SYSTEMIC LIQUIDITY RISK*

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ABSTRACT

The new Basel III regulatory package offers the first global framework for the regulation of liquidity risk. This new regulation intends to address the externalities imposed upon the rest of the financial system (and, ultimately, on the real economy) generated by excessive maturity mismatches. Nevertheless, the new regulation focuses essentially on the externalities generated by each bank individually, thus being dominantly microprudential. We argue that there might also be a specific role for the macroprudential regulation of liquidity risk, most notably in what concerns systemic risk. Our argument is based on theoretical results by Farhi and Tirole (2012) and Ratnovski (2009), and on empirical evidence by Bonfim and Kim (2012). In this article we present some of those empirical results, which provide evidence supporting the existence of collective risk-taking strategies in liquidity risk management, most notably amongst the largest banks.

1. INTRODUCTION

The need to regulate liquidity risk was perhaps one of the most important lessons of the global financial crisis. The proposals included in the Basel III package represent an important step forward, by providing a harmonized set of rules for internationally active banks. This regulation will provide the necessary incentives for banks to reduce their maturity mismatches and to avoid an excessive reliance on short term funding. Furthermore, banks will have to hold a significant amount of high quality liquid assets, which will allow them to more easily react to unexpected liquidity shocks without having to resort to fire sales.

Despite this notable progress, something may be missing from this new framework: the regulation of the systemic component of liquidity risk. According to the IMF (2011), "systemic liquidity risk is the tendency of financial institutions to collectively underprice liquidity risk in good times when funding markets are functioning well because they are convinced that the central bank will almost certainly intervene in times of stress to maintain such markets, prevent the failure of financial institutions, and thus limit the impact of liquidity shortfalls on other financial institutions and the real economy."

In this article, we argue that further regulatory work should be envisaged in this area. The introduction of additional capital requirements for Systemically Important Financial Institutions (SIFIs) will not be sufficient to fully address this shortcoming in the regulatory framework, as this tool is designed to address a different market failure, more specifically, the too-big-to-fail problem. In what concerns systemic liquidity risk, the literature suggests that market failures are mainly associated with incentives for collective risk-taking, due to the explicit or implicit guarantees provided by the lender of last resort. Farhi and Tirole (2012) show

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that banks have incentives to engage in collective risk-taking strategies when there is a strong belief that a (collective) bailout is possible. For instance, let us suppose that in a given country several banks engage in funding liquidity strategies that are deemed as globally risky (*e.g.*, excessive reliance in short term debt to finance long-term assets, large funding gaps or persistent tapping of interbank markets). If several banks engage in these strategies simultaneously, there is naturally an increase in systemic risk. As discussed by Rochet and Tirole (1996) and Ratnovski (2009), a lender of last resort is not necessarily going to bail out one bank that gets into trouble because of its own idiosyncratic wrong choices (unless this bank is clearly too big or to systemic to fail). However, if several banks are at risk, the lender of last resort needs to take the necessary actions to contain systemic risk. In this case, the likelihood of a bailout should increase, as if one of these banks gets into trouble, very likely other banks will follow very soon. Hence, these risk-taking strategies may be mutually reinforcing in some circumstances. This collective behaviour transforms a traditionally microprudential dimension of banking risk into a macroprudential risk, which may ultimately generate much larger costs to the economy.

In this article we summarize some of the main results presented in Bonfim and Kim (2012), which provide empirical evidence supporting the hypothesis of collective risk-taking in liquidity risk management in banking. Using data for European and North-American banks in the run up to the global financial crisis of the last few years, we empirically assess whether there is evidence of collective herding behaviour of these banks in their liquidity risk management choices. Our results suggest that there was some herding in the pre-crisis period, most notably amongst the larger banks.

The remainder of the article is organized as follows. In section 2 we review the literature on liquidity risk management and regulation. In section 3 we present the data and some broad descriptive statistics, while in section 4 we discuss our main empirical results. In section 5 we summarize the current state-of--the-art in liquidity risk regulation and debate the policy implications of our results. Finally, in Section 6 we present some concluding remarks.

2. LITERATURE REVIEW

Over recent years, banks became increasingly complex institutions, being exposed to an intertwined set of risks. The 2008 financial crisis provided a painful illustration of how severe these risks can be and how they can seriously affect the real economy. However, regardless of how complex banks have become, there is an intrinsic risk that lies deep in their core function: banks are special due to their unique intermediation role. They grant loans to entrepreneurs and consumers, providing them with the necessary liquidity to finance their investment and consumption needs. However, banks use only a limited amount of their own resources to obtain this funding. Capital requirements on risky assets constitute a binding constraint for the minimum amount of own funds needed. Most of the funds used by banks are associated with liabilities to third parties. Traditionally, these liabilities would take the form of deposits. These liquid claims allow consumers to intertemporally optimize their consumption preferences, but leave banks exposed to the risk of bank runs, as shown by Diamond and Dybvig (1983). However, the risk of runs acts as a disciplining device on banks (Diamond and Rajan, 2001), given that depositors (Calomiris and Kahn, 1991), as well as borrowers (Kim *et al.*, 2005), have incentives to monitor the risks taken by banks.

Through time, banks gained access to a more diversified set of liabilities to fund their lending activities, thus being exposed not only to traditional runs from depositors, but also to the drying up of funds in wholesale markets, as discussed by Huang and Ratnovski (2011) or Borio (2010), amongst many others. The events that took place in 2007-2008 included at least one traditional bank run from depositors (on Northern Rock, in the UK), but also many other “runs” in markets that were important for banks’ funding[1]. For a long period, interbank markets froze and most banks were not able to issue debt, even if guaranteed by high quality assets (as in the case of covered bonds)[2].

The increased reliance on wholesale funding makes the relationship between funding and market liquidity risk much stronger, as discussed by Brunnermeier and Pedersen (2009), Cai and Thakor (2009), Drehmann and Nikolau (2009), Freixas *et al.* (2011), Krishnamurthy (2010), Milne (2008), Strahan (2008), and Tirole (2011). Funding and market liquidity risk are two distinct concepts: whereas the former can be broadly defined as the risk of losing access to funding (through the form of runs or refinancing risk), the latter can be defined as the ability to sell assets without disrupting their markets prices and eventually incurring in large losses (see, for instance, Cai and Thakor, 2009, Milne, 2008, or Tirole, 2011). Brunnermeier and Pedersen (2009) and Brunnermeier (2009) show that under certain conditions market and funding liquidity risk may be mutually reinforcing, leading to liquidity spirals, most notably when there are systemic risk concerns. For example, if a bank is not able to rollover some of its debt, it may be forced to sell some of its assets to obtain liquidity. However, the fire sale of assets will depress asset prices and shrink banks' assets, given that they are marked-to-market, thus making access to funding even more constrained (Nikolau, 2009).

Given this, even though banks are the main providers of liquidity to the economy, they have to adequately manage the liquidity risk underlying their balance sheet structure, as their maturity transformation function makes them inherently illiquid. To alleviate the maturity gap between assets and liabilities, banks can hold a buffer of liquid assets (Acharya *et al.*, 2011, Allen and Gale, 2004a and 2004b, Farhi *et al.*, 2009, Gale and Yorulmazer, 2011, Rochet and Vives, 2004, Tirole, 2011, and Vives, 2011). However, holding liquid assets is costly, given that they provide lower returns than illiquid assets. Moreover, holding a liquidity buffer may also be inefficient, as it limits banks' ability to provide liquidity to entrepreneurs and consumers. Hence, even though banks have some incentives to hold a fraction of liquid assets (in the form of cash, short term assets or government bonds, for instance), these buffers will hardly ever be sufficient to fully insure against a bank run or a sudden dry up in wholesale markets.

Against this setting, regulation becomes necessary to mitigate some of these risks. One justification for the need to regulate liquidity risk is related to the fact that banks do not take into account the social optimum when they optimize the relationship between risk and return. However, a bank failure may constitute a huge externality on other banks and, ultimately, on the whole economy. This risk is exacerbated by the fact that liquidity shocks are events with very low probability (though with potentially very high impact), thus making it easy to overlook them during good periods. Allen and Gale (2004a, 2004b) show that liquidity risk regulation is necessary when financial markets are incomplete, though emphasizing that all interventions inevitably create distortions. Furthermore, Rochet (2004) argues that banks take excessive risk if they anticipate that there is a high likelihood of being bailed-out in case of distress. Ex-ante regulation of banks' liquidity may mitigate this behaviour. Many other authors share the view that liquidity risk regulation is necessary (Acharya *et al.*, 2011, Brunnermeier *et al.*, 2009, Cao and Illing, 2010, Gale and Yourlmazer, 2011, Holmstrom and Tirole, 1998, and Tirole, 2011, for example). Furthermore, there is mounting evidence on collective risk taking behaviours and systemic liquidity risk, as discussed by Acharya (2009), Acharya and Yorulmazer (2008), Boot (2011), Rajan (2006), and Tirole (2011). Against this background, there are increasing calls for a macroprudential approach to the regulation of liquidity risk (Farhi and Tirole, 2012, Boot, 2011, and Cao and Illing, 2010).

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1 In fact, Northern Rock was more affected by the "run" on wholesale funding than by the traditional depositor run.

2 For further details and analysis of the freeze in interbank markets and constraints in debt issuance during the global financial crisis see Acharya and Merrouche (2012), Afonso *et al.* (2011), Allen and Carletti (2008), Angelini *et al.* (2011), Brunnermeier (2009), or Cornett *et al.* (2011).

3. DATA AND SUMMARY STATISTICS

3.1 Data

Given that one of our objectives is to assess the extent to which banks take each others' choices into account when managing liquidity risk, it is relevant to consider a sufficiently heterogeneous group of banks. With that in mind, we collect data from Bankscope for the period between 2002 and 2009, thus covering both crisis and pre-crisis years. We collect data on European and North-American banks, selecting only commercial banks and bank holding companies for which consolidated statements are available in universal format, so as to ensure the comparability of variables across countries. Savings banks were not included in the dataset, as they usually have different liquidity risk profiles and funding strategies. Using these filters, we collect data for the 500 largest banks (according to Bankscope's universal ranking) during 8 years, for 43 countries. Excluding banks without information on total assets, we obtain 2968 bank-year observations. Almost half of the observations refer to banks in Canada, France, Germany, Italy, Netherlands, Russian Federation, UK and US.

3.2 Liquidity risk measurement

As discussed by Tirole (2011), liquidity cannot be measured by relying on a single variable or ratio, given its complexity and the multitude of potential risk sources. As such, we consider three complementary liquidity indicators: i) loans to customer deposits; ii) the interbank ratio, defined as the ratio between interbank assets (loans to other banks) and interbank liabilities (loans from other banks, including central bank funding); and iii) the liquidity ratio, defined as liquid assets (deposits and loans to banks with less than 3 months residual maturity, quoted/listed government bonds realizable within 3 months, cash and equivalents) as a percentage of customer deposits and short-term funding.

The ratio between credit granted and deposits taken from customers provides a broad structural characterization of banks' main funding risks. Given that customers deposits are generally a stable funding source (in the absence of bank runs), those banks that finance most or all of their credit with deposits should, ceteris paribus, be less exposed to liquidity risk. In contrast, banks that show a large funding gap, *i.e.*, a very high loan-to-deposit ratio, will be more exposed to this risk, as they will need to rely on wholesale funding markets. Against this background, banks in which wholesale market funding as a percentage of assets is higher will be more sensitive to refinancing risk. This latter risk will be higher the shorter is the maturity of market funding. Hence, the analysis of the balance sheet structure based on the above mentioned liquidity indicators (loan-to-deposit ratio, funding gap or market funding as a percentage of assets) does not allow for a complete assessment of liquidity risk, as these indicators are unable to take into account the maturity mismatch between assets and liabilities. Furthermore, these are essentially structural indicators and thus strategic and cyclical changes may take some time to be reflected in the data. As such, the liquidity indicators mentioned above are insufficient to globally assess the liquidity position of credit institutions.

The interbank ratio allows assessing another dimension of bank's funding liquidity risk, evaluating whether banks are net borrowers or net lenders in interbank markets. Interbank markets allow markets to close, by allowing banks with short-term liquidity needs to obtain funds from other banks with temporary excess liquidity. However, after August 2007, unsecured money markets became severely impaired for a long period. Wagner (2007a) shows that interbank markets may be inefficient in providing liquidity when banks are hit by aggregate liquidity shocks. Against this background, the interbank ratio measured, for instance, as the ratio between interbank assets and interbank liabilities, may also be an important input to the assessment of liquidity risk. In fact, if banks structurally rely on funding from interbank markets, which is usually characterized by very short maturities, they may have severe difficulties in rolling over their debt in periods of distress.

Finally, another important dimension of liquidity risk is related to the buffer of liquid assets held by banks. Refinancing risk may be mitigated if banks hold a comfortable buffer of high quality very liquid assets that they can easily dispose of in case of unexpected funding constraints. In this respect, the ratio of liquid assets to short-term funding also provides important insights into banks' liquidity risk.

Taken together, these indicators allow us to capture different dimensions of liquidity risk, including structural balance sheet risks, exposures to short-term funding in interbank markets and the availability of a pool of highly liquid assets to face unexpected shocks. A more complete liquidity indicator would rely on the overall maturity mismatch between assets and liabilities. However, the data necessary for such an indicator are not available.

In Panel A of Table 1 we present summary statistics for these three indicators and in Panel B we depict their evolution during the sample period.

During the last decades, banks have moved from a traditional intermediation paradigm in which most loans were funded through deposits (thus implying loan to deposits ratios not far from 100%) to a new framework of bank funding. As access to wholesale markets became more generalized, banks were able to diversify their funding sources. This had implications on the maturity transformation role of banks. Looking at the pre-crisis period, we observe a consistent increase in this ratio, from 116.7 per cent in 2002 to 148.8 per cent in 2008.

The interbank ratio also recorded some deterioration during this period. Nevertheless, it is important to note that the financial market turmoil that began in August 2007 makes the intertemporal analysis of this ratio more challenging. During most of the global financial crisis, the lack of confidence led to severe disruptions in the functioning of interbank markets. Uncollateralized operations almost ceased to exist during significant periods and high haircuts were imposed on collateralized operations. Thus, there is a clear series break in this indicator from August 2007 onwards.

In contrast, there does not seem to exist evidence of any dilapidation of the buffer of liquid assets or of a relative increase in short-term funding of European and North-American banks in the run up to the crisis. However, in 2008 there was a marked deterioration in this liquidity ratio, mainly due to the strong growth in customer and short-term funding. Hence, even though most banks did not have to sell liquid assets to face short term funding needs, their maturity profile took a pronounced turn for the worse. During this period, many banks were not able to issue medium and long-term debt securities, thus shortening the average maturity of their liabilities.

Table 1

LIQUIDITY INDICATORS - SUMMARY STATISTICS

	Panel A - Global summary statistics								
	N	mean	min	p1	p25	p50	p75	p99	max
Loans to customer deposits	2744	133.9	0.3	5.3	76.5	106.1	151.2	738.1	961.3
Interbank ratio	2403	139.5	0.0	0.5	29.5	70.6	160.9	892.1	998.6
Liquidity ratio	2926	37.8	-6.6	1.1	15.5	28.8	46.6	172.8	842.3

	Panel B - Liquidity indicators over time (mean)								
	2002	2003	2004	2005	2006	2007	2008	2009	Total
Loans to customer deposits	116.7	105.2	116.4	131.0	134.9	137.5	148.8	139.7	133.9
Interbank ratio	212.3	182.3	156.4	148.0	147.1	136.6	106.8	116.2	139.5
Liquidity ratio	39.6	37.4	35.9	38.5	38.8	36.5	32.1	32.2	37.8

Sources: Bankscope and author's calculations.

Notes: The interbank ratio is defined as interbank assets as a percentage of interbank liabilities (loans to other banks as a percentage of loans from other banks). The liquidity ratio is defined as liquid assets (deposits and loans to banks with less than 3 months residual maturity, quoted/listed government bonds realizable within 3 months, cash and equivalent), as a percentage of customer deposits and short term funding.

4. EVIDENCE OF HERDING BEHAVIOUR IN LIQUIDITY RISK MANAGEMENT

It is possible to argue that banks do not optimize their liquidity choices strictly at the individual level. For instance, when other banks are taking more risk, any given bank may have the incentives to engage in similar strategies. These collective risk-taking strategies may be optimal from an individual perspective, as they should allow banks to increase profitability without increasing the likelihood of bankruptcy, due to the explicit or implicit commitment of the lender of last resort, as theoretically conjectured by Ratnovski (2009).

Using data for European and North-American banks in the run up to the global financial crisis of the last few years, in this section we empirically assess whether there is evidence of collective herding behaviour of these banks in their liquidity risk management choices. This analysis is very relevant from a policy perspective, as it may contribute to the discussion on how regulation can provide the correct incentives to minimize negative externalities. Indeed, evidence of collective risk-taking behaviours on liquidity risk may support the need to consider specific macroprudential tools to address systemic liquidity risks.

4.1 Statistical evidence of herding behaviour

4.1.1 Methodology

Our first step is to estimate measures of herding frequently used in financial markets (see, for example, Graham, 1999, Grinblatt *et al.*, 1995, Scharfstein and Stein, 1990, or Wermers, 1999). To do that, we adapt the often used herding measure proposed by Lakonishok *et al.* (1992) and applied to bank herding by Uchida and Nakagawa (2007) and, more recently, by Van den End and Tabbae (2012). This methodology allows testing the extent to which the liquidity choices of banks collectively deviate from what could be suggested by overall macroeconomic conditions. Implicitly, we are considering a concept of "rational herding", as defined by Devenow and Welch (1996). In other words, we do not consider that banks simply mimic each other's behaviours, but rather that they do so because there are important externalities that affect the optimal decision making process.

We compute:

$$H_i = | P_i - P_t | - E | P_i - P_t |$$

where P_i is the proportion of banks that show an increase in risk for a given liquidity indicator in each country and in each year, computed as $\frac{X_i}{N_i}$. X_i is the number of banks that recorded a deterioration of a liquidity indicator in a country in a given year, and N_i is the total number of banks operating in each country and in each year. For the loan-to-deposit ratio, X_i refers to the number of banks that showed an increase in this ratio, while for the other two liquidity indicators X_i refers to the number of banks that recorded a decrease in these indicators, *i.e.*, an increase in risk. P_t is the mean of P_i in each year. P_t can be interpreted as an indicator of banks' liquidity choices that reflect overall macroeconomic and financial conditions. The difference between P_i and P_t measures to what extent liquidity indicators in one country and in one year deviate from the overall liquidity indicators in that year, *i.e.* from common factors. According to the methodology proposed by Lakonishok *et al.* (1992), when banks independently increase or decrease liquidity indicators, P_i and P_t become closer and $| P_i - P_t | \to 0$. However, when several banks collectively deviate and increase or decrease their liquidity indicators, P_i departs from P_t. The second term in the equation is used to normalize the herding measure.

Computing this at the country level is crucial if we consider that the incentives for herding are much stronger amongst national peers. The common belief of bail out is more likely to be shared by banks in the same country. Indeed, the arguments to support that banks take riskier strategies because banks operating in other countries do so are much weaker than when considered at the national level. This will be particularly true if competition between banks exists within markets segmented by national borders.

4.1.2 Results

Table 2 shows our estimates for this herding measure for the three liquidity indicators. In some years we find significant evidence of herding behaviour, most notably in the years preceding the global financial crisis. For the loan-to-deposit ratio, there was statistically significant herding behaviour in 2003 and 2005. Collective risk-taking behaviour also seems to have been present in interbank markets between 2004 and 2006. The results are even stronger for the liquidity ratio, with significant results for the entire pre-crisis period (2003 to 2007). Finally, we also observe some herding during the crisis in the loan-to--deposit ratio. This may reflect a general decrease in this ratio due to a collective deleveraging process in some countries during this period.

All in all, these results support the hypothesis of collective risk taking before the crisis. Nevertheless, this traditional herding measure has several limitations and cannot be regarded as a full characterization of collective risk taking. This is essentially a static measure and, more importantly, it only considers whether or not there was an increase in risk, without considering its magnitude. Furthermore, this measure does not take into account all other possible determinants of liquidity choices. It is possible that common behaviours are observed because banks are affected by common shocks or because they share common characteristics, rather than by true herding behaviour. Hence, only in a multivariate setting, where bank specific characteristics and time effects are explicitly controlled for, it becomes possible to isolate the impact of other banks' choices on each individual bank. In the next subsection we deal with the identification challenges raised by this multivariate analysis.

Table 2

MEASUREMENT OF HERD BEHAVIOR (MEAN)

	Loans to customer deposits	Interbank ratio	Liquidity ratio
2003	0.063***	-0.004	-0.019**
2004	0.011	0.024***	0.039***
2005	0.028***	-0.014**	-0.017***
2006	-0.008	-0.017***	0.022***
2007	-0.005	0.003	-0.032***
2008	-0.011	0.001	0.004
2009	-0.028***	0.010	0.005

Sources: Bankscope and author's calculations.

Notes: Herd behaviour measure based on Uchida and Nakagawa (2007) and Lakonishok et al (1992). The herding measure is computed as Hi = |Pi - Pt | - E|Pi - Pt |, where Pi is the proportion of banks that show an increase in risk for a given liquidity indicator in each country and in each year (i.e., increases in loan to deposit ratios or decreases in the interbank or liquidity ratio) and Pt is the mean of Pi in each year. Liquidity indicators as defined in previous tables.*** significant at 1%; ** significant at 5%; * significant at 10%.

4.2 Multivariate analysis

4.2.1 Identification methodology

In a multivariate setting, the impact of peers' liquidity indicators on a bank's liquidity decisions could be estimated through the following equation:

$$Liqx_{it} = \alpha_0 + \alpha_i + \beta_0 \sum_{j \neq i} \frac{Liqx_{jt}}{N_{it} - 1} + \beta_1 X_{it-1} + i_t + e_{it} \quad (1)$$

where $Liqx_{it}$ is one of the three liquidity indicators analyzed (loan-to-deposit ratio, interbank ratio and liquidity ratio, respectively), and $\sum_{j \neq i} \frac{Liqx_{jt}}{N_{it} - 1}$ represents the average liquidity indicators of peers. In this setting, the coefficient β_0 captures the extent to which banks' liquidity choices reflect those of the relevant peer group. α_0 is a constant, α_i is the bank fixed effect, i_t is the year fixed effect and e_{it} is the estimation residual. X_{it-1} is a vector of control variables, which includes a set of core bank indicators on solvency, size, profitability, efficiency and specialization. More specifically, the variables included are: the Tier 1 capital ratio calculated according to the rules defined by the Basel Committee; bank size measured by the log of assets; two indicators on profitability (return on assets and net interest margin); the cost-to-income ratio, which is a proxy for cost-efficiency; and net loans as a percentage of total assets, to measure to what extent a bank is specialized in lending. In each estimation, we also control for the other two liquidity indicators. All variables are lagged by one period to mitigate concerns of simultaneity and reverse causality.

However, the estimation of equation 1 entails serious econometric problems: as we argue that peer choices may affect the decisions of a specific bank, we cannot rule out that the decisions of that bank will not, in turn, affect the choices made by peers. This reverse causality problem in peer effects is usually referred to as the reflection problem. This problem was initially described by Manski (1993), who distinguishes three different dimensions of peer effects: i) exogenous or contextual effects, related to the influence of exogenous peer characteristics; ii) endogenous effects, arising from the influence of peer outcomes (in our case, peers' liquidity choices); and iii) correlated effects, which affect simultaneously all elements of a peer group. Empirically, it is very challenging to disentangle these effects.

This discussion makes clear that the estimation of the equation above would not allow for the accurate estimation of peer effects. Our solution to this important identification problem relies on the use of an instrument to address this endogeneity problem. As discussed in Brown *et al.* (2008) and Leary and Roberts (2010), such an instrument must be orthogonal to systematic or herding effects. Given this, we use the predicted values of liquidity indicators of peer banks based on a regression of the determinants of liquidity indicators[3]. The predicted values depend on the characteristics of the banks in the peer group, excluding bank *i*. These predicted values depend only on observable bank characteristics and should thus be orthogonal to systematic or herding effects.

As in the previous subsection, we define the benchmark peer group as the banks operating in the same country and in the same year. These are the banks that are more likely to engage in collective risk-taking behaviours due to implicit or explicit bailout expectations.

3 For further details on this identification strategy, see Bonfim and Kim (2012).

4.2.2 Results

In Table 3 we present the results of the instrumental variable approach in the estimation of peer effects in liquidity risk management. In the first three columns we present, for illustrative purposes, the results of the estimation of equation 1. Hence, in these columns the peer effects are included in the regressions without properly addressing the reflection problem discussed before. When running this simple, yet biased, estimation, we find strong evidence of positive peer or herding effects in individual banks' choices of loan to deposit ratios (column 1) and of the liquidity ratio (column 3). The higher the funding gap of other banks in a given country, the higher should be the loan to deposit ratio of a given bank in that country. At the same time, the lower the average liquidity ratio of peers is (either because they hold few liquid assets or because they rely excessively on short-term funding) the more vulnerable is a bank's liquidity position. In what concerns the interbank ratio, this specification does not yield any significant results regarding peer effects.

The second group of columns displays our main empirical results, when adequately dealing with the serious endogeneity problem created by considering peer effects. When we use the predicted values of peer's liquidity indicators as instruments, we conclude that the results presented in the first three columns

Table 3

REGRESSIONS ON PEER EFFECTS IN LIQUIDITY STRATEGIES

	Interaction with other banks - country year rivals (without instrumental variables)			Interaction with other banks (country year rivals) - Instrumental variable = predicted values of rivals' liquidity ratios			First-step regressions		
	Loans to customer deposits	Interbank ratio	Liquidity ratio	Loans to customer deposits	Interbank ratio	Liquidity ratio	Loans to customer deposits	Interbank ratio	Liquidity ratio
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Peers' loans to customer deposits	0.223***	-	-	-0.118		-	0.453***		
	3.04	-	-	*-0.26*		-	*3.58*		
Peers' interbank ratio	-	0.158	-	-	-0.785	-	-	-0.062	
	-	*1.31*	-	-	*-0.20*	-	-	*-0.60*	
Peers' liquidity ratio	-	-	0.248***	-	-	0.224	-	-	0.250***
	-	-	*2.82*	-	-	*0.38*	-	-	*3.65*
Bank-specific controls	S	S	S	S	S	S	S	S	S
Fixed-effects	S	S	S	S	S	S	S	S	S
Number of observations	1 211	1 241	1 210	1 180	1 222	1 178	1 180	1 222	1 178
Number of banks	323	342	322	323	342	322	323	342	342
R2 within	0.127	0.083	0.236	0.076	.	0.223	0.000	0.000	0.000
R2 between	0.153	0.019	0.452	0.108	0.010	0.453	0.013	0.031	0.174
R2 overall	0.176	0.019	0.429	0.114	0.007	0.434	0.039	0.002	0.214

Sources: Bankscope and author's calculations.

Notes: All regressions include bank fixed-effects. *t*-statistics in italic. Peers are defined as the j≠i banks operating in the same country and in the same year as bank i. Columns 1, 2 and 3 show the results obtained when peer liquidity choices are considered directly in the regressions, i.e., not addressing the reflection problem. Columns 4 to 6 show the results of three instrumental variables regressions (one for each liquidity indicator), where the instruments are the predicted values of peers' liquidity ratios. Columns 7, 8 and 9 show the first stage estimation results for these three instrumental variables regressions. Both in the first and second step of the estimation several bank specific variables are included: the Tier 1 capital ratio calculated according to the rules defined by the Basel Committee; bank size measured by the log of assets; two indicators on profitability (return on assets and net interest margin); the cost-to-income ratio; and net loans as a percentage of total assets. In each estimation, we also control for the other two liquidity indicators. The interbank ratio is defined as interbank assets as a percentage of interbank liabilities (loans to other banks as a percentage of loans from other banks). The liquidity ratio is defined as liquid assets (deposits and loans to banks with less than 3 months residual maturity, quoted/listed government bonds realizable within 3 months, cash and equivalent), as a percentage of customer deposits and short term funding. *** significant at 1%; ** significant at 5%; * significant at 10%.

do not hold: peer effects are not statistically significant in any of the three regressions, even though for the liquidity ratio the associated coefficient remains positive and large. Thus, there seems to be a strong indication that neglecting endogeneity in peer effects may originate biased and incorrect results.

This lack of significance cannot be attributed to the weakness of the instrument used. A good instrument should have an important contribution in explaining the potentially endogenous variable, *i.e.* the average peers' liquidity choices, but it should not directly affect the dependent variable. In the last group of columns of Table 3 we show that the chosen instrument is strongly statistically significant in the two regressions most affected by the endogeneity problem: the one on loan-to-deposit ratios and the other on the liquidity ratio.

However, given that our previous measures of herding behaviour suggested the existence of peer effects, we consider that it is important to run several robustness tests before rejecting the hypothesis of collective behaviour in a multivariate setting.

From all the robustness tests conducted, the only consistently significant results are presented in Table 4.[4] These tests involved testing other possible definitions of the peer group. Indeed, the definition of the peer group is a critical issue in the analysis of peer effects (Manski, 2000) and deserves further analysis. Even though we believe that defining peers as other banks in the same country is the most reasonable assumption, due to the common lender of last resort, this definition may be challenged.

When we test different definitions of peer groups, we are able to obtain consistently significant results for a specific group of banks. More specifically, we are able to find consistent and significant evidence that peer effects are important determinants in the liquidity choices of the largest banks. There are several possible related reasons behind this result. First, larger banks are likely to compete mainly among themselves, replicating risk-taking strategies that allow for profit maximization. Second, larger banks have access to more diversified funding sources, usually with lower funding costs, thus allowing them to collectively engage in similar funding and liquidity strategies. Third, larger banks may have better liquidity risk management tools, reflected in similar liquidity choices. Finally, and perhaps more importantly, larger banks are more likely to be bailed out in case of systemic distress than smaller banks, thus facing more similar incentives.

We also find some evidence that small banks might be following the strategies of larger banks, but this result only holds for one specific definition of large banks (*i.e.*, those belonging to the Euribor panel).

In sum, when all banks are considered, evidence on peer effects is statistically weak, after dealing with the endogeneity problem. These results are consistent with the evidence obtained by Jain and Gupta (1987), who analyze herding effects between US commercial banks, finding only weak evidence of herd behaviour. However, we are able to find consistent evidence that there are significant peer effects amongst larger banks.

5. REGULATION AND POLICY IMPLICATIONS

The regulation of liquidity risk can be justified by the fact that banks do not take into account the social optimum when they optimize the relationship between risk and return. Ex-ante regulation of banks' liquidity may mitigate this behaviour, as discussed by Acharya *et al*. (2011), Allen and Gale (2004a, 2004b), Brunnermeier *et al.* (2009), Cao and Illing (2010), Gale and Yourlmazer (2011), Holmstrom and Tirole (1998), Rochet (2004), and Tirole (2011).

4 A detailed description of all the robustness tests conducted may be found in Bonfim and Kim (2012). These included, among others, the exclusion of the crisis period, the inclusion of a set of country-specific macroeconomic variables, estimation in first differences, lagged peer effects, and exclusion of banks with asset growth above 50% (as they might have been involved in mergers and acquisitions).

Table 4

REGRESSIONS ON PEER EFFECTS IN LIQUIDITY STRATEGIES - ROBUSTNESS ON PEER GROUP DEFINITION

	Interaction with other banks - country year rivals (without instrumental variables)			Interaction with other banks (country year rivals) - Instrumental variable = predicted values of rivals' liquidity ratios			First-step regressions		
	Loans to customer deposits	Interbank ratio	Liquidity ratio	Loans to customer deposits	Interbank ratio	Liquidity ratio	Loans to customer deposits	Interbank ratio	Liquidity ratio
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Large banks (4th quartile in each country)									
Peer effects	0.003	0.193**	0.040	0.099	0.810**	0.135	1.157***	0.719***	1.022***
	0.05	*2.35*	*0.63*	*0.52*	*2.28*	*0.82*	*6.31*	*4.01*	*6.06*
Large banks (3rd and 4th quartiles)									
Peer effects	0.262***	0.221*	0.228***	-0.807*	0.586*	0.333	0.514***	1.167***	0.532***
	3.38	*1.96*	*2.81*	*-1.72*	*1.83*	*1.00*	*3.59*	*4.60*	*4.81*
Large banks (top 5 in each country)									
Peer effects	0.047	0.383***	0.261**	0.418**	0.887	-0.030	0.632***	0.563**	0.801***
	1.44	*3.61*	*2.33*	*1.99*	*1.51*	*-0.14*	*4.34*	*2.17*	*5.08*
Large banks (banks classified as SIFIs)									
Peer effects	-0.491***	0.025	0.369**	-0.146	0.115*	-0.992	0.026	2.081***	0.105
	-2.36	*0.46*	*2.24*	*-0.06*	*1.69*	*-0.31*	*0.44*	*4.98*	*0.48*
Small banks following large banks (Euribor panel)									
Peer effects	0.260	-0.087***	0.120	0.582	0.231	0.660***	0.633***	1.107***	0.657***
	0.88	*-3.22*	*1.50*	*1.35*	*0.84*	*2.73*	*9.01*	*24.34*	*8.85*

Sources: Bankscope and author's calculations.

Notes: *t*-statistics in italic. Each line shows the coefficients for these peer effects for different robustness tests. Bank quartiles were defined based on banks' total assets. Top 5 referes to the banks classified as being in the top 5 by assets in each country in Bankscope. The list of SIFIs (systemically important financial institutions) is the one disclosed by the Financial Stability Board in 2011. Columns 1, 2 and 3 show the results obtained when peer liquidity choices are considered directly in the regressions, i.e., not addressing the reflection problem. Columns 4 to 6 show the results of three instrumental variables regressions (one for each liquidity indicator), where the instruments are the predicted values of peers' liquidity ratios. Columns 7, 8 and 9 show the first stage estimation results for these three instrumental variables regressions. Both in the first and second step of the estimation several bank specific variables are included: the Tier 1 capital ratio calculated according to the rules defined by the Basel Committee; bank size measured by the log of assets; two indicators on profitability (return on assets and net interest margin); the cost-to-income ratio; and net loans as a percentage of total assets. In each estimation, we also control for the other two liquidity indicators. All regressions include bank fixed-effects. *** significant at 1%; ** significant at 5%; * significant at 10%.

However, a consensus is far from being reached on the optimal regulatory framework to mitigate liquidity risk, both academically and politically, though a remarkable progress has been achieved during the last few years. Traditionally, reserve requirements on bank deposits were the main tool for liquidity risk management, though they also play an important role in the implementation of monetary policy (Robitaille, 2011). More importantly, deposit insurance is by now broadly recognized as an important tool in preventing depositors' bank runs[5]. Explicit deposit insurance can sustain runs on bank deposits, as shown by Diamond and Dybvig (1983)[6]. However, deposit insurance can only be efficient in minimizing the likelihood of bank runs by depositors. For instance, Bruche and Suarez (2010) show that deposit insurance can cause a freeze in interbank markets when there are differences in counterparty risk. Indeed, deposit insurance is not sufficient to forestall all liquidity-related risks and may generate moral hazard (Ioannidou and Penas, 2010, Martin, 2006). Given the increased diversification of banks' funding sources (Strahan, 2008), other regulatory mechanisms must be envisaged to ensure the correct alignment of incentives. The dispersion of creditors and the diversification of risks and activities undertaken by banks make this issue even more complex.

Recent and ongoing discussions have suggested the possibility of further increasing capital requirements to also include liquidity risks[7] (Brunnermeier *et al.*, 2009). However, there are several opponents to this view. As argued by Ratnovski (2007), funding liquidity risk is in part related to asymmetric information on banks' solvency. Increasing solvency without reducing the asymmetric information problem would not reduce refinancing risk. Perotti and Suarez (2011) have also put forth a proposal regarding a liquidity insurance mechanism to avoid systemic crises.

Many authors discuss the importance of holding a liquidity buffer. In a recent paper, Ratnovski (2009) discusses the trade-offs between imposing quantitative requirements on banks' liquidity holdings and improving the incentive scheme in lender of last resort policies. This author argues that quantitative requirements can achieve the optimal liquidity level, but not without imposing costs, whereas a lender of last resort policy that takes into account bank capital information may reduce distortionary rents, thus allowing for a more efficient solution. Nevertheless, transparency seems to be a critical issue in the latter case, as also discussed in Ratnovski (2007). There are many other contributions in the academic literature pointing to the possibility of imposing minimum holdings of liquid assets (Acharya *et al.*, 2011, Allen and Gale, 2004a and 2004b, Farhi *et al.*, 2009, Gale and Yorulmazer, 2011, Rochet and Vives, 2004, Tirole, 2011, and Vives, 2011). However, Wagner (2007b) shows that, paradoxically, holding more liquid assets may induce more risk-taking by banks. Freixas *et al.* (2011) show that central banks can manage interest rates to induce banks to hold liquid assets, *i.e.*, monetary policy can help to promote financial stability. In turn, Bengui (2010) finds arguments to support a tax on short-term debt, whereas Cao and Illing (2011) show that imposing minimum liquidity standards for banks ex-ante is a crucial requirement for sensible lender of last resort policies. Finally, Diamond and Rajan (2005) and Wagner (2007a) focus on ex-post interventions.

Against this background, the new Basel III regulatory framework will be essentially based on the definition of minimum holdings of liquid assets and on restrictions to short-term funding. Globally, liquidity risk regulation was perhaps somewhat overlooked before the global financial crisis, with almost non-existent internationally harmonized rules (Rochet, 2008). However, the role played by funding liquidity during the global financial crisis made clear that a new international regulatory framework was necessary. In December 2010, the Basel Committee disclosed the final version of the international framework for liquidity risk regulation (Basel Committee, 2010), which is an important part of the new Basel III regulatory package. This new regulation provides the necessary incentives for banks to hold adequate liquidity buffers and to avoid over relying on short-term funding. Liquidity risk regulation will be based upon two key indicators: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR

5 During the recent crisis, many governments in advanced economies decided to increase the coverage of their national deposit insurance schemes to avoid panic runs.

6 However, Demirgüç-Kunt and Detagriache (2002) find that explicit deposit insurance increases the likelihood of banking crises, using data for 61 countries. This empirical result is stronger when bank interest rates are deregulated, the institutional environment is weak and the scheme is run or funded by the government.

7 In Basel II, capital requirements were set to explicitly cover credit, market and operational risks, but not liquidity risk.

will require banks to hold sufficient high-quality liquid assets to withstand a 30-day stressed funding scenario, being a ratio between the value of the stock of high quality liquid assets in stressed conditions and total net cash outflows, calculated according to scenario parameters defined in the regulation. High quality assets are considered to be those that have low credit and market risk, are easy to price, show a low correlation with risky assets and are listed on a developed and recognized exchange market. In turn, the NSFR is a longer-term structural ratio designed to address liquidity mismatches and to encourage an increased reliance on medium and long-term funding, thus increasing the average maturity of banks' liabilities. The NSFR is the ratio between the available and the required amount of stable funding, which should be at least 100%. According to the Basel Committee (2010), "this metric establishes a minimum acceptable amount of stable funding based on the liquidity characteristics of an institution's assets and activities over a one year horizon. This standard is designed to act as a minimum enforcement mechanism to complement the LCR and reinforce other supervisory efforts by promoting structural changes in the liquidity risk profiles of institutions away from short-term funding mismatches and toward more stable, longer-term funding of assets and business activities." The two indicators are complementary and ensure that banks hold an adequate pool of liquid assets, while simultaneously adopting a reasonable and prudent maturity mismatch.

This new regulation addresses the externalities generated by each bank individually, thus being dominantly microprudential. Still, the new regulation also entails some macroprudential concerns: on one hand, the LCR is calibrated to ensure that banks are able to withstand a 30-day period without access to market funding, under stress conditions; on the other hand, the NSFR limits the risk of collective excessive reliance on short-term funding. However, none of these ratios explicitly addresses systemic liquidity risk. There is increasing evidence that there is a systemic component in liquidity risk, thus asking for a specific macroprudential approach to this market failure. Indeed, our empirical results show that there are significant herding effects between banks, most notably amongst the largest banks. Moreover, these empirical results complement recent theoretical evidence showing that when most banks are overtaking risks, each bank manager has clear incentives to herd, instead of leaning against the wind. In this respect, Ratnovski (2009) argues that, in equilibrium, banks have incentives to herd in risk management, choosing suboptimal liquidity as long as other banks are expected to do the same. These collective risk-taking strategies may be optimal from an individual perspective, as they should allow banks to increase profitability without increasing the likelihood of bankruptcy, due to the explicit or implicit bail out commitment of the lender of last resort. These arguments are also discussed in detail by Farhi and Tirole (2012), who argue that when banks simultaneously increase their liquidity risk, through larger maturity mismatches, current and future social costs are being created. Given all these market failures, regulation is needed to ensure that these externalities are considered by banks in their liquidity risk management. Nevertheless, the costs and distortions generated by such regulation also need to be taken into account.

Acharya *et al*. (2011) consider the effect of the business cycle on banks' optimal liquidity choices and prove that during upturns banks' choice of liquid assets jointly decreases. In turn, Allen *et al.* (2012) show that when banks make similar portfolio decisions systemic risk increases, as defaults become more correlated. Jain and Gupta (1987) find (weak) evidence on bank herding during a crisis period. Collective risk taking incentives and behaviours are also discussed by Acharya (2009), Acharya and Yorulmazer (2008), Boot (2011), Rajan (2006), and Tirole (2011).

This emerging evidence on systemic liquidity risk calls for adequate macroprudential instruments that address the sources of such risks. Farhi and Tirole (2012) show that authorities' interventions during crises might sow the seeds for the next crisis, as they provide incentives for collective risk-taking. Their framework points to the advantages of a new macroprudential approach to the regulation of liquidity risk, in which regulators consider not only the risk taken individually by each institution, but also the overall maturity transformation of strategic institutions. In their model, the optimal regulation is associated with a liquidity requirement or, equivalently, a limit on short-term funding. These authors argue that breaking down large banks in smaller units would not entirely mitigate systemic liquidity risk, as the problem is not only about being too-big-to-fail, but about being also too-many-to-fail (Acharya and Yorulmazer, 2007). Nevertheless, our empirical results show that herding behaviours are mainly concentrated amongst the largest banks, thus suggesting that the too-big-to-fail market failure might still be relevant. To some extent, Farhi and Tirole (2012) share this view, as they argue that if regulation is costly it may be optimal to impose a regulatory pecking order, imposing harsher regulatory constraints on institutions that are more likely to be bailed out.

Cao and Illing (2010) also contributed to this debate by developing a model of endogenous liquidity risk to analyse the regulation of systemic liquidity risk. They argue that the microprudential regulation of liquidity risk is insufficient to deal with the nature of externalities that create incentives for institutions to lean to excessive correlation in risk-taking, thus generating systemic risk. They contradict the consensus established since Holmstrom and Tirole (1998), who argued that the public provision of emergency liquidity is an efficient response to aggregate liquidity shocks. The model developed by Cao and Illing (2010) demonstrates that there are externalities that result in excessive maturity mismatches, creating systemic liquidity risk. This mechanism may be reinforced by central bank intervention, as it destroys the incentives for prudent financial intermediation. Within this framework, these authors show that regulations that impose "narrow banking" or capital requirements to deal with systemic liquidity risk are inferior to a mix between ex-ante liquidity regulation and ex-post lender of last resort policies.

Perotti and Suarez (2011) have also contributed to this debate, by proposing the implementation of a mandatory liquidity charge. This charge should work as a Pigouvian tax, discouraging banks' strategies that impose externalities on the rest of the financial system and, ultimately, on the whole economy. The liquidity charge proposed by Perotti and Suarez (2011) should be proportional to banks' maturity mismatches and applied to all institutions with access to safety net guarantees. These authors propose that this charge could be paid continuously to supervisors during normal times. In compensation, supervisors would provide emergency liquidity during systemic crisis. In turn, Boot (2011) argues that higher capital and liquidity requirements need to be complemented with more system-oriented measures, which focus on externalities and interconnectedness.

The new instruments proposed by the Basel Committee to regulate liquidity risk do not explicitly address systemic liquidity risk, focusing mainly on the externalities generated by each bank individually[8]. It is possible to argue that by making each institution individually less risky, systemic risk is being somewhat mitigated. In turn, the new regulation on Systemically Important Financial Institutions (SIFIs), which imposes capital add-ons on these institutions to correct externalities generated by the too-big-to-fail problem, will possibly help to mitigate systemic liquidity risk. SIFIs can generate systemic liquidity risk not only through their size, but also through their interconnectedness (IMF, 2011). These institutions can hold similar exposures of liquid assets or can have access to common funding sources. The empirical evidence presented in the previous section clearly shows that these very large institutions tend to engage in collective risk-taking strategies, through herding mechanisms. By requiring these institutions to hold more capital, their overall riskiness might be somewhat contained. However, these additional capital requirements do not address the specific sources of systemic liquidity risk.

Against this background, specific macroprudential tools should be designed to address systemic liquidity risk. This could entail imposing tighter limits for SIFIs on the new liquidity regulatory tools, for instance. Another possibility would be to fine tune the LCR and the NSFR to impose harsher penalties when macroprudential authorities identify excessive concentration in specific funding sources[9]. Nevertheless,

8 The LCR is calibrated to ensure that institutions are able to withstand shocks arising from an idiosyncratic or systemic shock, thus embodying some macroprudential concerns on systemic risk.

9 It should be noted that the new regulation already contributes to mitigate interconnectedness, through the run-off rates imposed on exposures to other financial institutions.

it is virtually impossible to fully prevent systemic liquidity crisis, as institutions will always present some correlation in their holdings of liquid assets and in their funding sources[10]. An alternative approach would be to develop a liquidity surcharge scheme based on the contribution of each institution to systemic liquidity risk (IMF, 2011), in the spirit of the proposals put forth by Perotti and Suarez (2011).

Another potential missing element in the new regulation might be related with the need to introduce countercyclical elements, in order to mitigate excessive risk taking during upturns. For instance, Acharya *et al.* (2011) show that during upturns banks' choice of liquid assets jointly decreases. In turn, Perotti (2011) argues that the new liquidity regulation is too rigid, as the limits to ratios cannot be calibrated through the cycle. Furthermore, this author argues that the new buffers are actually procyclical: as buffers discourage aggregate net liquidity risk only if they are costly, the low funding costs during upturns will probably imply non-binding restrictions during such periods.

In sum, two macroprudential concerns may be missing in the new regulation for liquidity risk: systemic risk and procyclicality.

6. CONCLUDING REMARKS

It is possible to argue that banks do not optimize their liquidity choices strictly at the individual level. When other banks are taking more risk, any given bank may have the incentives to engage in similar strategies. These collective risk-taking strategies may be optimal from an individual perspective, as they should allow banks to increase profitability without increasing the likelihood of bankruptcy, due to the explicit or implicit commitment of the lender of last resort.

Using data for European and North-American banks in the run up to the global financial crisis of the last few years, we empirically assess whether there is evidence of collective herding behaviour of these banks in their liquidity risk management choices.

This issue may have relevant policy implications, as banks may have incentives to engage in collective risk-taking strategies when there is a strong belief that a (collective) bailout is possible (Farhi and Tirole, 2012). When other banks are taking more risk, a given bank may be encouraged to pursue similar strategies if its managers believe they are likely to be rescued in case of distress. Hence, these risk-taking strategies may be mutually reinforcing in some circumstances. This collective behaviour transforms a traditionally microprudential dimension of banking risk into a macroprudential risk, which may ultimately generate much larger costs to the economy. As liquidity risk is usually regulated from a microprudential perspective, a better knowledge of these interactions among banks may have very important consequences on the design of macroprudential policy.

By adapting the herding measure proposed by Lakonishok *et al.* (1992) to our setting, we find that there was some herding behaviour in the pre-crisis period, reflected in a broad deterioration of liquidity indicators. Given the limitations of this measure, we extend our analysis to a multivariate setting. However, the empirical estimation of these peer effects amongst banks in such a framework raises some econometric challenges, related with the reflection problem (Manski, 1993). When we deal with this identification problem through an instrumental variables approach, we can find evidence of robust and significant peer effects only for the largest banks. These banks are usually perceived as being more likely to be bailed out in case of distress, as they are usually too-big or too-interconnected-to-fail. This serious moral hazard problem in banking encourages excessive risk-taking, and has fuelled an encompassing debate on the need to regulate systemically important financial institutions (SIFIs).

Our results support the existence of collective risk-taking behaviours on liquidity risk. Given this, we argue that additional macroprudential policy tools may need to be considered, such as additional liqui-

10 In practice, the LCR may actually increase the correlation in the holdings of liquid assets.

dity buffers on parts of the banking system or during upturns, in order to mitigate systemic risks and procyclicality. Furthermore, given that peer effects in liquidity risk management are significant mainly for the largest banks, it is possible to argue that the regulation on systemically important financial institutions may already play an important role in reducing incentives for collective risk-taking. Hence, even though the Basel III regulatory package does not explicitly deal with the systemic component of liquidity risk, it is possible that the more demanding regulatory requirements for systemically important financial institutions help to better align risk-taking incentives. Nevertheless, further work on the definition of macroprudential tools to address systemic liquidity risk is warranted.

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