on government securities after subtracting the cost of funding from the central bank) and the cost incurred on additional funding if the liquidity shock is near the bank's default limit. The latter depends on the banks' risks and perception of risks.

The model shows differences in the LCR effectiveness for two types of banks' business models. First, for the more traditional one (with structural liquidity surplus, L/D < 100%), the LCR measure enables banks to lend more in the interbank market (by letting them subtract possible cash inflows from the expected outflows under a liquidity stress scenario) but at the cost of allowing them to maintain lower default limits (thresholds on the maximum liquidity shock the banks can withstand without entering default). Second, banks with structural liquidity deficits that need other funding sources than retail deposits (L/D > 100%), like subsidiaries that receive finance from their parent banks, face tighter requirements on high-quality liquid assets (HQLA), keep higher default limits and lend less in the interbank market. For this business model, often seen in emerging markets, including Romania, the LCR measure fosters banks' resilience to liquidity shocks. However, this LCR functionality might encourage them to overlook contagion risk from their parent and parent banks' economies, especially under favorable financial conditions.

Prudential authorities should complement the LCR measure with other instruments (like liquidity stress test) that better assess banks' liquidity risk due to maturity mismatch. Banks' liquidity risk management can partially mitigate the differences in LCR effectiveness through precautionary holdings of additional liquidity buffers. Banks with higher risk aversion prefer maintaining a higher no-penalty limit (the maximum liquidity shock the bank can accommodate without a penalty fee) and an increased default threshold and are less willing to lend in the interbank market.

The model can be extended by adding the banks' decisions on providing liquidity to the real sector through credit lines. This will broaden the analysis of banks' behavior as liquidity providers to the economy and the implications of the existing prudential regulation on liquidity risk.

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Appendix

If the bank uses market funding for its needs ($F_0 \geq 0$) the balance sheet identity is:

$$S_0 + Res_0 + L + B = E_L + E_B + D_0 + CB_0 + F_0 \quad (14)$$

Under the condition that $inflows > 75\%\,\theta_D D_0 + 75\%\theta_F F_0$ the bank will hold government assets:

$$S_0 = \frac{\lambda\theta_D(25\% + \xi_D\sigma_D)}{(1-h_{LCR})(1-\eta_0)}D_0 + \frac{25\%\lambda\theta_F}{(1-h_{LCR})(1-\eta_0)}F_0 - \frac{r_{MRR}(1+\xi_D\sigma_D)}{(1-h_{LCR})(1-\eta_0)}D_0 \quad (15)$$

To simplify the above equation, I add some notations such as $S_0 = a_0 D_0 + b_0 F_0$.

The central bank funding is:

$$CB_0 = \eta_0(1-h_{CB})S_0 \quad (16)$$

After the liquidity shock, the bank's balance sheet identity is:

$$S_0 + Res_1 + L + B = E_L + E_B + (1-x)D_0 + CB_0 + F_0 + CB_1 \quad (17)$$

As the inflows from the interbank market were higher than the expected outflows before the shock, they will also be higher than the anticipated outflows after the shock.

The required minimum level of government securities portfolio is:

$$S_1 = \frac{\lambda\theta_D(1-x)}{1-h_{LCR}}D_0 + \frac{25\%\lambda\theta_F}{1-h_{LCR}}F_0 - \frac{r_{MRR}(1-x)}{1-h_{LCR}}D_0 \quad (18)$$

The additional unencumbered government securities portfolio is:

$$\begin{aligned} S_{extra} &= (1-\eta_0)S_0 - S_1 \\ &= x\frac{25\%\lambda\theta_D}{1-h_{LCR}}D_0 - x\frac{r_{MRR}}{1-h_{LCR}}D_0 + \frac{\lambda\theta_D\xi_D\sigma_D}{1-h_{LCR}}D_0 - \frac{r_{MRR}\xi_D\sigma_D}{1-h_{LCR}}D_0 \end{aligned} \quad (19)$$

The bank will be able to pay depositors with ease if:

$$x \leq lim_1 = \frac{\xi_D\sigma_D\left(r_{MRR} + \lambda\theta_D\frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR}\frac{1-h_{CB}}{1-h_{LCR}}\right)}{1 - r_{MRR} - 25\%\lambda\theta_D\frac{1-h_{CB}}{1-h_{LCR}} + r_{MRR}\frac{1-h_{CB}}{1-h_{LCR}}} \quad (20)$$

Suppose the bank needs additional funding after a liquidity shock. In that case, if the withdrawal rate is below a certain limit (described above), it can use the available unencumbered portfolio of government securities to obtain central bank finance:

$$CB_1 = [x(1-r_{MRR}) - r_{MRR}\xi_D\sigma_D]D_0 \quad (21)$$

The bank will be able to solve a liquidity shock larger than lim1 using its reserves at the central bank, but at an additional cost (the penalty cost of not fulfilling the minimum reserve requirements and the LCR requirements):

$$x \le lim_2 = \frac{\xi_D \sigma_D \left(r_{MRR} + \lambda\theta_D \frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} \right) + r_{MRR}}{1 - 25\%\lambda\theta_D \frac{1-h_{CB}}{1-h_{LCR}} + r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}}} \quad (22)$$

If the shock is even larger than $\lim_2$, the bank can recourse to its government securities portfolio to obtain additional funding from the central bank at the Lombard rate:

$$\begin{aligned} x \le lim_3 = {} & \xi_D \sigma_D \left(r_{MRR} + \lambda\theta_D \frac{1-h_{CB}}{1-h_{LCR}} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} \right) \\ & + r_{MRR} - r_{MRR} \frac{1-h_{CB}}{1-h_{LCR}} + 25\%\lambda\theta_D \frac{1-h_{CB}}{1-h_{LCR}} \\ & + 25\%\lambda\theta_F \frac{1-h_{CB}}{1-h_{LCR}} \frac{F_0}{D_0} \end{aligned} \quad (23)$$

If the shock is larger than $\lim_3$, the bank will default.

The bank will choose the level of interbank lending that will maximize its profit at t2:

$$\begin{aligned} \Pi_{t2} = {} & (r_f - \tau) S_0 + r_L (1 - pd_L lgd_L) L + r_B (1 - pd_B lgd_B) B - dE_L - dE_B \\ & - r_{CB} CB_0 - r_F F_0 - r_D \left(1 - \int_0^1 xg(x)dx \right) D_0 \\ & - \int_0^1 r_{CB} CB_1(x) g(x) dx \\ & - \int_{lim_1}^1 r_{pMRR} \eta_{1,res}(x) Res_1(x) g(x) dx \\ & - \int_{lim_2}^{lim_3} r_{Lombard} \eta_{1,s}(x) (1 - h_{CB}) S_1(x) g(x) dx \\ & - \int_{lim_3}^1 Cost_{default}(x) g(x) dx \end{aligned} \quad (24)$$

where g(x) is the probability distribution function of the liquidity shock. The solution is obtained by solving the nonlinear equation on B:

$$\begin{aligned} \frac{\partial \Pi_{t2}}{\partial B} = 0 \iff {} & \gamma_0 (1 - pd_B lgd_B) - \gamma_1 (1 - pd_B lgd_B) B - d\kappa w_B - r_F \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \\ & + 25\% \left[(r_f - \tau) - r_{CB} \eta_0 (1 - h_{CB}) \right] \frac{\lambda\theta_F}{(1 - h_{LCR})(1 - \eta_0)} \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \\ & - 25\% r_{Lombard} (1 \\ & - h_{CB}) S_1(lim_3) g(lim_3) \lambda\theta_F \frac{1 - h_{CB}}{1 - h_{LCR}} \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \frac{1}{D_0} = 0 \end{aligned} \quad (25)$$

where

$$r_B = \gamma_0 - \gamma_1 B \iff \frac{\partial r_B}{\partial B} = -\gamma_1$$

$$\frac{\partial lim_3}{\partial B} = 25\% \lambda\theta_F \frac{1 - h_{CB}}{1 - h_{LCR}} \frac{1 - \kappa w_B}{1 - b_0 + e_0 b_0} \frac{1}{D_0}$$

The equation is nonlinear as g(x) depends on B. I use a numerical algorithm to solve for the optimal level of B. For g(x), I used the standard normal distribution function. I also tested the model using the log-normal distribution function for g(x). The results are similar.