

# The Effects of Liquidity Regulation on Bank Assets and Liabilities\*

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Under Basel III rules, banks became subject to a liquidity coverage ratio (LCR) from 2015 onward, to promote short-term resilience. Investigating the effects of such liquidity regulation on bank balance sheets, we find (i) cointegration of liquid assets and liabilities, to maintain a minimum short-term liquidity buffer; and (ii) that adjustment in the liquidity ratio is skewed towards the liability side. This finding contrasts with established wisdom that compliance with the LCR is mainly driven by changes in liquid assets. Moreover, microprudential regulation has not prevented a procyclical liquidity cycle in secured financing that is strongly correlated with leverage.

JEL Codes: E44, G21, G28.

## 1. Introduction

The Basel Committee on Banking Supervision (BCBS) has introduced a liquidity coverage ratio (LCR) from 2015 onward. It requires banks to hold a sufficient level of high-quality liquid assets against expected net liquid outflows over a thirty-day stress period, to promote short-term resilience (BCBS 2009). The introduction of the LCR was motivated by the liquidity crisis of 2007–8, which occurred in combination with a solvency crisis. In this context, our contribution addresses two questions: (i) what is the impact of a liquidity constraint such as the LCR on individual bank behavior? and (ii)

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what has been the role of liquidity regulation before, during, and after the liquidity and solvency crisis of 2007–8?

We study these questions by using a unique database for Dutch banks, which have been subject to liquidity regulation that is comparable to Basel III's LCR since 2003. We can systematically track liquid assets, liabilities, and their ratio during the upswing and downswing of the financial cycle. Moreover, to investigate the link between liquidity and capital regulation, we collected bank-level information on (core) capital, assets, and risk weights.

On the first question—i.e., the impact of the LCR on bank behavior—several studies assume that the causality runs from liabilities to assets. These studies find that banks adjust their assets in response to a negative funding shock (Berrospide 2012; De Haan and van den End 2013a, 2013b). An innovative element in our study is that we let the data determine the direction of causality. We argue that a constraint on the ratio between liquid assets and required liquidity implies that the two variables should be cointegrated, which is supported by our findings. The error-correction regressions indicate that banks adjust their liabilities—and to a lesser extent their liquid assets—when the LCR is above its equilibrium value, while the adjustment is even more skewed towards the liability side when the LCR is below its equilibrium value. In line with this finding, we find that wholesale funding (with a high run-off rate in the denominator of the LCR) has been replaced by more stable deposits during the aftermath of the crisis.

To address the second question—i.e., the role of liquidity regulation—we take a macroprudential perspective and investigate aggregate patterns in our variables before, during, and after the crisis. Results indicate a strong increase in the levels of available and required liquidity (the constituent parts of the LCR) before the financial crisis and a strong decrease afterwards. This cycle in short-term assets and liabilities occurs mostly through secured financing. It is accompanied by increasing leverage during the upturn and decreasing leverage during the downturn. This is in line with earlier results for the United States on the link between liquidity and leverage (Adrian and Shin 2010). Moreover, the LCR itself is strongly correlated with the leverage ratio and shows a procyclical pattern. During increased risk taking in the upturn of the financial cycle, “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. It is followed by de-risking and an increase in the LCR during the subsequent downturn. This finding of procyclicality implies that banks' short-term liquidity buffers are at their lowest point when the crisis starts, exactly when they are needed the most. At the same time, regulatory risk-weighted capital requirements have not been a binding constraint, partly due to the procyclicality of risk weights.

The rest of this paper is organized as follows. Section 2 presents our conceptual framework. Section 3 provides the estimation results on bank behavior under a liquidity constraint. Section 4 investigates aggregate patterns for liquidity and solvency. Section 5 concludes.

## 2. Conceptual Framework

The LCR is defined as a ratio with the numerator representing the amount of "high-quality liquid assets" (HQLA), i.e., assets that can be easily and immediately converted into cash at little or no loss of value (Bank for International Settlements 2013). Liquid assets primarily consist of cash, central bank reserves, and, to a certain extent, marketable securities, sovereign debt, and central bank debt.<sup>1</sup> The denominator is the net cash outflow within thirty days, which is the difference between outgoing and incoming cash flows.

The LCR is defined as

$$LCR = \frac{\text{High Quality Liquid Assets}}{\text{Cash outflows} - \text{Cash inflows}}, \quad (1)$$

where the cash outflows are subject to prescribed run-off rates and the cash inflows are subject to prescribed haircuts in order to assign

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<sup>1</sup>There are two categories of assets that can be included in the stock of HQLA: level 1 assets can be included without a limit, while level 2 assets can only comprise up to 40 percent of the stock. Level 1 assets are limited to cash, central bank reserves, and marketable securities representing claims on or guaranteed by, e.g., sovereigns, central banks, and the BIS (with a 0 percent risk weight under the standardized approach for credit risk). Sovereign or central bank debt can, under certain conditions (BIS 2013), also be reported as level 1 assets. Level 2 assets consist of other marketable securities, corporate debt securities, and covered bonds that satisfy certain conditions. See BIS (2013) for a comprehensive definition of HQLA.

these items a liquidity weight. The similarity between Basel III and the existing Dutch supervisory framework makes it possible to construct a comparable measure for the LCR; the Dutch liquidity coverage ratio (DLCR).

In line with previous studies (e.g., Bonner 2012; De Haan and van den End 2013a), the DLCR is defined as

$$DLCR_{i,t} = \frac{AL_{i,t}}{RL_{i,t}} = \frac{\sum_j a_j \cdot Asset_{i,j,t} + \sum_k b_k \cdot Inflow_{i,k,t}}{\sum_l c_l \cdot Liability_{i,l,t} + \sum_m d_m \cdot Outflow_{i,m,t}}, \quad (2)$$

where  $AL_{i,t}$  and  $RL_{i,t}$  stand for, respectively, available liquidity and required liquidity of bank  $i$  at time  $t$ . The variables  $a_j$ ,  $b_k$ ,  $c_l$ , and  $d_m$  represent the regulatory weights for the 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 the 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.

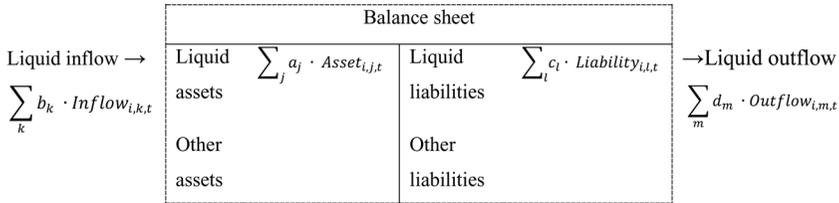
The LCR and the DLCR reflect the same regulatory philosophy and are very similar. The main differences are the regulatory weights. In particular, the stock of HQLA is more narrowly defined for the LCR than for the DLCR. For the latter, the haircuts and run-off rates were determined by the Dutch regulator under the “Liquidity Regulation under the Wft,” for the first time in January 2003.<sup>2</sup> 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.”<sup>3</sup>

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<sup>2</sup>Wft stands for “Wet op het financieel toezicht,” the Dutch Financial Supervision Act.

<sup>3</sup>The main change is a narrower definition of liquid assets; specifically, 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

**Figure 1. Stylized Bank Balance Sheet**



In part, the changes anticipated the new international rules, related to the Basel III requirements.

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 behavior. 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-stable funding (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.

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 sum, we hypothesize that the series for available and required liquidity are cointegrated with bank-specific equilibria.

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demand deposits has been decreased to reflect their observed stability during the crisis. Overall, the adjustments have led to more stringent liquidity standards.

### 3. Estimation Results

#### 3.1 *Unit-Root Tests and Cointegration*

To test this hypothesis, we use monthly data from the Dutch supervisory liquidity report over 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 subject to the liquidity regulation. We use data for fifty-nine banks for which the reported data are complete for the whole period under consideration.<sup>4</sup> Ideally our data set would have been long enough to cover several financial cycles; however, it gives us some comfort that our data set covers at least the upswing and downswing of one financial cycle.

The long-run relationship between actual liquidity and required liquidity can only be estimated if the series are non-stationary and integrated at the same order. Given the expected heterogeneity in bank behavior, we use a panel unit-root test that allows for different individual fixed effects in the intercepts and slopes of the cointegration equation. Out of the full sample of fifty-nine banks, the series actual liquidity and required liquidity are both integrated at order 1 for forty-one banks (see tables 1 and 2). Hence, we test for cointegration only for those banks. The results in table 3 indeed strongly reject the null hypothesis of no cointegration against the alternative of cointegration for each individual bank.<sup>5</sup>

#### 3.2 *Error-Correction Model*

Given the finding of cointegration at the individual bank level, the long-run equilibrium relationship can be estimated by fully modified ordinary least squares (FMOLS) for heterogeneous cointegrated

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<sup>4</sup>The underlying data are confidential. 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 aggregate data or estimation results and not the underlying data.

<sup>5</sup>We use Pedroni's (2001) cointegration test, since it allows for cross-sectional interdependence with different individual effects in the intercepts and slopes of the cointegration equation (i.e., a bank-specific long-run equilibrium).

**Table 1. Panel Unit-Root Test**

This table shows the results of the panel unit-root test based on the Im-Pesaran-Shin (IPS) method, where the null hypothesis is that of a unit root. The appropriate number of lags is selected by Schwarz information criterion (SIC). The p-values are shown in parentheses. \*\*\* denotes the 1 percent significance level. Based on the results for the full sample, the data set is limited to banks with time series that are integrated at order 1. The decision for exclusion is made based on the presence of a unit root at the 5 percent significance level (see table 2).

	Actual Liquidity		Required Liquidity	
	Level	First Differences	Level	First Differences
<i>Full Sample (Fifty-Nine Banks)</i>				
# Obs.	6,808	6,766	6,788	6,731
Test Statistic	-6.653 (0.000)***	-88.193 (0.000)***	-9.522 (0.000)***	-92.021 (0.000)***
<i>Limited Sample (Forty-One Banks)</i>				
# Obs.	4,722	4,710	4,703	4,691
Test Statistic	-0.657 (0.256)	-72.827 (0.000)***	1.076 (0.859)	-77.239 (0.000)***

**Table 2. Intermediate Unit-Root Results**

This table shows the individual augmented Dickey-Fuller (ADF) test results for all individual time series. The null hypothesis of a unit root (non-stationarity) is tested against the alternative that there is no unit root. The results in table 1 show that the null hypothesis cannot be rejected for all fifty-nine series. However, the intermediate ADF results indicate that most of the series suggest non-stationarity, meaning that the series are integrated at order 1 for forty-one banks. The appropriate number of lags is selected by SIC. \*, \*\*, and \*\*\* denote 10 percent, 5 percent, and 1 percent significance levels, respectively.

Bank	Actual Liquidity		Required Liquidity		Bank	Available Liquidity		Required Liquidity	
	Probability	Lag	Probability	Lag		Probability	Lag	Probability	Lag
1	0.44	0	0.46	0	16	0.09	0	0.03**	2
2	0.58	0	0.99	2	17	0.54	2	0.99	4
3	0.07	3	0.65	5	18	0.99	9	0.85	2
4	0.79	0	0.81	0	19	0.30	2	0.35	0
5	0.00***	1	0.00***	2	20	0.00***	0	0.02**	1
6	0.19	3	0.33	3	21	0.68	0	0.72	5
7	0.29	1	0.81	7	22	0.00***	0	0.00***	0
8	0.99	0	1.00	2	23	0.16	6	0.05	11
9	0.40	2	0.64	2	24	0.00***	0	0.00***	0
10	0.28	0	0.06*	0	25	0.12	1	0.71	1
11	0.24	2	0.13	2	26	0.30	0	0.30	0
12	0.38	4	0.51	4	27	0.43	4	0.24	2
13	0.61	0	0.55	0	28	0.35	1	0.19	2
14	0.57	3	0.82	3	29	0.76	2	0.00***	6
15	0.00***	0	0.00***	0	30	0.01**	2	0.04**	2

(continued)

Table 2. (Continued)

Bank	Actual Liquidity		Required Liquidity		Bank	Available Liquidity		Required Liquidity	
	Probability	Lag	Probability	Lag		Probability	Lag	Probability	Lag
31	0.62	1	0.00***	0	46	0.01**	0	0.47	2
32	0.85	0	0.33	5	47	0.89	12	0.00***	0
33	0.25	0	0.19	0	48	0.59	2	0.19	1
34	0.36	2	0.58	2	49	0.00***	0	0.00***	0
35	0.33	1	0.51	2	50	0.31	1	0.75	1
36	0.29	2	0.36	2	51	0.46	0	0.03**	2
37	0.00***	0	0.00***	0	52	0.48	2	0.77	2
38	0.27	0	0.39	0	53	0.28	1	0.05**	1
39	0.34	5	0.32	5	54	0.12	0	0.12	1
40	0.07*	1	0.07*	1	55	0.03**	1	0.28	1
41	0.30	1	0.87	1	56	0.00***	0	0.00***	0
42	0.62	1	0.64	1	57	0.34	3	0.48	2
43	0.29	6	0.54	4	58	0.94	2	0.86	3
44	0.34	2	0.39	2	59	0.63	1	0.18	2
45	0.00***	0	0.11	2					

**Table 3. Cointegration Test Results**

This table shows the results of Pedroni's cointegration test. The null hypothesis of no cointegration is tested against the alternative that a cointegrating vector exists for each individual bank. The table shows panel statistics (left column) and group statistics (right column). The appropriate number of lags for each individual time series is selected by SIC. p-values are in parentheses. \*\*\* denotes the 1 percent significance level.

	<b>Within Dimension</b>		<b>Between Dimension</b>	
Panel v-Statistic	9.764***	(0.000)	-33.845***	(0.000)
Panel rho-Statistic	-14.877***	(0.000)	-20.493***	(0.000)
Panel PP-Statistic	-10.809***	(0.000)	-11.473***	(0.000)
Panel ADF-Statistic	-10.781***	(0.000)		
<b>Notes:</b> The panel-statistics approach pools over the “within” dimension. It tests the null hypothesis that the first-order autoregressive coefficient on the residuals is the same for each individual bank. The group-statistics approach pools over the “between” dimension. It allows the autoregressive coefficient to differ for each individual.				

panels. The bank-specific long-run equilibrium relationship between actual liquidity and required liquidity is given by

$$AL_{i,t} = \alpha_i^{AL} + \widehat{\beta}_{i,FMOLS}^{AL} RL_{i,t} + \varepsilon_{i,t}, \quad (3)$$

where  $\alpha_i^{AL}$  represents the individual fixed effects, and  $\widehat{\beta}_{i,FMOLS}^{AL}$  is the FMOLS estimator correcting for heterogeneity and serial correlation by adjusting the initial OLS estimator.

The lagged residuals from equation (3) define the error-correction terms (*ECT*) in the following vector error-correction model:

$$\Delta AL_{i,t} = \alpha_i^{AL} + \rho^{AL} ECT_{i,t-1}^{AL} + \gamma_i \Delta RL_{i,t-1} + u_{i,t}^{AL}, \quad (4)$$

where  $\alpha_i^{AL}$  represents the individual fixed effects,  $\Delta AL_{i,t}$  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.  $\Delta RL_{i,t-1}$  is included to control for short-term adjustments, and  $u_{i,t}^{AL}$  is the error term. The same approach can be applied for required liquidity.<sup>6</sup> 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 causality. Under this model, long-run causality is revealed by the statistical significance of the adjustment coefficient  $\rho^{AL}$ .

The results are shown in the first row of table 4. These imply that when a bank moves away from its long-run equilibrium, it adjusts both assets and liabilities, and that the adjustment is skewed toward the liability side of the balance sheet. That is, as the liquidity buffer is above (below) equilibrium, banks decrease (increase) their available liquidity and increase (decrease) their required liquidity. The estimated coefficient of  $-0.098$  for available liquidity indicates that, after a shock to the long-run equilibrium, about 10 percent of this disequilibrium is corrected within one month through an adjustment in liquid assets. Likewise, the estimated coefficient of  $-0.221$  for required liquidity indicates that about 22 percent of this disequilibrium is corrected within one month through an adjustment in liabilities. Given that required liquidity is determined by

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<sup>6</sup>Then equations (3) and (4) will be replaced by, respectively,  $RL_{i,t} = \alpha_i^{RL} + \widehat{\beta}_{i,FMOLS}^{RL} AL_{i,t} + \varepsilon_{i,t}$  and  $\Delta RL_{i,t} = \alpha_i^{RL} + \rho^{RL} ECT_{i,t-1}^{RL} + \gamma_i \Delta AL_{i,t-1} + u_{i,t}^{RL}$ .

Table 4. (Asymmetric) Adjustment Coefficients

This table shows the error-correction terms from the generalized least squares (GLS) results for the (threshold) error-correction model for forty-one 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 \*\* and \*\*\* denote 5 percent and 1 percent significance levels, respectively.

	Dependent Variable			Dependent Variable	
Symmetric	$\Delta AL$	$\rho^{AL}$	$-0.098^{***}$ (0.011)	$\Delta RL$	$\rho^{RL}$
Asymmetric	$\Delta AL$	$\rho_{below}^{AL}$	$-0.059^{**}$ (0.022)	$\Delta RL$	$\rho_{below}^{RL}$
	$\Delta AL$	$\rho_{above}^{AL}$	$-0.129^{***}$ (0.021)	$\Delta RL$	$\rho_{above}^{RL}$
					$-0.221^{***}$ (0.024) $-0.314^{***}$ (0.026) $-0.142^{***}$ (0.029)

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 first model is that it does not allow for 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:

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

The asymmetric error-correction model is estimated by

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

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

where  $\rho_{below}^{AL}(\rho_{above}^{AL})$  and  $\rho_{below}^{RL}(\rho_{above}^{RL})$  represent the error-correction speed-of-adjustment coefficients given that a bank is below (above) its average liquidity level.

The results in the second row of table 4 suggest that the adjustment on the liability side becomes stronger when the DLCR is below its equilibrium. On average, 31 percent 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, with only a 6 percent change in available liquidity. 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 percent of the deviation from the long-run equilibrium.

### 3.3 *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 rerun the estimations for the period up to end-2010. Table 5 presents the results. The outcomes indicate an even stronger adjustment toward the liability side of the balance sheet.

### 3.4 *Discussion of Results*

Our estimations indicate that a regulatory liquidity constraint influences bank behavior, and that Dutch banks primarily adjust their funding mix when their DLCR falls below its long-run equilibrium. This section briefly compares our results with the academic literature on the effects of liquidity regulation on bank behavior.<sup>7</sup>

Several authors investigate the effects of liquidity regulation on banks' liquid assets. 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 net cash outflows. In another study, De Haan and van den End (2013b) 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

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<sup>7</sup>To save space, we focus only on studies based on econometric evidence, as it 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; these studies include Ayadi, Arbak, and De Groen (2012), European Banking Authority (2012), and Coeuré (2013). However, the data discussed in section 4 indicate that the reliance on central bank funding is limited for Dutch banks. Toward 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 was seen as a safe haven during the sovereign crisis of 2011–12. 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.

**Table 5. Robustness Check**

This table shows the generalized least squares (GLS) results for the (threshold) error-correction model for forty-one 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 percent and 1 percent significance levels, respectively.

	Dependent Variable		Dependent Variable	
Symmetric	$\Delta AL$	$\rho^{AL}$	$\Delta RL$	$\rho^{RL}$
Asymmetric	$\Delta AL$	$\rho_{below}^{AL}$	$\Delta RL$	$\rho_{below}^{RL}$
	$\Delta AL$	$\rho_{above}^{AL}$	$\Delta RL$	$\rho_{above}^{RL}$

$-0.106^{***}$   
 (0.014)  
 $-0.095^{**}$   
 (0.025)  
 $-0.119^{***}$   
 (0.026)  
 $-0.292^{***}$   
 (0.020)  
 $-0.357^{***}$   
 (0.036)  
 $-0.215^{***}$   
 (0.043)

securities, especially equities.<sup>8</sup> Using data on U.S. commercial banks, Berrospide (2012) studies the behavior 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 the aforementioned studies relies on the assumption that banks adjust liquid assets in response to shifts in their funding profile. Hence, our finding that adjustment can also take place on the liability side of the balance sheet complements the existing literature. More recently, Banerjee and Mio (2014) point to the effects of liquidity regulation on both assets and liabilities. Their study is closest to our approach. They find that banks that became subject to liquidity regulation significantly increased their share of HQLA. At the same time, banks also increased their share of domestic retail deposits, offset by a similar reduction in short-term wholesale funding and non-resident deposits. The main difference with our paper is that we study the adjustment to liquidity shocks after the regulation has been put in place, and we rely on cointegration instead of causal regressions.

## 4. Aggregate Data

### 4.1 *Patterns around the Crisis*

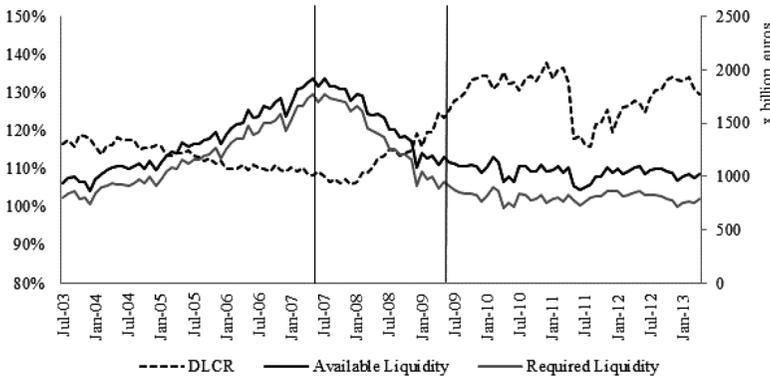
We now turn to the second question on the role of liquidity regulation before, during, and after the liquidity and solvency crisis of 2007–8. To do so, we shift focus from bank-level data toward aggregate patterns in the data for the Dutch banking sector as a whole. Figure 2 shows the average level of the DLCR for all banks in the sample and its development over time.

At the aggregate level, available liquidity always lies above required liquidity, so that the DLCR requirement is respected and

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<sup>8</sup>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.

**Figure 2. Dutch Liquidity Coverage Ratio (DLCR) and Its Components**



**Notes:** The graph displays the aggregate level of liquidity of fifty-nine 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.

minimum short-term liquidity buffers are maintained. As expected, available and required liquidity show strong co-movements, also at the aggregate level. Both series increase strongly in the run-up to the financial crisis, so that the aggregate balance expands strongly, and then decrease during the crisis. These large movements in available and required liquidity mainly cancel out in the ratio, but not fully. In the run-up to the crisis, required liquidity increases somewhat faster than available liquidity. As a result, the DLCR decreases gradually towards the direction of the regulatory minimum ratio of 1. During the crisis, required liquidity decreases more strongly than available liquidity, so that the DLCR shows a substantial increase. This suggests a procyclical pattern of increased risk taking in the upswing of the financial cycle, i.e., a move toward “cheaper” wholesale funding (with a high run-off rate in the denominator of the DLCR). It also suggests de-risking during the crisis, when wholesale funding dries up and needs to be replaced by more stable funding sources.

The aggregate data contradict established wisdom that changes in liquid assets are 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 strongly increases during the crisis, while liquid assets fall. Finally, the data show that the liquidity crisis of 2007–8, characterized 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, as it shows a substantial increase.

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.<sup>9</sup> However, we do observe data around the regulatory changes of May 2011. Data show a fall in available liquidity, due to an increase in haircuts, that leads to a drop in the DLCR. This is followed by a gradual increase in the DLCR that is mostly driven by available liquidity, toward a similar level to that observed during October 2009–May 2011.

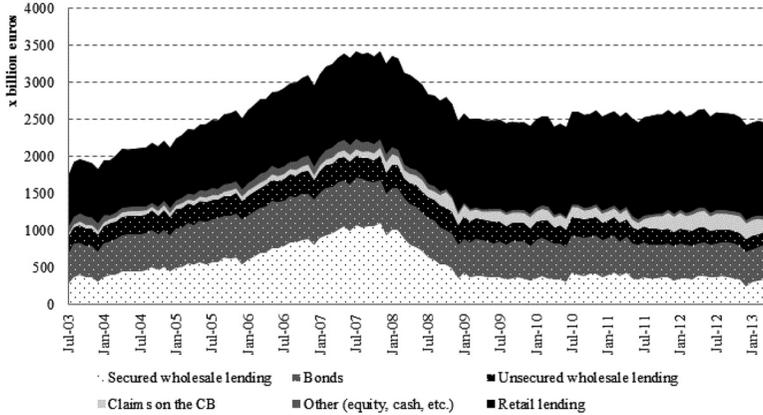
#### *4.2 Balance Sheet Composition*

Figures 3–6 provide an overview of the shifts in total assets and liabilities for the Dutch banking sector as a whole, and total assets and liabilities weighted by their liquidity value (i.e., available and required liquidity). On the asset side, secured wholesale lending, consisting of (reverse) repos and securities lending, increases steadily over 2003–7 and then declines strongly during the crisis. As secured wholesale lending is defined as highly liquid, it accounts for most of the dynamics in available liquidity. Likewise, on the liability side, the strongest dynamics are observed in secured wholesale funding, which mainly consists of repos. Moreover, over time, we observe a shift from wholesale funding toward retail demand deposits (with a low run-off rate). Overall, it appears that the liquidity components of the aggregate balance sheet reflect rapid balance sheet expansion and contraction over the financial cycle, driven by both secured funding and lending.

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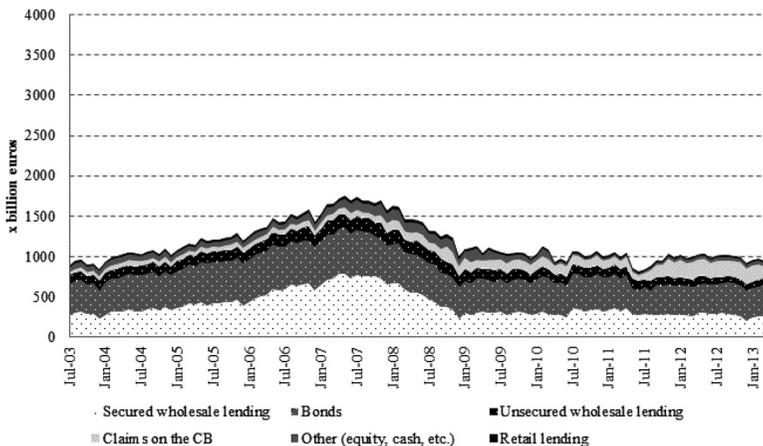
<sup>9</sup>For the United Kingdom, Banerjee and Mio (2014) find that an increase in liquid assets has been one of the effects of the introduction of liquidity regulation.

**Figure 3. Breakdown of Total Assets**



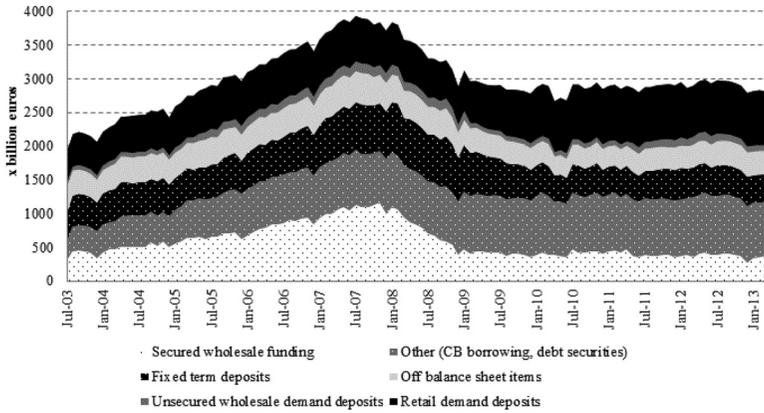
**Notes:** This figure shows the aggregate asset allocation for the full sample of fifty-nine banks over time, based on consolidated balance sheets. The order of the series is as follows, from bottom to top: secured wholesale lending, bonds, unsecured wholesale lending, claims on the CB, other (equity, cash, etc.), retail lending.

**Figure 4. Breakdown of Available Liquidity (liquidity-weighted assets)**



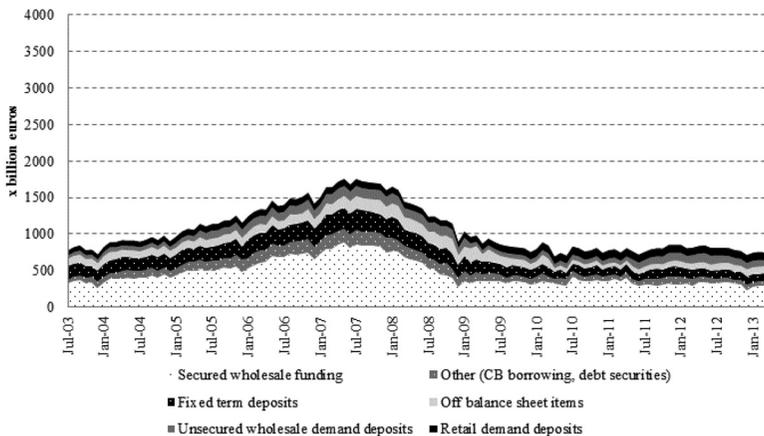
**Notes:** This figure shows the aggregate asset totals weighted by their liquidity value for the full sample of fifty-nine banks over time, based on consolidated balance sheets. The order of the series is as follows, from bottom to top: secured wholesale lending, bonds, unsecured wholesale lending, claims on the CB, other (equity, cash, etc.), retail lending.

**Figure 5. Breakdown of Total Liabilities**



**Notes:** This figure shows the aggregate funding mix for the full sample of fifty-nine banks over time, based on consolidated balance sheets, including off-balance-sheet items (therefore total liabilities exceeds the total assets in figure 1). The order of the series is as follows, from bottom to top: secured wholesale funding, other (CB borrowing, debt securities), fixed term deposits, off-balance-sheet items, unsecured wholesale demand deposits, retail demand deposits.

**Figure 6. Breakdown of Required Liquidity (liquidity-weighted liabilities)**



**Notes:** This figure shows the aggregate liabilities weighted by their liquidity value for the full sample of fifty-nine banks over time, based on consolidated balance sheets. The order of the series is as follows, from bottom to top: secured wholesale funding, other (CB borrowing, debt securities), fixed term deposits, off-balance-sheet items, unsecured wholesale demand deposits, retail demand deposits.

### 4.3 *Discussion of Results*

From a microprudential perspective, the liquidity rules appear to have been effective in the Dutch case, given that a minimum buffer of liquid assets has always been maintained to cover possible outflows, as captured by required liquid assets. At the same time, the liquidity regulation did not prevent a procyclical liquidity cycle driven by secured financing. Our findings therefore provide empirical support to the “consensus view” on systemic liquidity risk (Acharya, Krishnamurthy, and Perotti 2011). According to this view, microprudential measures such as the LCR help support stability but are not sufficient. First, they focus on individual liquidity risk but not on systemic liquidity risk. Second, they do not target liquidity risk in particular in securities financing transactions and derivatives. Third, they are not countercyclical.

Several authors have already pointed to the relevance of secured financing—and repos in particular—in explaining the buildup of risk prior to the financial crisis in the United States, and contagion between institutions when this risk crystallized (e.g., Brunnermeier and Pederson 2009; Gorton and Metrick 2012; Copeland, Martin, and Walker 2014). Our results point to the relevance of secured financing for European countries such as the Netherlands. Future research would be needed to provide further insights, especially on the role played by the type of collateral (such as asset-backed securities versus government bonds) and the pattern of margins and haircuts that may have been driving fire sales during the crisis, which our data set unfortunately does not provide. Such research could inform policy discussions on the use of through-the-cycle or countercyclical margins and haircuts on securities financing transactions, as currently discussed in international forums such as the Financial Stability Board (FSB 2014).

A related approach points to the links between liquidity and leverage in the U.S. context. Adrian and Shin (2010) suggest that financial market liquidity can be understood as the rate of growth of aggregate balance sheets. They argue that during the upswing of the financial cycle, asset prices increase so that capital increases and leverage falls.<sup>10</sup> This provides an incentive to financial institutions

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<sup>10</sup>Here leverage is defined as the ratio of total assets over capital.

to use this “excess capital” to maximize return on equity. They may therefore extend their balance sheet through borrowing funds to purchase assets, so that capital falls (and leverage increases) back to its previous level. This translates into procyclical patterns in the size of banks’ balance sheets. For U.S. investment banks, Adrian and Shin (2010) present evidence for the expansion and contraction of balance sheets via repos (i.e., using purchased securities as collateral for the cash borrowing).<sup>11,12</sup>

To investigate such a possible link between liquidity and leverage for Dutch banks, and with risk-weighted capital requirements more generally, we complemented our data set with balance sheet data on risk weights, total assets, and (core) capital.<sup>13</sup> Based on the possible link between liquidity and leverage, we expect a correlation between the cycle in available and required liquidity and the leverage ratio (defined here as equity over total assets). This occurs given that the series for available and required liquidity reflect debt-financed balance sheet expansion and contraction. All else equal (i.e., if equity would be constant), such a pattern would reflect procyclical leverage. This procyclical pattern of the leverage ratio is confirmed in figure 7, which also highlights the strong correlation of the leverage ratio with the DLCR.

Given that liquidity problems often reflect underlying solvency problems (Admati and Hellwig 2013), a link between liquidity ratios and risk-weighted capital ratios could also be expected. As shown in figure 8, the correlation is indeed positive but not as strong as for the

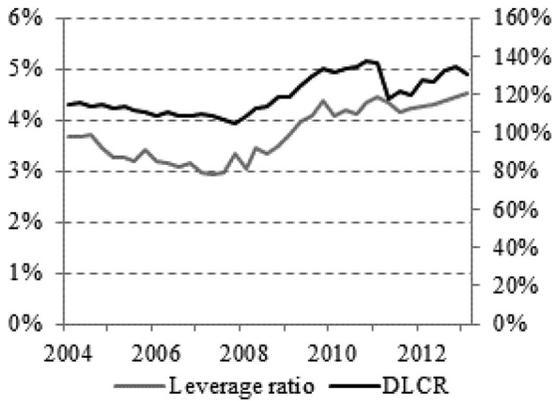
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<sup>11</sup>The Dutch banking sector is dominated by the largest three banks and is therefore highly concentrated: the largest three banks account for around 75 percent of the total assets. These banks are universal banks: they combine traditional banking with a sizable presence in securities markets. Our aggregate results therefore partly reflect the presence of these large banks in securities markets.

<sup>12</sup>Similarly, Geanakoplos (2010) points to procyclical leverage driven by procyclical margins and haircuts on collateral.

<sup>13</sup>The confidential data originates from the supervisory solvency reporting requirement. In contrast to the monthly reporting of liquidity data, the solvency data is reported quarterly. Besides that, and also in contrast to the liquidity data reporting, foreign branches with a parent company within the European Union are exempted from reporting, since the Dutch regulator plays no role in solvency supervision of these banks. Hence, data on both the solvency and liquidity position are available for thirty banks. However, these thirty banks still represent 90 percent of the total Dutch banking sector, based on 2013:Q1 data and measured by total assets.

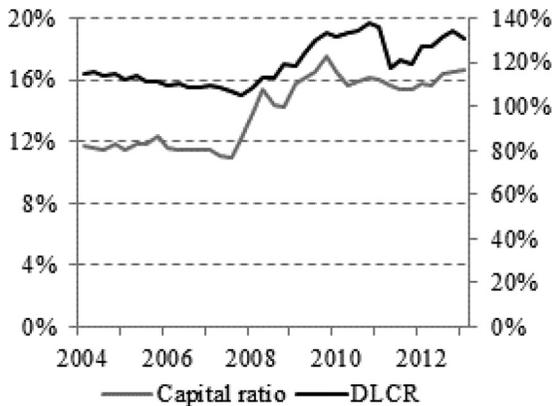
**Figure 7. Liquidity and Leverage Ratio<sup>a</sup>**



**Notes:** This figure shows the weighted-average leverage ratio (left scale) and DLCR (right scale) for a sample of thirty banks on a quarterly basis for the period 2004:Q1–2013:Q1.

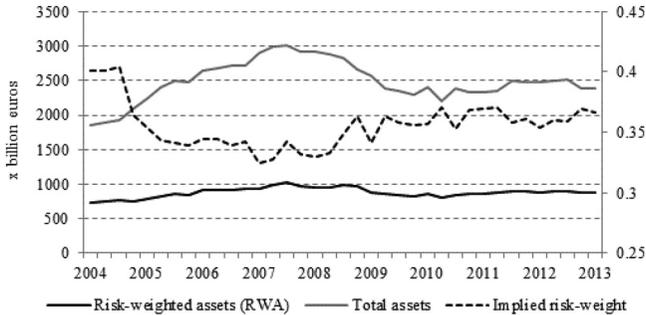
<sup>a</sup>The leverage ratio is defined as total tier 1 capital divided by total assets.

**Figure 8. Liquidity and Capital Ratio<sup>a</sup>**



**Notes:** This figure shows the weighted-average capital ratio (left scale) and DLCR (right scale) for a sample of thirty banks on a quarterly basis for the period 2004:Q1–2013:Q1.

<sup>a</sup>The capital ratio is defined as the total eligible capital divided by total risk-weighted assets (Basel definition).

**Figure 9. Risk Weights**

**Notes:** This figure shows the aggregate asset totals, risk-weighted assets, and the implied average risk weights (right scale) on a quarterly basis for the period 2004:Q1–2013:Q1.

leverage ratio. This difference can be explained by the procyclical change in average risk weights during our sample period (figure 9). As a result, risk-weighted capital requirements remained relatively stable above their regulatory minimum in the run-up to the crisis, despite increasing leverage. Further discussions on the performance of risk weights as ex ante and ex post measures of risk are subject to a separate literature, which is beyond the scope of this paper (see Le Lesle and Avramova 2012).

Finally, our finding of a procyclical pattern in the DLCR is in line with Goodhart et al. (2012). These authors argue that banks naturally have more liquid assets during booms than during busts, and that if a liquidity ratio is binding during a boom, it will be even more restrictive during a bust, making it a procyclical regulatory ratio. Therefore, the authors propose countercyclical haircuts (i.e., liquidity weights), so that the liquidity requirements become time varying and the liquidity buffer can be released during times of financial stress.

## 5. Conclusion

The main implication of our study is that banks adjust their liquid liabilities, and to a lesser extent their liquid assets, in response to shocks in their liquidity positions. In the Dutch case, liquidity

regulation appears to have been effective from a microprudential perspective but not from a macroprudential perspective. While banks respect the minimum liquidity ratio, liquidity regulation has not prevented a procyclical liquidity cycle in short-term secured financing that is strongly correlated with leverage. At the same time, the increase in leverage was not visible in the regulatory capital ratios. Hence, monitoring the risk-weighted capital requirements, or the LCR as a ratio, does not necessarily signal the buildup or materialization of aggregate risks. It may need to be complemented by monitoring the LCR's constituent parts, both at an institutional level and for the banking sector as a whole, and interpreted against the background of movements in balance sheet size and leverage.

Furthermore, and in line with previous research, our findings point to the significant role of secured financing for explaining the leverage and liquidity cycle. This calls for further research on the role played by the type of collateral, and the pattern of asset prices, margins, and haircuts that may have been driving the liquidity cycle and fire sales during the crisis.

## References

- Acharya, V., A. Krishnamurthy, and E. Perotti. 2011. "A Consensus View on Liquidity Risk." VoxEU.org, September 21.
- Admati A., and M. Hellwig. 2013. *The Bankers' New Clothes: What's Wrong with Banking and What to Do about It*. Princeton, NJ: Princeton University Press.
- Adrian, T., and H. S. Shin. 2010. "Liquidity and Leverage." *Journal of Financial Intermediation* 19 (3): 418–37.
- Ayadi, R., E. Arbak, and P. W. De Groen. 2012. "Implementing Basel III in Europe: Diagnosis and Avenues for Improvement." CEPS Policy Brief No. 275.
- Banerjee, R., and H. Mio. 2014. "The Impact of Liquidity Regulation on Banks." BIS Working Paper No. 470.
- Bank for International Settlements. 2013. "Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools." (January).
- Basel Committee on Banking Supervision. 2009. "Strengthening the Resilience of the Banking Sector." Consultative Document.

- Berrospide, J. 2012. "Liquidity Hoarding and the Financial Crisis: An Empirical Evaluation." Manuscript, Board of Governors of the Federal Reserve System.
- Bonner, C. 2012. "Liquidity Regulation, Funding Costs and Corporate Lending." DNB Working Paper No. 361.
- Brunnermeier, M. K., and L. H. Pedersen. 2009. "Market Liquidity and Funding Liquidity." *Review of Financial Studies* 22 (6): 2201–38.
- Coeur , B. 2013. "Liquidity Regulation and Monetary Policy Implementation: From Theory to Practice." Speech presented at Toulouse School of Economics, Toulouse, October 3.
- Copeland, A., A. Martin, and M. Walker. 2014. "Repo Runs: Evidence from the Tri-Party Repo Market." *Journal of Finance* 69 (6): 2343–80.
- De Haan, L., and J. W. van den End. 2013a. "Bank Liquidity, the Maturity Ladder, and Regulation." *Journal of Banking and Finance* 37 (10): 3930–50.
- . 2013b. "Banks' Responses to Funding Liquidity Shocks: Lending Adjustment, Liquidity Hoarding and Fire Sales." *Journal of International Financial Markets Institutions and Money* 26: 152–74.
- Engle, R., and C. W. J. Granger. 1987. "Forecasting and Testing in Co-Integrated Systems." *Journal of Econometrics* 35 (1): 143–59.
- European Banking Authority Banking Stakeholder Group. 2012. "New Bank Liquidity Rules: Dangers Ahead." EBA Position Paper.
- Financial Stability Board. 2014. "Strengthening Oversight and Regulation of Shadow Banking: Regulatory Framework for Haircuts on Non-Centrally Cleared Securities Financing Transactions." (October).
- Geanakoplos, J. 2010. "The Leverage Cycle." In *NBER Macroeconomics Annual 2009*, Vol. 24, ed. D. Acemoglu, K. Rogoff, and M. Woodford, 1–65. University of Chicago Press.
- Goodhart, C. A., A. K. Kashyap, D. P. Tsomocos, and A. P. Vardoulakis. 2012. "Financial Regulation in General Equilibrium." NBER Working Paper No. 17909.
- Gorton, G. B., and A. Metrick. 2012. "Who Ran on Repo?" NBER Working Paper No. 18455.

- King, M. R. 2010. "Mapping Capital and Liquidity Requirements to Bank Lending Spreads." BIS Policy Paper No. 324.
- Le Lesle, V., and S. Avramova. 2012. "Revisiting Risk-Weighted Assets: Why Do RWAs Differ across Countries and What Can Be Done about It?" IMF Working Paper No. 12/90.
- Pedroni, P. 2001. "Fully Modified OLS for Heterogeneous Cointegrated Panels." In *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*, Vol. 15 of *Advances in Econometrics Series*, ed. B. H. Baltagi, T. B. Fomby, and R. C. Hill, 99–130. Emerald Group Publishing, Ltd.
- Perotti, E., and J. Suarez. 2010. "Liquidity Risk Charges as a Primary Macroprudential Tool." Policy Paper No. 1, Duisenberg School of Finance.
- Wagner, W. 2013. "Regulation Has to Come to Terms with the Endogenous Nature of Liquidity." Policy Brief No. 24, Duisenberg School of Finance.