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Bank liquidity management during financial crises

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Abstract

In this paper, we investigate the impact of financial crises on bank liquidity management, an issue which is crucial for financial stability. Using a sample of European publicly traded banks between 2004 and 2020, we find that financial crises shape banks' liquidity management. During the 2008 global financial crisis and the European sovereign debt crisis of 2010-2012, banks set lower liquidity targets and adjust to such targets faster than in non-crisis periods. Furthermore, different mechanisms are used to achieve these adjustments. During the 2008 global financial crisis, liquidity is improved via a reduction in lending and market debt and through equity repurchases. During the European sovereign debt crisis of 2010-2012, banks adjust their liquidity ratios upward by increasing deposits and reducing market debt. Our findings contribute to the literature on banks' liquidity management during financial crises and bear several policy implications.

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1 Introduction

Deficiencies in bank liquidity management in Europe were pointed out as one of the main reasons for the 2008 global financial crisis (GFC) and the 2010-2012 European sovereign debt crisis (SDC). Therefore, the post-crisis Basel III accords introduced new liquidity requirements to incentivize banks to hold enough liquidity to absorb exogenous shocks and hold stable funds to perform their lending activities even under critical circumstances.

Many studies aim to uncover the determinants and the implications of the GFC (Acharya and Mora, 2015; Cornett et al., 2011) and the SDC (Acharya et al., 2018; Becker and Ivashina, 2018). Most of these studies emphasize the failure of the financial system to fuel enough liquidity and show the necessity of efficient liquidity management in the banking sector. In this vein, DeYoung and Jang (2016) analyze bank liquidity management using the partial adjustment model commonly used to study bank capital structure (e.g., Berger et al., 2008; Lepetit et al., 2015; De Jonghe and Öztekin, 2015). They analyze whether banks set targets for their liquidity ratios and how quickly they adjust towards their optimal liquidity level when they deviate from it.

During the 2008 global financial crisis, banks faced challenges in managing their liquidity, to which they responded by offering higher interest rates to attract deposits and cut lending (Acharya and Mora, 2015). They faced similar difficulties during the European sovereign debt crisis but from different trigger factors. They endured equity losses, which incentivized them to deleverage and reduce their credit supply (Acharya et al., 2018).

Our paper aims to contribute to the liquidity adjustment and financial crises literature by addressing several questions on how banks adjust their liquidity during financial crises: How do financial crises impact banks' desired liquidity levels? When banks deviate from their target levels of liquidity, how quickly do they adjust toward their target during financial crises? Which mechanisms are used by banks to reestablish their desired levels of liquidity during financial crises? Given the differences in trigger factors and circumstances between the 2008 global financial crisis and the sovereign debt crisis, we analyze the impact of each financial crisis on liquidity targets, adjustment speeds, and adjustment mechanisms.

To analyze the impact of financial crises on bank liquidity adjustment, we start by estimating a partial adjustment model of bank liquidity towards a bank-specific and time-varying desired liquidity level (see DeYoung and Jang, 2016). To address our research questions, we focus on the total deposits-to-net loans ratio, to which we add its two components (i.e., total deposits-to-total assets ratio and net loans-to-total assets ratio) and the liquid assets-to-total assets ratio for 163 publicly traded banks from 16 European countries between 2004 and 2020.

We expect that banks' willingness to cut lending and make more efforts to attract new depositors might give them the capacity to adjust quickly toward their liquidity targets during the 2008 global financial crisis. Furthermore, we expect that the equity losses experienced by banks during the sovereign debt crisis, which decreases their capacity to absorb future shocks and incentivizes them to reduce lending, might push banks to quickly adjust toward their liquidity optimal levels

Our approach is similar to that of DeYoung and Jang (2016), who use a partial adjustment model to analyze U.S commercial banks' liquidity management. They find that banks actively manage their liquidity positions by targeting their loans-to-core deposits ratios. We augment and complement their study by drawing the following information on banks' liquidity management. First, we analyze the impact of financial crises on banks' liquidity ratios targeting and their adjustment speeds. We find that banks set lower liquidity targets during the two financial crises. Besides, they adjust faster. Second, we investigate the mechanisms banks use to adjust toward their liquidity targets. We find that, during the 2008 global financial crisis, banks adjust their liquidity by decreasing lending and market debt but also by repurchasing their equity. During the sovereign debt crisis, banks do not decrease lending or equity. Instead,

they increase deposits and decrease market debt. These findings contribute to the bank liquidity management literature, showing how financial crises shape banks' liquidity management.

The remainder of the paper proceeds as follows. Section 2 describes the methodology to estimate liquidity targets and adjustment speeds. Section 3 presents the data and variables of interest. Section 4 discusses our results. Section 5 provides robustness checks and further investigations. Section 6 concludes.

2 Partial adjustment model

Following DeYoung and Jang (2016), we use a partial adjustment model to model the dynamics of banks' liquidity adjustment. We focus on four bank liquidity adjustment features: the liquidity targets, the determinants of those targets, the adjustment speed toward those targets, and the liquidity adjustment speed determinants.

We assume that banks set a liquidity target $L^*_{i,t}$ and would always converge toward it. This liquidity target $L^*_{i,t}$ is unobserved and varies over time. It consists of the bank's observable characteristics $X_{i,t-1}$, and bank and time fixed effects. β is a vector of coefficients to be estimated.

$$L^*_{i,t} = \beta X_{i,t-1} \quad (1)$$

Banks can deviate from their targets. Their decision to adjust their liquidity depends on the tradeoff between the adjustment costs and the costs of operating with suboptimal liquidity. Exogenous shocks can increase the adjustment costs, pushing banks far away from their liquidity targets. During a financial crisis, banks face higher funding costs. They tend to offer higher rates to increase and sustain deposits. Banks may also react by decreasing lending. The above scenario makes converging toward the liquidity target costly and more challenging for banks. To seize this adjustment process, we assume that in each period, banks converge toward their liquidity targets by reducing a constant proportion λ of the gap between $L_{i,t-1}$ and $L^*_{i,t}$:

$$L_{i,t} - L_{i,t-1} = \lambda(L^*_{i,t} - L_{i,t-1}) + \varepsilon_{i,t} \quad (2)$$

Where λ is a scalar adjustment speed, λ ∈ [0; 1] with a higher value indicating that banks converge faster towards their liquidity targets. Substituting Eqs. (1) into (2) yields:

$$L_{i,t} - L_{i,t-1} = \lambda(\beta X_{i,t-1} - L_{i,t-1}) + \varepsilon_{i,t} \quad (3)$$

And, after rearranging, we obtain:

$$L_{i,t} = \lambda\beta X_{i,t-1} + (1 - \lambda) L_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

To calculate bank liquidity targets $L^*_{i,t}$, we recover the estimated adjustment speed $\hat{\lambda}$ from the estimated parameter $\widehat{(1-\lambda)}$ and then divide the estimated parameter $\widehat{\lambda\beta}$ by $\hat{\lambda}$ to recover $\hat{\beta}$ which we use in Eq. (1).

The liquidity adjustment speed λ yielded by Eq.(2) is constrained to be identical for each bank every year. However, the liquidity adjustment speed may vary from one bank to another according to the characteristics and the capacities of each bank. Also, banks may converge towards their liquidity targets at different speeds across time according to the current economic situation and bank specificities. For these reasons, we relax this constraint by defining λ as follows:

$$\lambda_{i,t} = \varphi Z_{i,t-1} \quad (5)$$

where $\lambda_{i,t}$ is the bank-specific, time-varying liquidity adjustment speed. $Z_{i,t-1}$ is a vector of bank and time period characteristics that affect the liquidity adjustment speeds. φ is a vector of coefficients to be estimated. Substituting Eq. (5) into Eq. (3) gives:

$$L_{i,t} - L_{i,t-1} = \varphi Z_{i,t-1}(\beta X_{i,t-1} - L_{i,t-1}) + \varepsilon_{i,t} \quad (6)$$

To estimate this nonlinear equation, we substitute the previously estimated value $\hat{\beta}$ for β. We then rearrange the terms by rewriting $L_{i,t}$ - $L_{i,t-1}$ as $\Delta L_{i,t}$, and $L^*_{i,t} - L_{i,t-1}$ as $GAP_{i,t-1}$, before rearranging:

$$\Delta L_{i,t} = \varphi(Z_{i,t-1}.GAP_{i,t-1}) + \varepsilon_{i,t} \quad (7)$$

The vector of exogenous regressors is now written as the product $Z_{i,t-1}.GAP_{i,t-1}$. The parameter φ can then be estimated and, once $\hat{\varphi}$ is in-hand, we can use Eq. (4) to calculate the liquidity adjustment speed $\lambda_{i,t}$ for each bank *i* in each time period *t*.

3. Data and variables

3.1 Data

We collect financial statement data from the WorldScope database produced by Refinitive. It comprises balance sheet and income statement data of publicly traded banks from 2004 to 2020 for 16 western European countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. We complement our data with macroeconomic data, collected from World Development Indicators (World Bank).

Our initial sample comprises 199 banks. To prevent the undue influence of outliers, we winsorize all bank variables at the 2.5th and 97.5th percentiles for the full sample. We exclude banks with less than four consecutive years of observations on standard variables (total assets, equity, loans, deposits, and net income) to prevent short panel bias. To focus on pure commercial banks, we exclude banks with a deposit-to-assets ratio below 20% and a loan-to-assets ratio below 10% (Beltratti and Stulz, 2012). We end up with an unbalanced panel of 2220 annual observations corresponding to 163 publicly traded banks. Table 1 displays the number of banks per country and the representativeness of the final sample. We gauge the representativeness of our final sample by dividing the total assets of each country in the final sample by the total assets of all banks in the initial sample in the same country for the year 2020. Table 1 indicates that the final sample accounts for more than 88% of the total assets of publicly traded banks covered by WorldScope in the selected countries.

Table 1

Distribution of sample banks by country and representativeness

Country	**Number of banks**	**Representativeness**
Austria	8	1
Belgium	1	0.5141
Denmark	20	0.9985
Finland	3	0.9901
France	17	1
Germany	17	0.9729
Greece	5	0.4550
Ireland	3	1
Italy	11	0.9826
Netherlands	3	1
Norway	30	0.9201
Portugal	2	0.9979
Spain	6	0.9793
Sweden	3	0.9731
Switzerland	21	0.3337
United Kingdom	13	0.9944
Total or Mean	**163**	**0.8820**

3.2. Liquidity target ratios

We measure bank liquidity using the total deposits-to-net loans ratio (*TDNL*), which reflects the portion of loans funded by deposits. Instead of targeting and managing the *TDNL* ratio directly, a bank might focus on one of the subcomponents of the ratio: the net loans-to-total assets ratio (*NLTA*) or the total deposits-to-total assets ratio (*TDTA*). Alternatively, they can manage the two subcomponents separately (DeYoung and Jang, 2016). To capture the dominant strategy followed by banks, we estimate the partial adjustment model for both *TDNL*, *TDTA*, and *NLTA* ratios. Previous studies show that banks' level of liquid assets affects credit supply (see Ananou et al., 2021; Kim and Sohn, 2017; Cornett et al., 2011). Banks' plausible targeting and active management of liquid assets may impact the management and targeting of their *NLTA* and *TDNL* ratios. Therefore, we also estimate the partial adjustment model for the liquid assets-to-total assets ratio (*LATA*).

3.3. Determinants of liquidity target ratios

We consider a vector of determinants $X_{i,t-1}$ that can affect banks' liquidity targets. We rely on the theoretical determinants of liquidity demand (Tirole, 2011) and the variables used by DeYoung and Jang (2016) to specify the determinants of banks' liquidity target ratios. We add crisis dummy variables to assess the impact of the crises on liquidity targets.

The global financial crisis (*GFC*) is defined as a dummy equal to one if observation falls into the period of 2007 to 2009. The sovereign debt crisis (*SDC*) is defined as a dummy equal to one if observation falls into the period of 2010 to 2012. We expect that during the two recent financial crises, banks targeted lower levels of liquidity because of the difficulties of attracting and maintaining funds during these periods.

Bank's size (*Size*) is the natural logarithm of total assets. We expect that larger banks will set lower liquidity targets due to their capacity to diversify their funding sources and their expectations of being rescued by the authorities in case of failure (Jiménez et al., 2012; Popov and Van Horen, 2015). Bank's equity (*Equity*) is defined as total equity divided by total assets. Well-capitalized banks might set higher or lower liquidity targets. On the one hand, with their capability to absorb negative shocks and raise the necessary funding, well-capitalized banks might target lower liquidity ratios (Carlson et al., 2013; Kapan and Minoiu, 2018). On the other hand, higher franchise value might incentivize well-capitalized banks to lend prudently and target higher liquidity ratios (Marcus, 1984; Keeley, 1990). Economic conditions are measured by the global domestic product growth (*GDPGrowth*). Previous studies highlight a positive impact of economic conditions on banks' lending (Ananou et al., 2021; Hasan et al., 2022). We expect that strong economic conditions (i.e., higher GDP growth) will incentivize banks to target lower liquidity ratios.

Summary statistics and variable definitions are displayed in Table 2.

Table 2
Summary statistics
Unbalanced panel of publicly traded European bank between 2004 to 2020 from WorldScope database

Variable	Definition	N	Mean	SD	Min	Median	Max
TDNL	Total deposits/net loans	2,220	0.8057	0.3195	0.2351	0.7680	2.1334
TDTA	Total deposits/total assets	2,220	0.5488	0.1701	0.2030	0.5609	0.8519
NLTA	Net loans/total assets	2,220	0.7151	0.1577	0.1925	0.7462	0.9223
LATA	Liquid assets/total assets	2,220	0.3008	0.1679	0.0826	0.2603	0.9125
∆TDNL	Annual change in TDNL	2,220	0.0109	0.0685	-0.1822	0.0079	0.2207
∆TDTA	Annual Change in TDTA	2,220	0.0026	0.0348	-0.0890	0.0021	0.0897
∆NLTA	Annual change in NLTA	2,220	-0.0048	0.0369	-0.1007	-0.0031	0.0916
∆LATA	Annual change in LATA	2,220	0.0032	0.0359	-0.0855	0.0027	0.0907
TargetTDNL	TDNL estimated target	2,220	0.8015	0.2788	0.1260	0.8146	1.3841
TargetTDTA	TDTA estimated target	2,220	0.5653	0.1268	0.2354	0.5694	0.8411
TargetNLTA	NLTA estimated target	2,220	0.6681	0.1121	0.3738	0.6849	0.8740
TargetLATA	LATA estimated target	2,220	0.2449	0.0600	0.1240	0.2444	0.3688
SpeedTDNL	TDNL estimated adjustment speed	2,220	0.1404	0.0583	0.0336	0.1571	0.2552
SpeedTDTA	TDTA estimated adjustment speed	2,220	0.1189	0.0266	0.0500	0.1187	0.2084
SpeedNLTA	NLTA estimated adjustment speed	2,220	0.2085	0.0347	0.1020	0.2210	0.2731
SpeedLATA	LATA estimated adjustment speed	2,220	0.2398	0.0567	0.1247	0.2367	0.3462
GFC	Dummy equal to one if observation falls into global financial crisis period of 2007 to 2009	2,220	0.1689	0.3748	0	0	1
SDC	Dummy equal to one if observation falls into sovereign debt crisis period of 2010 to 2012	2,220	0.1788	0.3833	0	0	1
Size	Natural logarithm of total assets	2,220	16.5590	2.3871	12.0366	16.4383	21.1244
Equity	Total equity/total assets	2,220	0.0797	0.0366	0.0246	0.0704	0.2340
GDPGrowth	Real gross domestic product growth	2,220	0.0110	0.0278	-0.1082	0.0166	0.2518
BelowTDNL	Equal to one if TDNL<TargetTDNL and zero otherwise	2,220	0.5586	0.4967	0	1	1
BelowTDTA	Equal to one if TDTA<TargetTDTA and zero otherwise	2,220	0.5180	0.4998	0	1	1
AboveNLTA	Equal to one if NLTA>TargetNLTA and zero otherwise	2,220	0.6658	0.4718	0	1	1
BelowLATA	Equal to one if LATA<TargetLATA and zero otherwise	2,220	0.4559	0.4982	0	0	1
GapTDNL	TDNL* minus TDNL	2,220	0.0065	0.3764	-1.9381	0.0535	0.7029
GapTDTA	TDTA* minus TDTA	2,220	0.0185	0.1538	-0.4901	0.0122	0.4774
GapNLTA	NLTA* minus NLTA	2,220	-0.0518	0.1662	-0.3969	-0.0664	0.6407
GapLATA	LATA* minus LATA	2,220	-0.0529	0.1581	-0.7621	-0.0106	0.1987

3. Results

We start by estimating Eq.(3) using the Blundell and Bond (1998) generalized method of moments (GMM) approach to investigate the desired level of liquidity targeted by banks. Then, we estimate Eq.(6) using the ordinary least squares (OLS) estimator to analyze how quickly banks adjust toward their liquidity targets during financial crises. We add bank fixed effects and time fixed effects in the estimations of the two equations.

3.1. Liquidity targets

The estimations of the banks' liquidity targets are reported in Table 3. For the total deposits-to-net loans ratio (column 1), the mean estimated target *TDNL** is equal to 0.8015, which is very close to the mean actual ratio (0.8057). The mean adjustment speed shows that, within one year, banks reduce 48% of the gap between *TDNL* and *TDNL**. Such an adjustment speed enables banks to close 90% of the *TDNL* gap in 3.47 years[1]. The above results show that European publicly traded banks actively manage and target the total deposits-to-net loans ratio.

Banks set lower *TDNL* targets during financial crises. At the GFC and the SDC, banks set a *TDNL* target of 0.685 and 0.7738, respectively, which is relatively low compared to the *TDNL* targets set by banks before and after the two financial crises The liquidity problems several banks face during the financial crises (Acharya and Mora, 2015) can explain why banks set lower liquidity targets during crisis periods.

The results in Table 3 show that banks do not target and actively manage the two components of the *TDNL* ratio separately. They actively manage and target only the total deposits component (total deposits-to-total assets ratio) and not liquidity on the asset side. This result is in line with the findings obtained by DeYoung and Jang (2016) for U.S. banks. Furthermore, we find that banks set higher targets for the liquid assets to total assets ratio during financial crises (Column 4), showing that financial crises incentivize banks to increase their liquid asset holdings, which was shown by Berrospide (2021).

Table 3

Estimating the target liquidity ratio

Parameters for the first stage of the partial adjustment model, estimated for an unbalanced panel of 163 European publicly traded banks from 2004 to 2020 for total deposits/net loans (TDNL), total deposits/total assets (TDTA), net loans/total assets (NLTA), and liquid assets to total assets (LATA). GFC is a dummy equal to one if observation falls into global financial crisis period of 2007 to 2009. SDC is a dummy equal to one if observation falls into sovereign debt crisis period of 2010 to 2012. Size is the natural logarithm of total assets. Equity is total equity/total assets. GDPGrowth is the real gross domestic product growth. First stage estimated using GMM (Blundell and Bond, 1998) with fixed bank effects and fixed year effects. P-values based on robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

	(1) **TDNL**	**(2)** **TDTA**	**(3)** **NLTA**	**(4)** **LATA**
L.Dependent variable	0.5152***	0.8018***	0.8955***	0.8510***
	(0.0778)	(0.0495)	(0.0355)	(0.0670)
GFC	-0.0946***	-0.0296**	-0.0145**	0.0142***
	(0.0227)	(0.0138)	(0.0059)	(0.0051)
SDC	-0.0369*	0.0129	-0.0216***	0.0203***
	(0.0187)	(0.0122)	(0.0061)	(0.0057)
Sizet-1	-0.0544**	-0.0075***	-0.0033**	0.0037*
	(0.0253)	(0.0022)	(0.0014)	(0.0021)
Equityt-1	-0.0159	-0.0043	0.0002	0.0012
	(0.0148)	(0.0027)	(0.0015)	(0.0012)

[1] Computed as log(0.1)/log(1-speed of adjustment)

GDPGrowtht-1	0.3264	0.7737***	0.0046	0.0096
	(0.2001)	(0.2482)	(0.0510)	(0.0419)
Constant	1.3032***	0.2267***	0.1302***	-0.0241
	(0.4391)	(0.0665)	(0.0483)	(0.0195)
Nbr. of obs.	2220	2220	2220	2220
Nbr. of banks	163	163	163	163
AR2 p-stat	0.7823	0.6633	0.5471	0.4669
Hansen p-stat	0.1965	0.1096	0.8487	0.2542
Year FE	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Adjustment speed λ	0.4848	0.1982	0.1045	0.149
Years to close 90% of the gap	3.4716	10.4210	20.8550	14.2724
Mean estimated target by period				
All sample	0.8015	0.5653	0.6681	0.2449
Pre-Crisis	0.8999	0.6196	0.7396	0.2345
Global Financial Crisis	0.6850	0.4718	0.5961	0.2393
Sovereign Debt Crisis	0.7738	0.5906	0.5227	0.2411
Post-Crisis	0.8194	0.5704	0.7224	0.2517

3.2. Liquidity adjustment speeds

The estimations of the liquidity adjustment speeds are displayed in Table 4. For the total deposits-to-net loans ratio (column 1), the average estimated bank-specific adjustment speed $\lambda_{i,t}$ is 0.1404, which is lower than the constrained adjustment speed[2] (λ=0.4848). This difference shows the importance of taking into consideration the differences across banks.

Before the GFC, banks reduce 14% of the *TDNL* gap in one year. However, banks adjust faster during the GFC and close 16% of the *TDNL* gap. Furthermore, they move faster during the SDC and reduce 17% of the liquidity gap. After the crisis, banks decrease their adjustment speeds and close only 12% of their *TDNL* gaps.

Therefore, during financial crises, European banks change their liquidity management by adjusting faster toward their liquidity targets. Banks' higher *TDNL* adjustment speeds during the SDC result from a faster adjustment toward their *TDTA* (column 2). During the GFC, the faster banks' *TDNL* adjustment speeds are associated with a slower adjustment of their *LATA** (column 4). These results can be linked to Baik et al. (2022) who find that banks adjust more rapidly their capital ratios after the GFC.

Overall, our results indicate that the GFC and SDC incentivize banks to reconsider their liquidity management behavior. Specifically, the difficulties of raising sufficient funding during financial crises (Acharya and Mora, 2015) push banks to set lower desired liquidity levels (i.e., targets) and manage those targets more actively by allocating non-trivial portions of their resources to improve their liquidity situation. For example, during the global financial crisis, Banco Santander reduced its liquidity target—measured as the ratio of total deposits to net loans—by 59% compared to the pre-crisis period. In parallel, the bank increased its adjustment speed toward this target from 5% to 7%. Likewise, during the sovereign debt crisis, the Spanish bank lowered its liquidity target by 46% relative to its pre-crisis level, while its speed of adjustment rose to 9%.

Those changes in bank liquidity management may translate into a weaker credit supply.

[2] In the estimation of the liquidity targets Eq.(3), we constrain all banks to have the same adjustment speed λ.

Table 4

Liquidity Adjustment Speeds during Financial Crises

This table displays bank liquidity adjustment speeds during financial crises using a sample of 163 European publicly traded banks during 2004-2020. ΔTDNL is the annual change in total deposits/net loans. ΔTDTA is the annual change in total deposits/total assets. ΔNLTA is the annual change in net loans/total assets. ΔLATA is the annual change in liquid assets/total assets. Gap is the difference between the actual liquidity ratio and the lagged liquidity target. GFC is a dummy equal to one if observation falls into global financial crisis period of 2007 to 2009. SDC is a dummy equal to one if observation falls into sovereign debt crisis period of 2010 to 2012. Below is a dummy equal to one if liquidity actual ratio<liquidity target. Above is a dummy equal to one if liquidity actual ratio>liquidity target. Size is the natural logarithm of total assets. GDPGrowth is the real gross domestic product growth. OLS with bank fixed effects and year fixed effects. P-values based on robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

	(1) ΔTDNL	(2) ΔTDTA	(3) ΔNLTA	(4) ΔLATA
Gapt-1	0.2364**	0.2431***	0.1443**	0.0389
	(0.0966)	(0.0566)	(0.0561)	(0.1230)
Gapt-1xGFC	0.0271***	0.0174	-0.0184	-0.0281**
	(0.0100)	(0.0183)	(0.0242)	(0.0126)
Gapt-1xSDC	0.0529***	0.0397***	-0.0601***	-0.0056
	(0.0094)	(0.0138)	(0.0229)	(0.0099)
Gapt-1xBelowt-1	0.0781*	0.0021		0.1044**
	(0.0420)	(0.0218)		(0.0444)
Gapt-1xAbovet-1			0.0669**	
			(0.0312)	
Gapt-1xSizet-1	-0.0095*	-0.0086***	0.0019	0.0097
	(0.0053)	(0.0032)	(0.0034)	(0.0067)
Gapt-1xGDPGrowtht-1	0.1221	0.4403	0.1048	-0.0645
	(0.2626)	(0.3289)	(0.2350)	(0.1704)
Constant	-0.0314***	-0.0023	0.0027	0.0026
	(0.0101)	(0.0029)	(0.0034)	(0.0044)
Year FE	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES
Observations	2,220	2,220	2,220	2,220
R-squared	0.1540	0.1279	0.1819	0.2015
Number of banks	163	163	163	163
Mean estimated adjustment speed λ by period				
All sample	0.1404	0.1189	0.2085	0.2398
Pre-Crisis	0.1443	0.1148	0.2155	0.2383
Global Financial Crisis	0.1605	0.1314	0.2124	0.2155
Sovereign Debt Crisis	0.1739	0.1422	0.1734	0.2383
Post-Crisis	0.1199	0.1075	0.2177	0.2492

3.3.Liquidity adjustment mechanisms

We analyze the mechanisms banks use to adjust their total deposits-to-net loans ratios depending on their positions relative to their targets (shortfall or surplus).

Banks can re-establish their desired level of liquidity by increasing or decreasing the different components of their balance sheets. To capture the mechanisms banks use to return to their targets, we regress the growth rate of the different balance sheet components on the TDNL ratio deviation. To the best of our knowledge, we are the first to use this approach to examine bank liquidity adjustment mechanisms. This approach is commonly used to study banks' capital adjustments (see e.g., Francis and Osborne, 2012; Lepetit et al., 2015; Bakkar et al., 2019). Specifically, we estimate the following model:

$$\Delta Mechanisms_{i,t} = \alpha_1 + \alpha_2 Shortfall_{i,t-1} + \alpha_3 Shortfall_{i,t-1} \times GFC_t + \alpha_4 Shortfall_{i,t-1} \times SDC_t + \alpha_2 Surplus_{i,t-1} + \alpha_3 Surplus_{i,t-1} \times GFC_t + \alpha_4 Surplus_{i,t-1} \times SDC_t + \alpha_5 GFC_t + \alpha_6 SDC_t + \alpha_7 Controls_{i,t-1} + \varepsilon_{i,t} \quad (7)$$

Where $\Delta Mechanisms_{i,t}$ is the growth rate of different balance sheet components (assets, loans, liquid assets, securities, deposits, total debt, long-term debt, short-term debt, and equity). $Shortfall_{i,t-1}$equal the absolute value[3] of the *TDNL* ratio gap if $TDNL_{i,t-1} < TDNL^*_{i,t}$ and zero otherwise. $Surplus_{i,t-1}$equal the absolute value of the *TDNL* ratio gap if $TDNL_{i,t-1} > TDNL^*_{i,t}$ and zero otherwise. GFC_t is a 2007-2009 global financial crisis dummy variable. SDC_t is a 2010-2012 sovereign debt crisis dummy variable. $Controls_{i,t-1}$ corresponds to the control variables. *MA* is a dummy for mergers and acquisitions equal to one if total assets growth exceeds 25%. *GDPgrowth* is the global domestic product growth. We estimate the model presented in Eq.(7) using an OLS technique including bank and time fixed effects.

The results are displayed in Table 5. During the GFC, banks with a *TDNL* shortfall shrink their lending, reduce their debts, particularly short-term debts, and repurchase equity. During the SDC, they raise more deposits and decrease their debts, particularly long-term debts and do not reduce their lending. These results highlight that banks' responses to a shortfall in their liquidity ratios vary across financial crises.

Banks that face *TDNL* surplus adopt different adjustment mechanisms. During the GFC, they make changes at the liability side of the balance sheet by reducing their deposits and increasing their borrowings. By contrast, during the SDC, they do not expand their borrowings and reduce only their deposit funding.

Differences in the liquidity adjustment mechanisms between the two financial crises reflect the differences in terms of trigger factors and implications of the two crises. During the GFC, the interbank market froze, and banks' liquidity dried up, incentivizing banks to decrease their lending to manage their liquidity risk (Cornett et al., 2011). However, during the SDC, the sovereign bonds were impaired, which hit the balance sheets of banks holding those bonds and caused equity losses (Acharya et al., 2018). Those losses might raise doubt about affected banks' solvency, increase borrowing costs, and make their access to the funding market more difficult.

[3] Following Lepetit et al. (2015), we use the absolute value of the TDNL ratio gap to ease the results' interpretation.

Table 5

Adjustments Mechanisms during Financial Crises for total deposits-to-net loans (TDNL) ratio.

This table displays bank TDNL adjustment mechanisms during financial crises using a sample of 163 European publicly traded banks during 2004-2020. ΔAssets is the annual change in total assets divided by average total assets. ΔLoans is the annual change in net loans divided by average total assets. ΔLiquidAssets is the annual change in liquid assets divided by average total assets. ΔSecurities is the annual change in securities divided by average total assets. ΔDeposits is the annual change in total deposits divided by average total deposits. ΔTotalDebt is the annual change in total debt divided by average total liabilities. ΔLTDebt is the annual change in long-term debt divided by average total liabilities. ΔSTDebt is the annual change in short-term debt divided by average liabilities. ΔEquity is the annual change in total equity divided by average total equity. Shortfall equal to the absolute value of the TDNL gap if TDNLi,t-1<TDNL i,t * and zero otherwise. Surplus equal to the absolute value of the TDNL gap if TDNLi,t-1>TDNL i,t * and zero otherwise. GFC is a dummy equal to one if observation falls into global financial crisis period of 2007 to 2009. SDC is a dummy equal to one if observation falls into sovereign debt crisis period of 2010 to 2012. MA is a dummy for mergers and acquisitions. Dummy equal to one if banks asses growth exceeds 25%. GDPGrowth is the real gross domestic product growth. OLS with bank fixed effects and year fixed effects. P-values based on robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	ΔAssets	**ΔLoans**	**ΔLiquidAssets**	**ΔSecurities**	**ΔDeposits**	**ΔTotalDebt**	**ΔLTDebt**	**ΔSTDebt**	**ΔEquity**
$Shortfall_{t-1}(\beta1)$	-0.0758*	-0.0725**	-0.0151	0.0006	0.0894*	-0.0860***	-0.0410**	-0.0447***	-0.0724
	(0.0434)	(0.0347)	(0.0213)	(0.0166)	(0.0533)	(0.0219)	(0.0174)	(0.0169)	(0.0490)
$Shortfall_{t-1}$xGFC(β2)	-0.0263	-0.0628**	0.0148	-0.0197	-0.0514	-0.0001	0.0267	-0.0218	-0.1999***
	(0.0359)	(0.0273)	(0.0232)	(0.0198)	(0.0410)	(0.0208)	(0.0238)	(0.0300)	(0.0514)
$Shortfall_{t-1}$xSDC(β3)	0.1055***	0.0989***	0.0302*	0.0014	0.2401***	-0.0144	-0.0166	0.0106	0.1247**
	(0.0381)	(0.0311)	(0.0175)	(0.0145)	(0.0448)	(0.0203)	(0.0208)	(0.0201)	(0.0503)
$Surplus_{t-1}(\omega1)$	-0.0809**	-0.0205	-0.0414*	-0.0300	-0.1125***	-0.0003	0.0002	0.0005	-0.0915***
	(0.0334)	(0.0219)	(0.0229)	(0.0195)	(0.0378)	(0.0102)	(0.0067)	(0.0090)	(0.0281)
$Surplus_{t-1}$xGFC(ω2)	0.0964**	-0.0092	0.0453**	0.0343*	0.0105	0.0383**	0.0077	0.0324**	0.0286
	(0.0373)	(0.0147)	(0.0222)	(0.0204)	(0.0227)	(0.0162)	(0.0090)	(0.0157)	(0.0284)
$Surplus_{t-1}$xSDC(ω3)	-0.0023	0.0178	0.0053	-0.0157	-0.0084	-0.0006	-0.0175	0.0201	0.0117
	(0.0308)	(0.0230)	(0.0181)	(0.0146)	(0.0408)	(0.0148)	(0.0113)	(0.0125)	(0.0416)
GFC	-0.0608***	-0.0409***	-0.0134	-0.0020	0.0007	-0.0477***	-0.0378***	-0.0101	0.0600***
	(0.0178)	(0.0126)	(0.0099)	(0.0084)	(0.0190)	(0.0079)	(0.0080)	(0.0086)	(0.0197)
SDC	-0.0426***	-0.0524***	0.0006	-0.0012	-0.0128	-0.0251***	-0.0130**	-0.0117	0.0023
	(0.0161)	(0.0125)	(0.0080)	(0.0069)	(0.0183)	(0.0085)	(0.0065)	(0.0080)	(0.0184)
MA_{t-1}	0.0029	0.0076	-0.0052	-0.0031	-0.0067	0.0042	0.0011	0.0032	0.0081
	(0.0118)	(0.0097)	(0.0058)	(0.0039)	(0.0130)	(0.0058)	(0.0048)	(0.0046)	(0.0128)
$GDPGrowth_{t-1}$	0.8013***	0.6623***	0.1125	0.0138	0.5366***	0.3210***	0.1752**	0.1419	0.4454**
	(0.2127)	(0.1632)	(0.0799)	(0.0769)	(0.2038)	(0.1066)	(0.0699)	(0.0961)	(0.2108)
Constant	0.0804***	0.0536***	0.0244***	0.0214***	0.0453**	0.0341***	0.0219***	0.0112*	0.0698***
	(0.0148)	(0.0124)	(0.0072)	(0.0052)	(0.0179)	(0.0074)	(0.0056)	(0.0064)	(0.0173)
Observations	2,220	2,220	2,220	2,220	2,220	2,218	2,213	2,202	2,220
R-squared	0.2113	0.1863	0.1241	0.1068	0.1341	0.1840	0.0806	0.0518	0.1468
Number of banks	163	163	163	163	163	163	163	163	163
Wald tests									
β1+β2	-0.1021*	-0.1353***	-0.0003	-0.0191	0.0380	-0.0860***	-0.01430	-0.0665**	-0.2723***
β1+β3	0.0297	0.0264	0.0151	0.0020	0.3295***	-0.1004***	-0.0577**	-0.0341	0.0523
ω1+ω2	0.0155	-0.0298	0.0039	0.0043	-0.1020**	0.0380**	0.0079	0.0329*	-0.0629*
ω1+ω3	-0.0832*	-0.0028	-0.0362	-0.0457	-0.1209**	-0.0008	-0.01728	0.0206	-0.0798

4. Robustness checks and further issues

This section checks the robustness of our liquidity adjustment speed results and investigates further issues. In Table 6, we re-run our *TDNL* ratio adjustment speed model on subsamples of large banks[4] versus small banks, banks from GIIPS countries (Greece, Italy, Ireland, Portugal, and Spain) versus banks from non-GIIPS countries, rescued[5] banks versus non-rescued banks. We find that: (1) regardless of the period, large banks manage their balance sheet liquidity less actively than small banks. (2) liquidity adjustment speeds are higher for banks from GIIPS countries in all cases. And (3) rescue packages do not incentivize recipient banks to operate away from their balance sheet liquidity targets. Instead, they use this added resource to adjust faster.

Finally, we run our adjustment speed model Eq.(6) using the bootstrapped procedure[6] and we re-examine this model after excluding the first stage of the health crisis (i.e., 2020). Our results remain the same[7].

Table 6

TDNL Adjustment Speeds during Financial Crises: effect of size, crisis severity, and rescue packages

This table displays cross-section analyses of bank liquidity adjustment speeds during financial crises using a sample of 163 European publicly traded banks during 2004-2020. ΔTDNL is the annual change in total deposits/net loans. Gap is the difference between the actual liquidity ratio and the lagged liquidity target. GFC is a dummy equal to one if observation falls into global financial crisis period of 2007 to 2009. SDC is a dummy equal to one if observation falls into sovereign debt crisis period of 2010 to 2012. Below is a dummy equal to one if liquidity actual ratio<liquidity target. Size is the natural logarithm of total assets. GDPGrowth is the real gross domestic product growth. OLS with bank fixed effects and year fixed effects. P-values based on robust standard errors are shown in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% level, respectively.

	ΔTDNL					
	Large Banks	**Small Banks**	**GIIPS**	**NonGIIPS**	**Rescued**	**NonRescued**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Gapt-1	0.5717**	0.2100*	-0.6451**	0.2405**	0.1052	0.2708***
	(0.2587)	(0.1239)	(0.2806)	(0.0956)	(0.3556)	(0.1009)
Gapt-1xGFC	0.0189	0.0117	0.0346	0.0199**	0.0484*	0.0260**
	(0.0196)	(0.0249)	(0.0693)	(0.0097)	(0.0273)	(0.0126)
Gapt-1xSDC	0.0369**	0.0770***	-0.0238	0.0495***	0.0457***	0.0665***
	(0.0161)	(0.0163)	(0.0515)	(0.0092)	(0.0125)	(0.0125)
Gapt-1xBelowt-1	0.0178	0.0700	0.0772	0.0705*	0.2541*	0.0529
	(0.1004)	(0.0490)	(0.1071)	(0.0421)	(0.1357)	(0.0439)
Gapt-1xSizet-1	-0.0261**	-0.0075	0.0489***	-0.0105**	-0.0011	-0.0120**
	(0.0126)	(0.0077)	(0.0162)	(0.0050)	(0.0176)	(0.0056)
Gapt-xGDPGrowtht-1	0.4026	-0.2710	-0.7448*	0.3646	-0.0761	0.2741
	(0.4211)	(0.4996)	(0.3750)	(0.2923)	(0.2976)	(0.3577)
Constant	0.0111	-0.0499***	0.0021	-0.0323***	-0.0732***	-0.0226**
	(0.0109)	(0.0144)	(0.0139)	(0.0113)	(0.0254)	(0.0109)
Year FE	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
Observations	774	1,446	390	1,830	548	1,672
R-squared	0.2008	0.1485	0.3506	0.1425	0.2470	0.1585
Number of banks	53	110	27	136	37	126

[4] Following Bakkar and Nyola (2021), we define large banks as banks with total assets higher than 30 billion euros.

[5] We base on Petrovic and Tutsh (2009) to define banks rescued during the GFC.

[6] As we used estimated variables (targets) to compute the gap measures, we check the robustness of our results using a bootstrap procedure with 500 replications (Pagan, 1984).

[7] Robustness checks results are available upon request.

Mean estimated adjustment speed λ by period						
All sample	0.0902	0.1628	0.2608	0.1336	0.2138	0.1332
Pre-Crisis	0.1007	0.1609	0.2520	0.1371	0.2254	0.1339
Global Financial Crisis	0.1073	0.1624	0.2954	0.1500	0.2560	0.1517
Sovereign Debt Crisis	0.1065	0.2245	0.2624	0.1644	0.2254	0.1788
Post-Crisis	0.0745	0.1409	0.2506	0.1158	0.1897	0.1104

5. Conclusion

This paper investigates how banks have managed their liquidity during the GFC and the SDC. Our results reveal that financial crises shape banks' liquidity management. During financial crises, banks set lower liquidity targets, and they adjust faster by reducing larger portions of the gap between the actual liquidity ratio and the target ratio. They also use different adjustment mechanisms compared to normal times. Our findings contribute to the bank liquidity management literature and shed light on how financial crises change banks' liquidity behavior. The Basel III liquidity requirements announced after the GFC are expected to enable banks to better absorb possible shocks in the future. However, too stringent rules may also affect banks' profitability and risk behavior. Therefore, supervisors could periodically revise the minimum ratios that banks need to comply with and converge to depending on economic conditions but also on their individual characteristics.

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