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TI 14-018/IV/DSF 72

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# The Effects of Liquidity Regulation on Bank Assets and Liabilities

**Patty Duijm* and Peter Wierts†‡**

ABSTRACT

Under Basel III rules, banks become subject to a liquidity coverage ratio (LCR) from 2015 onwards, to promote short-term resilience. We investigate the effects of such liquidity regulation on bank liquid assets and liabilities. Results indicate co-integration of liquid assets and liabilities, to maintain a minimum short-term liquidity buffer. Still, microprudential regulation has not prevented an aggregate liquidity cycle characterised by a pro-cyclical pattern in the size of balance sheets and risk taking. Our error correction regressions indicate that adjustment in the liquidity ratio is balanced towards the liability side, especially when the liquidity ratio is below its long-term equilibrium. This finding contrasts established wisdom that the LCR is mainly driven by changes in liquid assets. Policy implications focus on the need to complement microprudential regulation with a macroprudential approach. This involves monitoring of aggregate liquid assets and liabilities and addressing pro-cyclical behaviour by restricting leverage.

JEL codes: E44, G21, G28.

Keywords: market liquidity, funding liquidity, liquidity regulation, liquidity coverage ratio, Basel III, banks, microprudential, macroprudential, co-integration, error correction models.

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‡ We thank, without implicating them, Clemens Bonner, Jan Willem van den End, Leo de Haan, Willem Heeringa, Aerdt Houben, Patrick de Neef, Dirk Schoenmaker, Jan Willem Slingenberg, and Robert Vermeulen for their helpful comments. The usual disclaimer applies.

## 1. Introduction

The Basel Committee on Banking Supervision (BCBS) plans to introduce a Liquidity Coverage Ratio (LCR) from 2015 onwards. The LCR requires banks to hold a sufficient level of high quality liquid assets against expected net liquid outflows over a 30-day stress period. The introduction of the LCR is seen as one of the key reforms to promote a more resilient banking sector. The objective is to 'promote the short-term resilience of the liquidity risk profile of banks' (BCBS, 2009, p. 1).

The introduction of the LCR has prompted increasing interest in the effects of liquidity regulation on bank behaviour. Several studies focus on the effects on banks' liquid assets. However, given that the LCR is defined as a ratio, banks can increase their liquid assets and/or decrease their expected liquid outflows in order to improve the ratio. An innovative element in our study is that we let the data determine the direction of causality. Formally, we argue that liquid assets and liabilities should be co-integrated. We test for this using a unique database for Dutch banks, which have been subject to liquidity regulation that is comparable to the Basel III's LCR since 2003. We can systematically track liquid assets, liabilities, and their ratio, both during periods of upswing and downswing of the financial cycle. Findings indicate co-integration with bank-specific long-run equilibriums.

Our results show that minimum microprudential LCR ratios have generally been adhered to. In this respect the rules can be seen as effective. At the same time, results also indicate a pro-cyclical pattern in liquid assets and liabilities: in good times balance sheets expand due to increases in liquid assets and liabilities (and vice versa). We confirm previous evidence for the US on the role of secured wholesale funding in driving these changes in balance sheet size. As a ratio, the LCR does not limit such shifts since they affect both the numerator and the denominator.

Moreover, we find evidence of pro-cyclical risk-taking over the financial cycle. Liquidity buffers decrease in good times and increase in bad times. Liquidity buffers in the system are at their lowest point at the start of the crisis, exactly when they are needed the most. In line with this pro-cyclical pattern in risk taking over the financial cycle, our error correction regressions indicate that adjustment in the LCR is balanced towards the liability side. During increased risk-taking, 'cheaper' short-term wholesale funding (with a high run-off rate in the denominator of the LCR) is used to finance riskier and more profitable liquid assets (with a lower liquidity weight in the numerator), so that the LCR deteriorates (and vice versa). This finding contrasts existing literature that has mainly focused on the effect of the LCR on liquid assets. Results indicate that restricting leverage may be crucial in addressing the liquidity cycle with respect to short-term assets and funding.

The rest of this paper is organized as follows. Section 2 briefly summarises related literature. Section 3 presents our conceptual framework. Section 4 takes a first look at the data. Section 5 provides the estimation results. Section 6 discusses policy implications and concludes.

## 2. Literature Review

Banks typically transform short-term liabilities into longer-term illiquid assets. Given that selling illiquid assets is costly, banks have an incentive to self-insure against unexpected liability outflows by maintaining a stock of liquid assets. However, liquid assets generally generate a lower return than less liquid assets. By implication, banks will trade-off risk reduction against reduction in return.

Several market failures explain why banks may hold insufficient liquidity buffers from a social perspective. The underlying market failures provide the rationale for liquidity regulation. First, liquidity buffers make bank runs less likely. Thereby, they decrease the probability of negative externalities for the financial system as a whole (Kowalik, 2013). Second, liquidity buffers decrease the probability of fire sales, deleveraging, liquidity hoarding and restriction of credit (Van den End and Kruidhof, 2013). These elements create negative externalities due to their effects on asset prices and the availability of funding. Third, market liquidity and funding liquidity can be mutually reinforcing, leading to liquidity spirals (Brunnermeier and Pedersen, 2009). Finally, the possibility of liquidity provision by central banks may create moral hazard on the side of banks (Farhi and Tirole, 2009). Liquidity buffers then increase the time before a bank will call on the central bank. At times of liquidity stress, liquidity buffers give time to management and supervisors to find solutions to their liquidity needs (BCBS, 2010). Therefore, a key part of the new Basel III regulation is the introduction of the Liquidity Coverage Ratio (LCR). By requiring banks to hold high quality liquid assets at least equal to their expected net cash outflows over a 30-day stress period, the LCR seeks to ensure that banks are able to withstand a 30-day stress scenario without any intervention by other parties. The prospect of internationally harmonised liquidity requirements has directed attention in the academic literature towards their effect on bank behaviour.[1]

Next to the LCR, the Net Stable Funding Ratio (NSFR) is part of the proposals of the Basel Committee. The NSFR addresses the mismatches between the maturity of a bank's assets and that of its liabilities. The focus of this paper is however on (very) short-term resilience instead of maturity mismatch as discussed in other papers (e.g. Perotti and Suarez, 2011).

Bonner et al. (2013) investigate whether liquidity regulation substitutes or complements bank incentives to hold liquid assets. Using data from 30 OECD countries, their findings suggest that liquidity regulation substitutes bank incentives to hold high liquid assets. De Haan and Van den End (2013b) study banks' responses to negative funding liquidity shocks, using data for Dutch banks. Using a panel Vector Autoregression (p-VAR) approach, they find that in response to negative funding liquidity shocks, Dutch banks reduce wholesale lending, hoard liquidity in the form of liquid bonds and central bank reserves, and conduct fire sales of securities, especially equities.[2] In another study, De Haan and Van den End (2013a) examine the liquidity management of Dutch banks. They model the stock of liquid assets as a function of the stock of liquid liabilities and the future cash inflows and outflows. A key finding is that banks keep liquid assets as a buffer against both the stock of liquid liabilities and against net cash outflows. Using data on U.S. commercial banks, Berrospide (2012) studies the behaviour of banks' liquid assets as a function of banks' size, their capital ratio, their unused commitment ratio and their share of core deposits (as a proxy for the role of stable sources of funding). The author finds that stable sources of funding, such as deposits and bank capital, are key determinants of the holdings of liquid assets.

Overall, the econometric approach in these studies relies on the assumption that banks adjust liquid assets in response to shifts in their funding profile. More recently, Banerjee and Mio (2014, forthcoming) point to the effects of liquidity regulation on both assets and liabilities. In

[1] To save space, we focus only on studies based on econometric evidence, as their approach is closest to ours. In addition, there is a literature on the wider economic effects of liquidity regulation, which also focuses mainly on the asset side. Examples are King (2010), Perotti and Suarez (2010) and Wagner (2013). Other studies highlight that the LCR may provide incentives for increased reliance on central bank funding, among others EBA (2012), Ayadi et al. (2012) and Coeuré, (2013). Data as discussed in section 4 however indicate that the reliance on central bank funding is limited for the Dutch banks. Towards the end of the observation period, claims on the central bank increase markedly and outweigh reliance on central bank funding. This is consistent with the argument that The Netherlands were seen as a safe haven during the sovereign crisis of 2011-2012. A possible effect of liquidity regulation on central bank funding could therefore better be studied in countries where the reliance on central bank funding is higher.

[2] The authors suggest that the positive relation between equity holdings and secured funding could also reflect the use of equities in repos and securities lending transactions. When these activities are buoyant, banks' equity holdings are useful as collateral, while these become less useful when the secured funding market collapses.

their study on the implementation of liquidity regulation in the UK, they find that banks that became subject to the regulation significantly increased their share of high quality liquid assets. This increase was offset by an equally sized reduction in intra-financial assets. At the same time, banks also increased their share of domestic retail deposits, which was offset by a similar sized reduction in short-term wholesale funding and non-resident deposits.

Adrian and Shin (2010) analyse aggregate consequences of individual bank behaviour with respect to liquidity and leverage. During the upswing of the financial cycle, asset prices increase so that capital increases (and leverage falls[3]) in the absence of a behavioural response. Banks tend to actively manage their balance sheets and now have an incentive to use this 'excess capital'. They extend their balance sheet through borrowing and purchase of assets, so that capital falls (and leverage increases) back to its previous level. This translates into pro-cyclical patterns in the size of banks' balance sheets. For the US investment banks, the authors present evidence for the expansion and contraction of balance sheets via repos (i.e. using purchased securities as collateral for the cash borrowing). Moreover, given that the measured risk on these securities is low in good times, required economic capital falls, and behavioural responses may even lead to an increase in leverage in good times (and vice versa). Second round effects between shifts in balance sheets and asset prices may magnify these effects.

## 3. Conceptual framework

The LCR is defined as a ratio with the numerator representing the amount of 'High Quality Liquid Assets' (HQLA), such as central bank balances, cash reserves, and government bonds. The denominator presents the net cash outflow within 30 days, i.e. the difference between outgoing and incoming cash flows.

Hence, the LCR is defined as:

$$LCR = \frac{High\ Quality\ Liquid\ Assets}{Cash\ outflows - Cash\ inflows} \tag{1}$$

where the cash outflows are subject to prescribed 'run-off rates' and the cash inflows are subject to prescribed 'haircuts' in order to assign these items a liquidity weighting. The

[3] Here leverage is defined as the ratio of total assets over capital.

similarity between Basel III and the existing Dutch supervisory framework makes it possible to construct a measure for the LCR; the Dutch Liquidity Coverage Ratio (DLCR).

This method is in line with previous studies (e.g. Bonner, 2012; De Haan and Van den End, 2013a) and the DLCR is defined as:

$$DLCR_t = \frac{AL_{it}}{RL_{it}} = \frac{\sum_j a_j \cdot Asset_{ijt} + \sum_k b_k \cdot Inflow_{ikt}}{\sum_l c_l \cdot Liability_{ilt} + \sum_m d_m \cdot Outflow_{imt}} \tag{2}$$

where $AL_{it}$ and $RL_{it}$ stand for, respectively, available liquidity and required liquidity of bank $i$ at time $t$.[i] The variables $a_j$, $b_k$, $c_l$, and $d_m$ represent the respective regulatory weights for respectively the various assets $j$, cash inflows $k$, liabilities $l$, and cash outflows $m$. Hence, available liquidity is defined as the weighted stock of liquid assets plus the weighted cash inflows scheduled within the coming month. The liquidity weight on assets is defined as 100 minus the haircut. These haircuts are determined by the supervisor and aim to reflect lack of market liquidity in times of stress. Required liquidity is defined as the weighted stock of liquid liabilities plus the weighted cash outflows scheduled within the coming month. The liquidity weight on liabilities is defined as the run-off rate. These run-off rates aim to reflect the probability of withdrawal and hence the funding liquidity risk.

As one can see, the LCR and the DLCR are built on the same regulatory philosophy and are therefore very similar. The main differences are the regulatory weights. In particular, the definition of the stock of high-quality liquid assets is more narrowly defined for the LCR than for the DLCR. For the latter, the haircuts and run-off rates were determined by the Dutch regulator for the first time under the 'Liquidity Regulation under the Wft' in January 2003.[4] There has been one structural change during the period under consideration. In May 2011, the Dutch Central Bank supplemented its existing rules with the 'Liquidity Regulation under the Wft 2011'.[5] In part, the changes anticipate on the new international rules, related to the Basel III requirements.

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[4] For reasons of space, the haircuts and run-off rates are not presented in tables, but are available at: http://www.toezicht.dnb.nl/4/4/2/50-204136.jsp

[5] The main change is a narrower definition of liquid assets; the haircuts for debt instruments issued by credit institutions and other institutions (e.g. corporate bonds) have been increased due to the perceived illiquidity of these assets under stressed markets. At the same time, the run-off rate for demand deposits has been decreased to reflect their experienced stability during the crisis. Overall, the adjustments have led to more stringent liquidity standards.

Given the similarity between the Dutch regulatory framework and the Basel III regulation, we will use the DLCR to study the effects of liquidity regulation on bank behaviour. To comply with the DLCR banks manage their balance sheet so that their available liquidity is larger than or equal to their required liquidity. To reduce the probability of non-compliance due to shocks in their liquidity position, banks aim for a positive margin between actual liquidity and required liquidity. However, a high liquidity buffer above the regulatory minimum is costly as less liquid assets (e.g. corporate bonds) and less liquid liabilities (e.g. short-term wholesale funding) might be more profitable. As a result of these two opposing forces, we expect banks to aim for a stable long-term relationship between available and required liquidity.

**Figure 1. Stylized bank balance sheet**

| | Balance sheet | | |
|---|---|---|---|
| Liquid inflow → $\sum_k b_k \cdot Inflow_{ikt}$ | Liquid assets $\sum_j a_j \cdot Asset_{ijt}$ | Liquid liabilities $\sum_l c_l \cdot Liability_{ilt}$ | →Liquid outflow $\sum_m d_m \cdot Outflow_{imt}$ |
| | Other assets | Other liabilities | |

As both components of the DLCR belong to the same balance sheet (see figure 1) there should be a relation between actual liquidity and required liquidity. This relation defines their co-movement over time, although the causality is unknown ex ante. We expect this long-term relationship partly to be determined by bank-specific characteristics, such as its size (e.g. whether it is seen as 'too big to fail') and its business profile. In section 5, we formally test for this by determining whether the series are co-integrated with bank-specific equilibriums.

As indicated in the literature review, Adrian and Shin (2010) argue that increases in asset prices may lead to expansions in the amount of liquid assets and liabilities in the upturn of the financial cycle (and vice versa), which would influence the size of the balance sheet. Moreover, risk taking would increase in the upturn and decrease in the downturn of the financial cycle; this could be reflected in the buffer of liquid assets over liquid liabilities. Given that the DLCR is a ratio, banks have three policy options for adjusting their liquidity position to shocks such as those in asset prices; by a change in the portfolio allocation (available liquidity), a change in the funding mix (which defines required liquidity), or both. By applying an error correction model to co-integrated series, we can test for the direction of causality between liquid assets and liabilities, and for the speed of the adjustment mechanism.

## 4. Data

*4.1 A first look at the data*

The data result from the quantitative liquidity requirement that was introduced in The Netherlands in 2003. The dataset contains monthly data from the Dutch supervisory liquidity report and covers the period July 2003 until April 2013. The report includes detailed information on liquid assets and liquid liabilities at an individual bank level for all banks that are subject to the liquidity regulation. We use data for 59 banks for which reported data are complete for the whole period under consideration.[6]

Figure 2 shows the average level of the DLCR for all banks in the sample and its development over time. Unfortunately, the data do not include the run-up to the introduction of the liquidity regulation. This is a limitation of our study: we cannot make inferences on a possible level shift in liquid assets and liabilities due to the introduction of a binding liquidity ratio. We do however observe data around the regulatory changes of May 2011. Data show a fall in liquid assets, due to an increase in haircuts, that leads to a drop in the DLCR. This is followed by a gradual increase in the DLCR towards a similar level to that observed during October 2009-May 2011.

At the aggregate level, available liquidity always lies above required liquidity, so that the DLCR requirement is respected and minimum short-term liquidity buffers are maintained. As expected, available and required liquidity show strong co-movements. The pattern of balance sheet expansion and contraction over the financial cycle is also confirmed. Both series increase strongly in the run-up to the financial crisis, and then decrease during the crisis. These findings are however not reflected in the DLCR as they cancel out in the ratio. Moreover, the decrease in the DLCR in the upswing of the financial cycle suggests increased risk taking, while the opposite happens in the downswing.

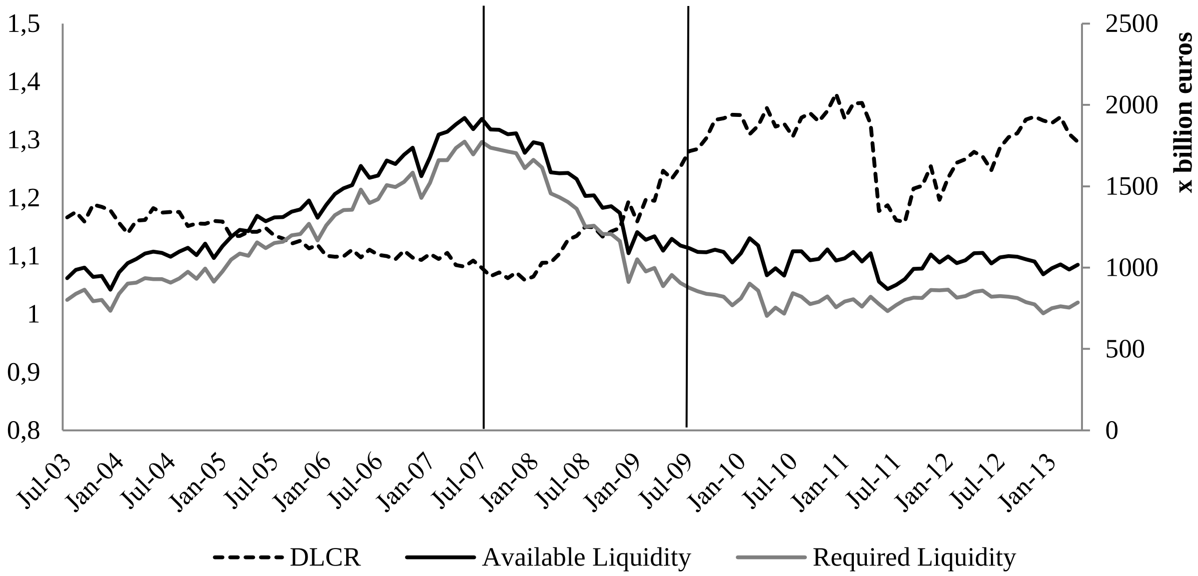
The data moreover contradict established wisdom that changes in liquid assets would be driving the liquidity ratio. On the contrary, the DLCR decreases in the run-up to the financial crisis while the amount of liquid assets increases. The DLCR then increases strongly during the crisis, while liquid assets fall. Finally, the data show that the liquidity crisis of 2007/08,

6 The underlying data are confidential; we only show aggregate results. Where we show estimation results for individual banks, we number them randomly so that results cannot be traced back to actual banks. Moreover, we only show estimation results and not underlying data.

characterised by a strong outflow of both liquid assets (decrease in available liquidity) and liabilities (decrease in required liquidity), is directly visible in the individual series, but not in the ratio.

**Figure 2. Dutch liquidity coverage ratio and its components**

The graph displays the aggregate level of liquidity of 59 Dutch banks for the period July 2003 until April 2013. The DLCR (left scale) is defined as the ratio of available liquidity over required liquidity. The available and required liquidity are given in billion euros (right scale) on a monthly basis.




*4.2 Balance sheet composition*

Tables A1.1 and A1.3 in Annex 1 provide an overview of the shifts in assets and liabilities, while Tables A1.2 and A1.4 show these amounts weighted by their liquidity value. That is, the series that are behind the observed movement in the DLCR, available liquidity and required liquidity. On the asset side, in particular secured wholesale lending, consisting of (reverse) repos and securities lending, declines strongly during the crisis. As secured wholesale lending is defined as highly liquid, it accounts for most of the decrease in available liquidity. On the liability side, the strongest decline is observed in secured wholesale funding, which mainly consists of repos. As the run-off rate on repos is high, the required liquidity decreases, and this confirms the role of secured funding as a vehicle for pro-cyclical balance sheet management. Moreover, over time, we observe a shift from wholesale funding towards retail demand deposits (with a low run-off rate).

## 5. Results

*5.1 Unit root tests and co-integration*

The long-run relationship between actual liquidity and required liquidity can only be estimated if the series are non-stationary and integrated of the same order. Given the expected heterogeneity in bank behaviour, we use a panel unit root test that allows for different individual fixed effects in the intercepts and slopes of the co-integration equation. Results are shown in Annex A.2.1. Out of the full sample of 59 banks, the series actual liquidity and required liquidity are both integrated at order one for 41 banks. Hence, we test for co-integration only for those banks. Ideally our dataset would have covered several financial cycles; however the fact that our dataset covers the upswing and downswing of at least one financial cycle (Figure 2) gives us some comfort. Results indeed strongly support co-integration and the existence of a long-run equilibrium that differs among banks. Details are in Annex A.2.2.

*5.2 Error Correction Model*

Given the finding of co-integration at the individual bank level, the long-run equilibrium relationship can be estimated by Fully Modified OLS (FMOLS) for heterogeneous co-integrated panels. The long-run equilibrium relationship between actual liquidity and required liquidity is given by:

$$AL_{i,t} = \alpha_i + \hat{\beta}^{AL}_{FMOLS} RL_{i,t} + \varepsilon_{i,t} \tag{3}$$

where $\hat{\beta}_{FMOLS}$ is the FMOLS estimator correcting for heterogeneity and serial correlation by adjusting the initial OLS estimator.[7]

The lagged residuals from equation (3) define the Error Correction Term (*ECT*) in the following vector error correction model:

$$\Delta AL_{i,t} = \alpha_i^{AL} + \rho^{AL} ECT^{AL}_{i,t-1} + \sum_{j}^{L} \gamma_{i,j} \Delta RL_{i,t-j} + u^{AL}_{i,t} \tag{4}$$

where $\Delta AL_{i,t}$ represents the level change of actual liquidity from time *t-1* to time *t*, and $\rho^{AL}$ represents the error correction speed of adjustment of actual liquidity. The same approach can

[7] $\hat{\beta}^{AL}_{FMOLS} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(AL_{it} - \overline{AL_\iota})(AL_{it} - \overline{AL_\iota})'\right]^{-1}\left[\sum_{i=1}^{N}\sum_{t=1}^{T}(AL_{it} - \overline{AL_\iota})\,(\widehat{AL^{+}_{it}} - T\hat{\Delta}^{+}_{\varepsilon u})\right]$

be applied for required liquidity.[8] To check for convergence to the long-run equilibrium the estimated speed of adjustment coefficient should show a negative sign. This so-called Engle and Granger (1987) two-step procedure is applied to make inferences about the direction of cauasality. Under this model, long-run causality is revealed by the statistical significance of the adjustment coefficient $\rho^{AL}$. The optimal lag order $L$ is chosen based on the Schwarz Information Criterion (SIC), and $u_{i,t}^{AL}$ is the error term.

The results in the first row of table 1 imply that when a bank moves away from its long-run average liquidity level the adjustment is balanced towards the liability side of the balance sheet. That is, as the liquidity buffer is above (below) average, banks increase (decrease) their required liquidity. The estimated coefficient of -0.22 indicates that, after a shock of the long-run equilibrium, about 22% of this disequilibrium is corrected within one month. Given that required liquidity is determined by the weighted liabilities and cash outflows, the results indicate that banks adjust their funding mix - and to a lesser extent their portfolio allocation - when their liquidity position has changed.

A drawback of this model is that it does not allow for an asymmetric adjustment, i.e. it does not distinguish situations in which the liquidity buffer is above and below average. Banks may need to adjust more strongly when their DLCR falls below its long-run equilibrium and approaches the regulatory minimum. To allow for this asymmetry two dummy variables are introduced:

$$I_{i,t}^{AL} = \begin{cases} 1 & if\ ECT_{i,t-1}^{AL} < 0 \\ 0 & if\ ECT_{i,t-1}^{AL} \geq 0 \end{cases} \qquad I_{i,t}^{RL} = \begin{cases} 1 & if\ ECT_{i,t-1}^{RL} \geq 0 \\ 0 & if\ ECT_{i,t-1}^{RL} < 0 \end{cases} \tag{5}$$

The asymmetric error correction model is estimated by:

$$\Delta AL_{i,t} = \alpha_i^{AL} + I_{i,t}^{AL}\rho_{below}^{AL}ECT_{i,t-1}^{AL} + (1 - I_{i,t}^{AL})\rho_{above}^{AL}ECT_{i,t-1}^{AL} + \sum_j^L \gamma_{i,j}\Delta RL_{i,t-j} + v_{i,t}^{AL} \tag{6}$$

$$\Delta RL_{i,t} = \alpha_i^{RL} + I_{i,t}^{RL}\rho_{below}^{RL}ECT_{i,t-1}^{RL} + (1 - I_{i,t}^{RL})\rho_{above}^{RL}ECT_{i,t-1}^{RL} + \sum_j^L \gamma_{i,j}\Delta AL_{i,t-j} + v_{i,t}^{RL} \tag{7}$$

where $\rho_{below}^{AL}(\rho_{above}^{AL})$ and $\rho_{below}^{RL}(\rho_{above}^{RL})$ represent the error correction speed of adjustment

8 Then Eq. (3) and (4) will be replaced by, respectively; $RL_{i,t} = \alpha_i + \hat{\beta}_{FMOLS}^{RL}AL_{i,t} + \varepsilon_{i,t}$ , where $\hat{\beta}_{FMOLS}^{RL} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}(RL_{it} - \overline{RL_\iota})(RL_{it} - \overline{RL_\iota})'\right]^{-1}\left[\sum_{i=1}^{N}\sum_{t=1}^{T}(RL_{it} - \overline{RL_\iota})\,\widehat{(RL_{\iota t}^{+}} - T\hat{\Delta}_{\varepsilon u}^{+})\right]$ and $\Delta RL_{i,t} = \alpha_i^{RL} + \rho^{RL}ECT_{i,t-1}^{RL} + \sum_j^L \gamma_{i,j}\Delta AL_{i,t-j} + u_{i,t}^{RL}$

coefficients given that a bank is below (above) its average liquidity level.

The results in the second row of Table 1 suggest that the adjustment on the liability side then becomes stronger. On average, 31% of the deviation from the long-run equilibrium is corrected within one month by a decrease in required liquidity. At the same time, adjustment on the asset side becomes slightly weaker and less significant. When shocks move the DLCR above its long-run equilibrium, banks decrease liquid assets and increase short-term liabilities. On average, shifts in liquid assets and liabilities both correct approximately 13-14% of the deviation from long-run equilibrium.

**Table 1: (Asymmetric) adjustment coefficients**

This table shows the error correction terms from the Generalized Least Squares (GLS) results for the (Threshold) Error Correction Model for 41 banks over the period July 2003-April 2013 (4.749 observations). The heteroskedasticity of the error terms is corrected by using white robust standard errors and the standard deviations are displayed in parentheses. Cross-section weights are used and *** denotes the 1% level.

| | **Dependent variable** | | | **Dependent variable** | | |
|---|---|---|---|---|---|---|
| Symmetric | ΔAL | $\boldsymbol{\rho^{AL}}$ | -0.098***<br>(0.011) | ΔRL | $\boldsymbol{\rho^{RL}}$ | -0.221***<br>(0.024) |
| Asymetric | ΔAL | $\boldsymbol{\rho^{AL}_{\mathbf{below}}}$ | -0.059**<br>(0.022) | ΔRL | $\boldsymbol{\rho^{RL}_{\mathbf{below}}}$ | -0.314***<br>(0.026) |
| | ΔAL | $\boldsymbol{\rho^{AL}_{\mathbf{above}}}$ | -0.129***<br>(0.021) | ΔRL | $\boldsymbol{\rho^{RL}_{\mathbf{above}}}$ | -0.142***<br>(0.029) |

*5.3 Robustness Check*

As indicated already, regulatory changes to the DLCR were introduced in May 2011. As this may lead to a structural break, and in order to exclude anticipation effects, we re-run the estimations for the period up to end 2010. Table 2 presents the results. The outcomes indicate a stronger adjustment towards the liability side of the balance sheet.

**Table 2: Robustness check**

This table shows the Generalized Least Squares (GLS) results for the (Threshold) Error Correction Model for 41 banks over the period July 2003 - December 2010 (3.649 observations). The heteroskedasticity of the error terms is corrected by using white robust standard errors and the standard deviations are displayed in parentheses. Cross-section weights are used and ** and *** denote 5% and 1% significance levels respectively.

| | **Dependent variable** | | | **Dependent variable** | | |
|---|---|---|---|---|---|---|
| Symmetric | ΔAL | $\boldsymbol{\rho^{AL}}$ | -0.106*** (0.014) | ΔRL | $\boldsymbol{\rho^{RL}}$ | -0.292*** (0.020) |
| Asymetric | ΔAL | $\boldsymbol{\rho^{AL}_{\text{below}}}$ | -0.095** (0.025) | ΔRL | $\boldsymbol{\rho^{RL}_{\text{below}}}$ | -0.357*** (0.036) |
| | ΔAL | $\boldsymbol{\rho^{AL}_{\text{above}}}$ | -0.119*** (0.026) | ΔRL | $\boldsymbol{\rho^{RL}_{\text{above}}}$ | -0.215*** (0.043) |

## 6. Implications

Several implications follow from our study. First, the finding that systematic adjustment to negative liquidity shocks is balanced towards the liability side of the balance sheet (instead of assets) calls for a careful interpretation of liquidity ratios. Adjustment on the liability side also implies that the discussion on the wider economic effects of liquidity regulation needs to include this channel. In the Dutch case, outflows of market funding led to substitution by deposits, which increased competition for deposits[9]. This would be expected to increase funding costs. Depending on the level of competition, such increases could be translated into higher lending rates, which lowers the demand for credit. On the other hand, more competition might also lower bank's profitability and thereby ultimately impact the resilience of the banking system.

Second, and more general, the findings suggest that banks adjust their liquidity profile to meet the LCR requirement. This reflects the aim of the rules to increase short-term resilience. At the same time, it also suggests that liquidity regulation may substitute to some extent banks' incentives to manage their liquidity position[10]. Instead of assessing their own liquidity risk profile, banks might steer on the risk weights determined by the supervisor. Hence, supervisors should not rely on the ratio only, but they should also investigate the underlying drivers, i.e. developments in both the numerator (liquid assets) and the denominator (which is

9 In general, Dietrich et al. (2012) argue that by attracting more customer deposits a bank can reduce the required liquidity for lower cost than a bank trying to improve its liquidity ratio via long-term wholesale liabilities.

10 See Bonner et al. (2013).

derived from short-term liabilities). Moreover, it also implies that increased reliance on regulatory ratios may need to go hand in hand with increased supervisory scrutiny of risk management practices.

Third, our findings indicate that the DLCR did not prevent an aggregate liquidity cycle, with increases in balance sheet size and increased risk taking in the upswing of the financial cycle (and vice versa). Our findings provide empirical support to the 'consensus view' on systemic liquidity risk (Acharya et al., 2011). According to this view, microprudential measures such as the LCR (but also the Net Stable Funding Ratio) help, but they are not sufficient. First, they focus on individual liquidity risk, but not on systemic liquidity risk. Second, they are not countercyclical. Third, they do not target liquidity risk in particular in repos and derivatives. The macroprudential perspective calls for monitoring aggregate liquidity developments, both in assets and liabilities, and not to rely only on ratios. Most of this literature points to the need for instruments that address excessive accumulation of maturity mismatch and increase the stability of funding. The focus of our paper however has not been on maturity mismatch but on (very) short-term resilience. Results indicate that restricting leverage may be crucial in addressing the liquidity cycle in short-term assets and funding. From a balance sheet perspective, this provides support to the leverage ratio, which at least partly limits balance sheet expansion financed by repos (given that some capital now needs to be held against collateralised financing). Moreover, from a wider market perspective it supports the use of through-the-cycle or countercyclical margins and haircuts on repo transactions, as currently discussed also in international fora such as the Financial Stability Board.

## Literature Review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## Annex 1. Figures

**Figure A.1.1: breakdown of assets**

This figure shows the aggregate asset allocation for the full sample of 59 banks over time, based on consolidated balance sheets.

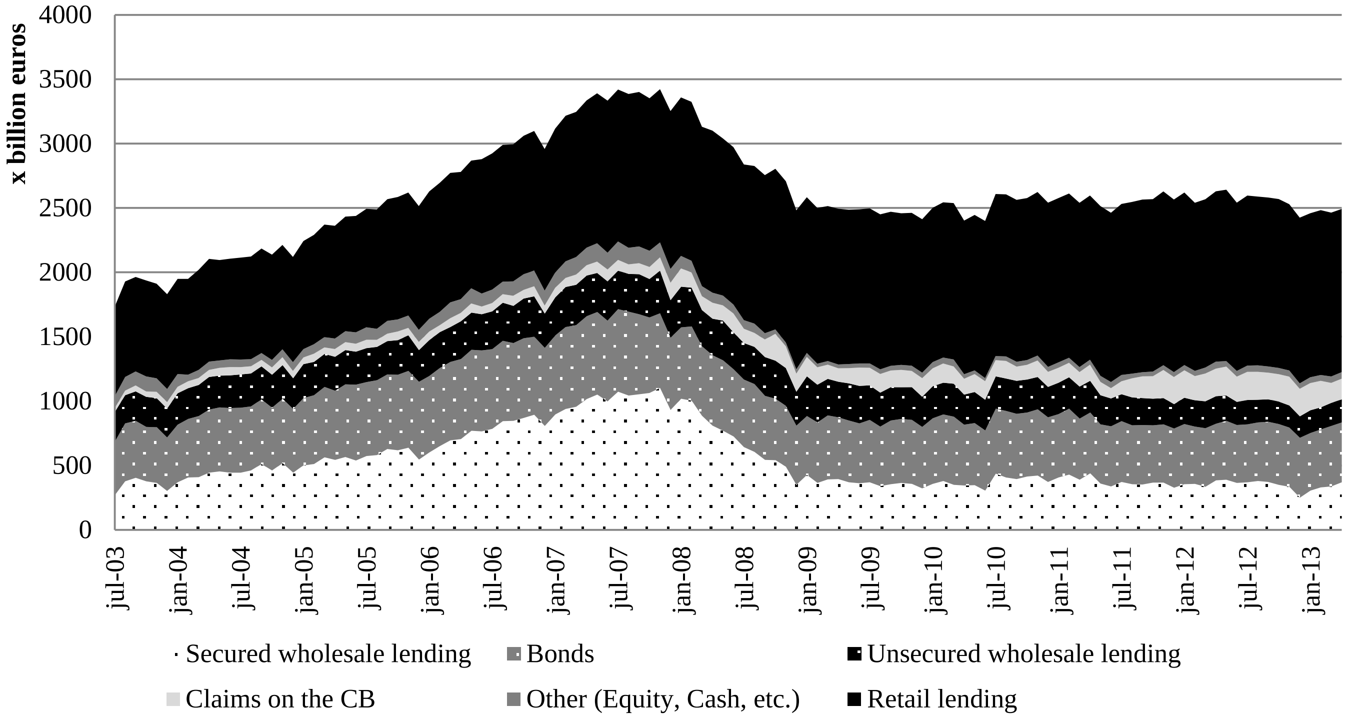



**Figure A.1.2: breakdown of available liquidity (liquidity weighted assets)**

This figure shows the aggregate asset totals weighted by their liquidity value for the full sample of 59 banks over time, based on consolidated balance sheets.

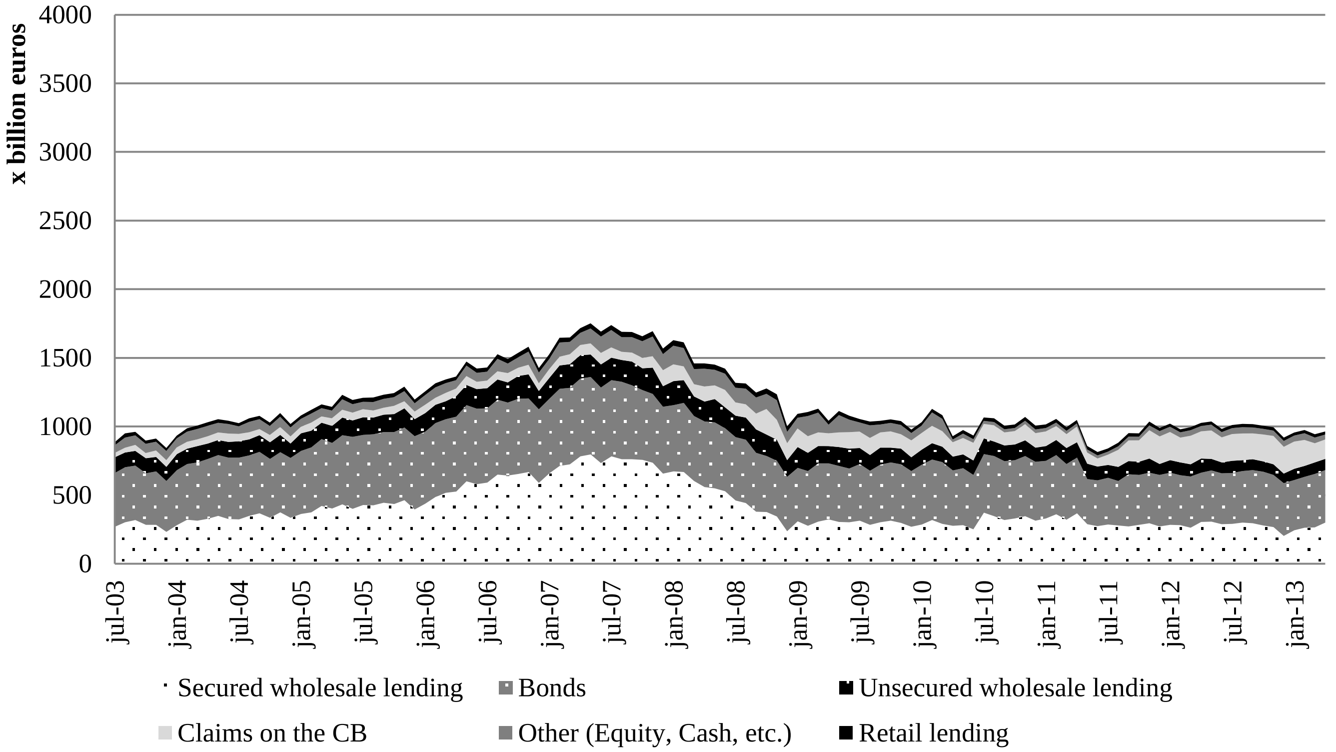


**Figure A.1.3: breakdown of liabilities**

This figure shows the aggregate funding mix for the full sample of 59 banks over time, based on consolidated balance sheets, including off balance sheet items (therefore total liabilites exceeds the total assets in Figure A.1.1).

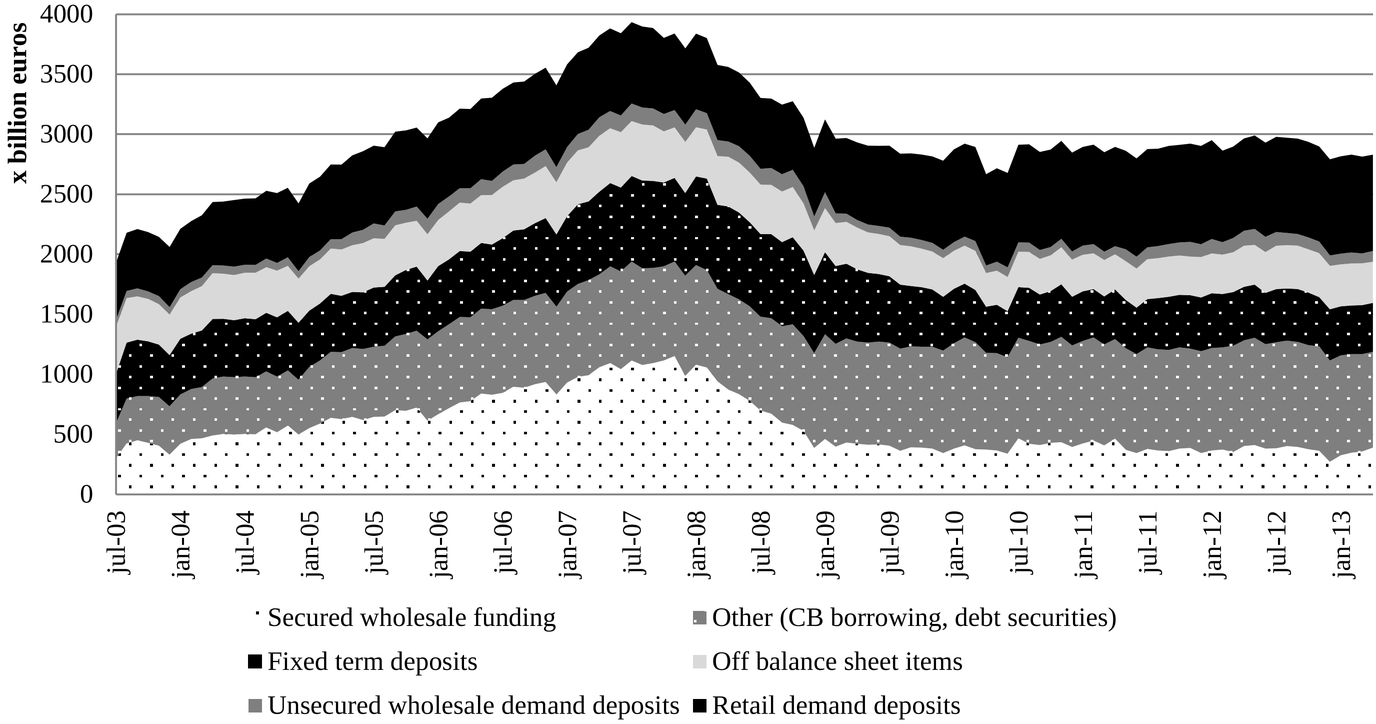
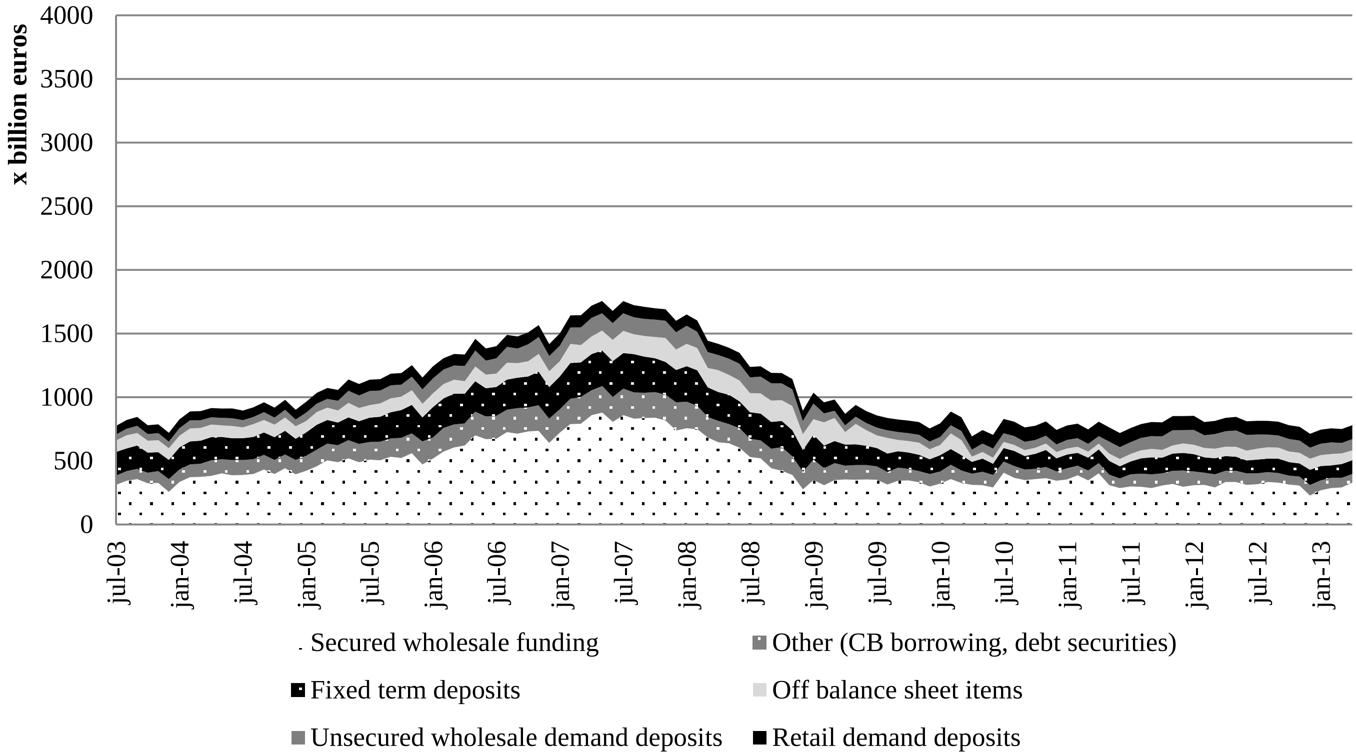



**Figure A.1.4: breakdown of required liquidity (liquidity weighted liabilities)**

This figure shows the aggregate liabilities weighted by their liquidity value for the full sample of 59 banks over time, based on consolidated balance sheets.



## Annex 2. Unit root tests and co-integration

### *A.2.1 Unit root tests*

As the long-run relationship between actual liquidity and required liquidity can only be estimated if the series are integrated of the same order, first the Im-Pesaran-Shin (IPS) unit root test is employed. Under this approach heterogeneity among banks is taken into account, allowing for individual fixed effects by estimating heterogeneous coefficients for the dependent variable. This heterogeneous panel unit root test does also capture different lag lengths among different banks.

The first line of table A.2.1 shows the results for the full panel of 59 banks. Results indicate the rejection of the null hypothesis of a unit root on the level data for both series based on the full sample of 59 banks.

Table A.2.2 shows the intermediate results for all banks in the sample. Results indicate that for 18 banks the null hypothesis is rejected for at least one of the series, so that conditions for co-integration do not hold. Therefore, the sample is limited to banks with cross-section units that have series that are both integrated of order one, I(1). That is, the series actual liquidity and required liquidity reject the presence of a unit root only after differencing once. The second line in table A.2.1 shows the IPS test results for the sample of 41 for which actual and required liquidity are both I(1). Therefore, we continue our study with the 41 banks that have liquidity series that are both integrated of order one.

**Table A.2.1: Panel unit root test**

This table shows the results of the panel unit root test based on the Im-Peseran-Shin (IPS) method. The appropriate number of lags is selected by SIC and the p-values are showed in parentheses. *** denotes the 1%-significance level. Based on the results for the full sample, the dataset is limited to banks with time series characterized by I(1) series. The decision for exclusion is made based on the presence of a unit root at the 5%-significance level.

| | **Actual Liquidity** | | **Required Liquidity** | |
|---|---|---|---|---|
| | Level | First differences | Level | First differences |
| *Full Sample (59 banks)* | | | | |
| # Obs. | 6808 | 6766 | 6788 | 6731 |
| Test statistic | -6.653 | -88.193 | -9.522 | -92.021 |
| | (0.000)*** | (0.000)*** | (0.000)*** | (0.000)*** |
| *Limited Sample (41 banks)* | | | | |
| # Obs. | 4722 | 4710 | 4703 | 4691 |
| Test statistic | -0.657 | -72.827 | 1.076 | -77.239 |
| | (0.256) | (0.000)*** | (0.859) | (0.000)*** |

## Table A.2.2. Intermediate unit root results

This table shows the individual ADF test results for each individual time series. The appropriate number of lags is selected by SIC. *, ** and *** denote 10%, 5% and 1% significance levels respectively.

| | *Actual Liquidity* | | *Required Liquidity* | | | *Available Liquidity* | | *Required Liquidity* | |
|---|---|---|---|---|---|---|---|---|---|
| **Bank** | **Probability** | **Lag** | **Probability** | **Lag** | **Bank** | **Probability** | **Lag** | **Probability** | **Lag** |
| 1 | 0.44 | 0 | 0.46 | 0 | 31 | 0.62 | 1 | 0.00*** | 0 |
| 2 | 0.58 | 0 | 0.99 | 2 | 32 | 0.85 | 0 | 0.33 | 5 |
| 3 | 0.07 | 3 | 0.65 | 5 | 33 | 0.25 | 0 | 0.19 | 0 |
| 4 | 0.79 | 0 | 0.81 | 0 | 34 | 0.36 | 2 | 0.58 | 2 |
| 5 | 0.00*** | 1 | 0.00*** | 2 | 35 | 0.33 | 1 | 0.51 | 2 |
| 6 | 0.19 | 3 | 0.33 | 3 | 36 | 0.29 | 2 | 0.36 | 2 |
| 7 | 0.29 | 1 | 0.81 | 7 | 37 | 0.00*** | 0 | 0.00*** | 0 |
| 8 | 0.99 | 0 | 1.00 | 2 | 38 | 0.27 | 0 | 0.39 | 0 |
| 9 | 0.40 | 2 | 0.64 | 2 | 39 | 0.34 | 5 | 0.32 | 5 |
| 10 | 0.28 | 0 | 0.06* | 0 | 40 | 0.07* | 1 | 0.07* | 1 |
| 11 | 0.24 | 2 | 0.13 | 2 | 41 | 0.30 | 1 | 0.87 | 1 |
| 12 | 0.38 | 4 | 0.51 | 4 | 42 | 0.62 | 1 | 0.64 | 1 |
| 13 | 0.61 | 0 | 0.55 | 0 | 43 | 0.29 | 6 | 0.54 | 4 |
| 14 | 0.57 | 3 | 0.82 | 3 | 44 | 0.34 | 2 | 0.39 | 2 |
| 15 | 0.00*** | 0 | 0.00*** | 0 | 45 | 0.00*** | 0 | 0.11 | 2 |
| 16 | 0.09 | 0 | 0.03** | 2 | 46 | 0.01** | 0 | 0.47 | 2 |
| 17 | 0.54 | 2 | 0.99 | 4 | 47 | 0.89 | 12 | 0.00*** | 0 |
| 18 | 0.99 | 9 | 0.85 | 2 | 48 | 0.59 | 2 | 0.19 | 1 |
| 19 | 0.30 | 2 | 0.35 | 0 | 49 | 0.00*** | 0 | 0.00*** | 0 |
| 20 | 0.00*** | 0 | 0.02** | 1 | 50 | 0.31 | 1 | 0.75 | 1 |
| 21 | 0.68 | 0 | 0.72 | 5 | 51 | 0.46 | 0 | 0.03** | 2 |
| 22 | 0.00*** | 0 | 0.00*** | 0 | 52 | 0.48 | 2 | 0.77 | 2 |
| 23 | 0.16 | 6 | 0.05 | 11 | 53 | 0.28 | 1 | 0.05** | 1 |
| 24 | 0.00*** | 0 | 0.00*** | 0 | 54 | 0.12 | 0 | 0.12 | 1 |
| 25 | 0.12 | 1 | 0.71 | 1 | 55 | 0.03** | 1 | 0.28 | 1 |
| 26 | 0.30 | 0 | 0.30 | 0 | 56 | 0.00*** | 0 | 0.00*** | 0 |
| 27 | 0.43 | 4 | 0.24 | 2 | 57 | 0.34 | 3 | 0.48 | 2 |
| 28 | 0.35 | 1 | 0.19 | 2 | 58 | 0.94 | 2 | 0.86 | 3 |
| 29 | 0.76 | 2 | 0.00*** | 6 | 59 | 0.63 | 1 | 0.18 | 2 |
| 30 | 0.01** | 2 | 0.04** | 2 | | | | | |

*A.2.2 Co-integration*

Having established the order of integration in the series, a panel co-integration test is used to examine the dynamic relationship between the actual and required liquidity. We use Pedroni's (2001) co-integration test, since it allows for cross-sectional interdependence with different individual effects in the intercepts and slopes of the co-integration equation (i.e. a bank-specific long-run equilibrium). An estimate for the long-run equilibrium relationship is given by:

$$AL_{i,t} = \alpha_i + \beta_i RL_{i,t} + \varepsilon_{i,t} \qquad (A.2.1)$$

where $\alpha_i$ represents the individual fixed effects, and $AL_{it}$ and $RL_{it}$ represent the actual liquidity and required liquidity for each bank $i$ at time $t$. The series $AL_{it}$ and $RL_{it}$ are said to be co-integrated if there exist a linear combination of these non-stationary series that itself is stationary. To test the null hypothesis of no cointegration, $\rho_i = 1$, the following unit root test is conducted on the residuals as follows:

$$\varepsilon_{i,t} = \rho_i \varepsilon_{i,t-1} + \omega_{i,t} \qquad (A.2.2)$$

Since co-integration does not imply causality, the equation can equally well be estimated with $RL_{it}$ as a left-hand side variable and $AL_{it}$ on the right-hand side. Table A.2.3 shows the Pedroni co-integration tests results. The null hypothesis of no co-integration is tested against the alternative that a cointegrating vector exists for each individual bank. All test statistics reject the null hypothesis of no co-integration at the 1% significance level.[14]

**Table A.2.3. Cointegration test results**

This table shows the results of Pedroni's cointegration test. The appropriate number of lags for each individual time series is selected by SIC. p-values are in parentheses. *** denotes the 1%-significance level.

| | Within dimension | | | Between dimension | |
|---|---|---|---|---|---|
| Panel v-Statistic | 9.764*** | (0.000) | Group rho-statistic | -33.845*** | (0.000) |
| Panel rho-Statistic | -14.877*** | (0.000) | Group PP-statistic | -20.493*** | (0.000) |
| Panel PP-statistic | -10.809*** | (0.000) | Group ADF-statistic | -11.473*** | (0.000) |
| Panel ADF-statistic | -10.781*** | (0.000) | | | |

14 Table A.2.3 shows panel statistics (left column) and group statistics (right column). The panel statistics approach pools of the 'within' dimension. It tests the null hypothesis that the first order autoregressive coefficient on the residuals is the same for every individual bank. The group statistics approach pools over the 'between' dimension. It allows the autoregressive coefficient to differ for each individual.