LIQUIDITY, BANKING REGULATION AND THE MACROECONOMY

Evidence on bank liquidity holdings from a panel of UK-resident banks

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Abstract

This paper provides a first comprehensive analysis of the determinants of UK banks' liquidity policy. We study both idiosyncratic and macro- determinants of banks' liquidity buffers. In particular, we investigate how central bank LOLR policy may affect banks' liquidity buffers. We find that the greater the potential support from the central bank in case of liquidity crises, the lower the liquidity buffer the banks hold. A second finding relates to the way liquidity buffers vary over the economic cycle: UK banks appear to pursue a counter-cyclical liquidity policy, with liquidity lower in upturns. In the spirit of Almeida et al (2004), we finally test whether countercyclical liquidity buffers might be the result of financial constraints on banks' lending policy and find support for this hypothesis. Using these findings the paper draws out a number of implications for banking regulation.

JEL classification: G21, G28, E58

1. Introduction

The importance of the financial system and within that of the banking sector for the well functioning of an economy is well documented. In particular, a number of studies have shown that a banking crisis can have large disruptive effects on the real economy, eg Hoggarth and Saporta (2001). For a long time, policymakers have put considerable effort into the design of bank capital regulation, as a way of safeguarding overall financial stability. The Basel Accord was issued in 1988, market risk was dealt with in 1996 and a revised (risk-based) framework was issued in June 2004 (Basel II). Accompanying this policy effort there is by now a large academic literature on bank capital and capital regulation.

However, as was pointed out by Diamond and Dybvig (1983), one of the key reasons why banks are fragile, is their role in transforming maturity and providing insurance as regards depositors' potential liquidity needs. Nevertheless, almost no effort has to date been devoted to an analysis of one of the key ingredients that make banks safer institutions: their own holdings of liquid assets. How much liquidity do banks hold as self-insurance against liquidity shocks? How might the size of bank liquidity buffers be influenced by bank idiosyncratic factors and by macro factors?

Little attention has also been paid to the role that the Lender of Last Resort (LOLR) may play in a liquidity crisis, and especially, how LOLR policy might interact with banks' liquidity policy. Repullo (2003) presents a model that shows that, while the presence of the LOLR may improve the safety of the financial industry, it may also have undesirable effects. In particular, the support of the LOLR in case of a crisis creates a moral hazard problem, reducing the incentive on the part of the banks to self-insure by holding liquidity buffers. Indeed, this line of reasoning may point to a justification for regulatory liquidity requirements, as a quid pro quo for LOLR support. This paper analyses empirically the case for regulating liquidity, using the Fitch support ratings of UK banks.

From the point of view of regulators and central banks thinking about the design of regulation, it is important to ascertain not only the micro-economic properties of regulation, but also to judge its impact on system risk and any potential interaction with the macro-economy. For example, as is well known, bank capital regulation, especially when it is risk-based, has the drawback that requirements bite in recessions, when bank lending may need to be encouraged and tend to be slack in economic upturns when bank lending may need to be reined in (see eg Kashyap and Stein (2004) for a detailed discussion). This concern has sparked a sizable

literature on how bank capital buffers change with macroeconomic conditions, see eg Ayuso *et al* (2004) and Lindquist (2003). On the other hand, again, little is known about the cyclical properties of banks' liquidity buffers. This paper examines this issue in detail so as to assess macro-implications of bank liquidity regulation.

One characteristic that makes our data set unique is that it contains a large number of banks that are resident in the UK, but foreign-owned and that may thus operate under a different set of constraints on their liquidity policy. Indeed the fact that banks are increasingly operating cross-border has sparked a debate among policymakers as to how to provide LOLR for internationally active banks and on whether there might be a case for international coordination both as regards the ex ante regulation of liquidity and the provision of LOLR to large complex financial institutions (LCFIs) that operate cross-border (see Large, 2004). In analysing both UK- and foreign-owned banks operating in the UK, we attempt to shed light on some of these difficult questions[4].

The paper is organised as follows. Section 2 surveys the conceptual background as regards bank's liquidity management that was drawn upon to inform the empirical analysis. Section 3 describes the dataset and the variables used. Section 4 provides some stylised facts and sections 5 and 6 discuss estimation issues and regression results. Section 7 concludes by summarising the key findings and drawing out implications for policy.

2. Conceptual background and model specification

Some basic concepts

The starting point is banks' role in providing liquidity insurance. Banks collect demandable deposits and invest these funds in long-term and illiquid assets, such as loans. Loans are not usually callable. But they are also difficult to sell on at short notice because of the informational advantage the originating bank has in loan valuation. It is for these reasons that banks may be vulnerable to liquidity shocks arising mainly from the liability side of their balance sheets. If a large fraction of depositors demand cash, the bank may need to liquidate

[4] See also Dziobek et al (2000) and BIS (2000) for discussion of more general guidelines for liquidity management at banking fiims.

illiquid assets. Since this entails a loss of value, a liquidity shortage may turn into a solvency crisis[5].

There are a number of mechanisms that banks can use to insure against such liquidity crises. Key among those is for banks to self-insure against liquidity shocks on the liability side of the balance sheet, by holding a buffer of liquid assets on the asset side. A large enough buffer will reduce the chance that liquidity demands threaten the viability of the bank. A second mechanism is for banks to co-insure in the interbank market. This relies on liquidity shocks being less than perfectly correlated across banks, and again requires banks to hold a certain amount of liquid assets to help each other out, in case of idiosyncratic shocks to particular institutions[6]. Of course, in the face of informational asymmetries and free-rider problems, this type of interbank insurance mechanism may not work perfectly in all situations, which is why the central bank (CB) typically acts as a Lender of Last Resort (LOLR) to provide emergency liquidity assistance (ELA) to particular institutions and to provide aggregate liquidity in case of a system-wide shortage.

Determinants of liquidity buffers: a basic framework

The early literature on banks liquidity buffers views liquidity management at banks as akin to a standard inventory problem, eg Baltensperger (1980) and Santomero (1984)[7]. The costs of keeping a stock of liquid assets of a particular size are weighed against the benefit of reducing the chance of being 'out of stock'. The key prediction of these theories is that the size of the liquidity buffer should reflect the opportunity cost of return foregone from holding liquid assets rather than loans. It should also relate to the distribution of liquidity shocks the bank may face, and in particular to the volatility of the funding basis as well as the cost of raising funds (eg in the interbank market) at short notice. In an extension of this literature, Agenor et al (2004) test whether the credit crunch in Thailand (1998) was related to supply or demand factors, and to this end estimate a banks' demand function for reserves. They derive a demand function for excess reserves that depends both on the distribution of the deposits withdrawals, the external cost of finance (penalty rates applied by the central bank) and the impact of regulation (the

[5] However, this fragility is also a source of efficiency. Diamond and Rajan (2001) argue that this structure is efficient in that it disciplines banks when carrying out their lending function. The threat of a run is an incentive for the bank to choose projects with high return. More generally, this also suggests that an "even more liquid" bank might not always be desirable for the efficiency of the financial system.

[6] This mechanism is described in detail in Rochet and Tirole (1996).

[7] Similar models have been provided to account for corporate liquidity management, eg Kim et al (1998)

reserve requirement applied by the central bank). For sufficiently high costs of external finance their estimation results are consistent with the theory outlined above. These considerations suggest a number of control variables for our analysis, including the impact of regulation, the opportunity cost of liquid funds and measures of uncertainty.

Moral hazard incentives

As noted above, banks have three possible layers of insurance, a buffer of liquid assets in banks' individual portfolios, unsecured lending/borrowing in the interbank market and a LOLR safety net. In a recent research paper, Repullo (2003) develops a model of strategic interactions between the central bank and one representative bank and shows that the presence of LOLR support may affect the bank's choice as regards the share of liquid assets in its portfolio[8]. The CB's objective is to trade off the fiscal cost of lending to the bank and the cost of the bank's failure. The bank's objective is to maximise the expected payoffs to its shareholders. Given this set-up, Repullo determines the equilibrium strategy of the bank taking into account the LOLR's response function and vice-versa. One finding is that that the choice among risky assets is not related to the presence of the LOLR. Nevertheless, the presence of a LOLR is shown to influence the level of the optimal buffer of liquid assets: the share of safe assets in the bank's portfolio decreases with the introduction of a LoLR. In an empirical paper, Gonzalez-Eiras (2003) draws conclusions consistent with Repullo (2003). He examines how Argentinean banks changed the amount of their liquidity holdings and demands after a Repo Agreement was implemented at the end of 1996, which enhanced the ability of the central bank to act as LoLR. He finds that this particular event implied a reduction of approximately 6.7 pp in banks' liquidity holdings. We test the empirical implications of Repullo (2003) in our sample of UK banks.

Financial frictions and the business cycle.

In the early literature on corporates' liquidity, Keynes (1936) pointed out that a liquid balance sheet may enable the firm to undertake valuable projects when they arise. Furthermore, he brought to the fore that the liquidity of the balance sheet depends on the extent to which firms have ready access to external funding. For a bank, this would mean that some banks which

[8] A small literature models other aspects of the LOLR, eg Goodhart and Huang (1999) and Ringbom *et al* (2004). Freixas et al (1999) provide a survey of this literature.

may want to extend new loans may be constrained by the amount of funds they can raise, due to financial frictions.

When banks' access to the capital markets is limited, eg because issuing equity is costly for banking firms or because interbank funding is limited, this opens up the possibility that banks liquidity holding may be related to the business cycle. In particular, it is conceivable that banks hoard liquidity during periods of economic downturn, when lending opportunities may not be as good and that they run down liquidity buffers during economic expansions when lending opportunities may have picked up. It is conceivable, too, that financing constraints on the part of banks limit the overall effectiveness of monetary policy. Banks may choose to hoard the increase in the overall liquidity the central bank provides to stimulate the economy in a recession.

In order to examine these questions we put a particular emphasis on the analysis of the impact of macroeconomic variables on banks' liquidity buffers. The question we would like to answer is whether financial frictions might induce a counter-cyclical behaviour of liquidity buffers, such that liquidity is low in periods of economic upturn and when the policy rate is high, while liquidity buffers are high in periods of economic downturn and when the policy interest rate is low.

Financial frictions, profitability and changes in liquidity

In order to examine the importance of financial frictions in more detail we conduct an analysis of *changes* in a bank's liquidity buffer in addition to examining the determinants of its level. In particular, corporate finance theory suggests that in the presence of financial frictions, internal sources of liquidity, such as the cash flow from ongoing projects could be used to build up a liquidity reserve. In a recent paper, Almeida *et al* (2004) propose that constrained firms may be managing more closely than unconstrained firms their internal source of liquidity, in order set aside funds for future investment opportunities. This results in a powerful test for the presence of financing constraints: if cash flow affects liquidity buffers then this questions the Modigliani-Miller theorem[9], which states that the structure of funding (including as regards internal versus external sources) is irrelevant.

Using a three-period model, where a profit-maximising firm has investment opportunities in the first and second period, that pay off in period three, the authors analyse the firm's choice as

[9] Modigliani and Miller (1958)

regards the amount of cash held between period one and two, in order to finance investment in period two. The firm is financially constrained and can raise funds only up to the level of its pledgeable underlying asset, whose liquidation value is verifiable[10]. When solving this intertemporal profit maximisation problem, the authors first characterise the first best solution that can be attained by non-constrained firms. For these firms the amount of cash held between period one and two is irrelevant. Empirically this implies that the link between liquidity holdings and current cash flows (ready source of internal finance) is loose or nonexistent.

Conversely, firms that are experiencing financial frictions may not be able to attain the optimal level of investment they would like to in period two. For these firms, there may be a benefit in managing liquidity, in order to increase their ability to finance future projects as they arise. And because holding liquidity has an opportunity cost, an optimal amount of liquidity arises from this trade-off. Empirically, this translates into a positive response of the firm's change in liquidity holdings to positive cash flows. Keeping a fraction of the cash flows, firms build up a liquidity buffer to have sufficient funds to invest in the future.

The model implies that the relationship needs also to account for future investment opportunities. Following the literature, Almeida *et al* use Tobin's Q as a proxy. They estimate their model on a large panel of US non-financial corporate and find strong empirical evidence of the importance of liquidity management: coefficients on cash flow and Tobin's Q are found significant and positive for this group of firms. Consistent with their model, Almeida et al interpret this as evidence in favour of financial constraints.

In this paper we examine whether a similar relationship may hold for banking firms. This would be an indication that banking firms are financially constrained, which in turn may have important implications for the design of bank regulation.

Model specification

We proceed in two steps. We first examine the determinants of the level of individual bank's liquidity ratio. Second, we adapt the Almeida *et al* (2004) methodology to test in more detail for the impact of financial constraints on the evolution of bank liquidity buffers.

[10] This way of modelling financial frictions was pioneered by Hart & Moore (1994).

3. The Data

We use unconsolidated balance sheet and profit and loss data, for a panel of 57 UK-resident banks, on a quarterly basis, over the period 1985Q1 to 2003Q4. These data relate to the banks' resident (UK) activity. The panel is unbalanced as some of the banks do not report over the whole period of time. Furthermore, profit and loss data are only available - on a quarterly basis - from 1992Q1. As far as possible, we adjust for bank mergers. This is crucial for the UK-owned banking sector, where several bank mergers and demutualization of building societies took place over the recent years. In order to limit the impact of mergers on the historical series, we aggregate data prior to a merger using backward static consolidation. Moreover, as mergers may cause structural changes in the data, dummies are added to take account of new banks inside groups or mergers. The initial sample at our disposal covers all banking institutions resident in the United Kingdom as of 31 December 2003. From the point of view of ultimate ownership, we focus on UK-owned banks but also include foreign-owned banks that have substantial operations in the UK. We truncate the sample by excluding banks that do not meet a size threshold of 5 billion Pounds in terms of assets reported in the UK at the end of 2003. On the other hand, the sample includes all banks (UK- or foreign-owned) that are participants in the large value payment system in the UK (CHAPS) and all those banks that keep settlement accounts with the Bank of England (clearing banks) and that might therefore be active players in the UK money market. Regarding aggregate data, we rely upon UK national accounts and on financial market data.

Our measure of liquidity is as described in Kashyap and Stein (2000). Liquid assets are composed of cash, reverse Repos, bills and commercial papers and comprise in addition all types of investments securities, such as equities and bonds. We construct two alternative liquidity ratios. The first is the share of liquid assets in the bank's total assets. This measure is interesting since it informs on the split between liquid and illiquid asset (such as loans) on the bank's balance sheet. However, arguably, it does not capture well the degree of liquidity mismatch inherent in the bank's balance sheet. To analyse this, we construct an alternative liquidity ratio as the ratio of liquid assets to total deposits. We run all regressions for these two dependent variables.

Table 1 summarises the set of variables we use in order to test for the different theoretical relationships outlined above.

Table 1: Dependant and explanatory variables in the econometric regressions

VARIABLE NAME	EXPLANATION	COMPUTATION	EXPECTED SIGN
Dependent variables			
Liquidity ratio (1) (in terms of total assets)	Buffer of liquid assets as a share of the balance sheet	liquid assets/total assets	
Liquidity ratio (2) (in terms of total deposits)	Buffer of liquid assets taking account of maturity mismatch	liquid assets/total deposits	
Idiosyncratic factors			
Support	Likelihood to obtain support from a LOLR in case of a liquidity shortage.	The Fitch support rating (ranging from 1 (most support) to 5 (least support))is inverted and thus transformed into a pseudo-probability of bail-out, ranging from 20% to 100%.	*negative*
Interest Margin	Opportunity cost of holding liquid assets in terms of foregone higher return from loans	Computed as the individual return on loans (sum of interests received over the total amount of loans) minus cost of funds	*negative*
Profit	1) Profitability of the bank as a ready source of liquidity *(analysed in the regression in level)*	Profit/total assets	*negative*
	2) current profit as source of saving for future lending opportunities, for liquidity-constrained banks *(analysed in the regression in changes)*	Profit/total assets	*positive*
Loan growth	Financial constraints. Ability to raise new funds if loan business expands compared to the rest of the balance sheet	Quarterly growth of total loans to non financial sector.	*negative*
Tobin's Q	Tobin's Q proxies future lending opportunities (significant only for	(Market value of equity + book value of other liabilities)/total assets	*positive*

	liquidity-constrained banks)		
Size	Controls for differences in size of firms	Log of total (book) assets	
Aggregate factors			
GDP growth	Business cycle	Quarterly growth of UK GDP, in constant prices	*negative*
Short term interest rate	Monetary policy effect	3 month UK Treasury Bill rate	*negative*

4. Stylised facts

Tables 2 and 3 illustrate some stylised facts as regards the composition of the balance sheet for the banks in our sample. In particular, they show the average ratio of each item in the balance sheet to total assets. The statistics are calculated as the mean for the entire sample and also separately for UK-owned and foreign-owned banks. A first thing to note is that foreign owned banks tend to be smaller on average, in terms of total assets, than UK-owned banks. Their balance sheets also differ in some other respects.

We can see that for the sample as a whole, banks use time deposits as the main source of funding, while sight deposits and CDs issued are the most important additional sources of funding. However, differences emerge when we look at the subcategories: UK-owned banks appear to be well diversified between sight deposits and time deposits, while foreign-owned banks appear to rely mainly on time deposits. On the asset side, we can see that for the sample as a whole, about half of the assets relate to money market lending. Once again, this picture changes substantially when we look at the subgroups. While UK banks have a well diversified asset portfolio, using most of their asset for loans to corporates and households, the foreign-owned banks are mainly engaged in money-market lending.

Charts 1 and 2 show the time series of the average ratio of liquidity over deposits and that of liquidity over total assets[11]. A significant increase occurs in the mid 90's. This might relate to the creation of the Repo market and the start of the Sterling Stock Liquidity Ratio (SSLR) regulation in the UK[12]. However, interestingly, foreign-owned banks are those that show the

[11] Our measure of liquidity is the sum of cash, investments, bills, gilt reverse repos and non gilt reverse repos. It is very similar to the one used by Kashyap and Stein (2000).

[12] See Chaplin et al (2000) for more detail.

biggest increase. Another important feature of the dataset is its skewed nature. As Chart 3 shows, the majority of banks in the sample are smaller banks. Further descriptive statistics for the main variables of interest are shown in Table 4.

5. Analysis of the level of liquidity

Econometric Specification

In our baseline specification we test for the effect of LOLR support, the effect of the short term interest rate and the effect of GDP growth. The estimated equation is:

$$Liq_{it} = c + c*NUK + \beta_{11}SR_{it} + \beta_{12}(NUK*SR) + \beta_{21}r_{it} + \beta_{22}(NUK*r_{it}) + \beta_{31}Y_{it} + \beta_{32}(NUK*Y_{it}) + \eta_i + \varepsilon_{it}$$

where *Liq* is the liquidity ratio (liquid assets over total assets or alternatively, liquid assets over total deposits), *c* is a constant, *NUK*: is the dummy variable for the foreign owned banks, *SR* is support, *r* is the short-term interest rate and *Y* is real GDP growth.

Note that, by interacting the constant with the NUK dummy we allow for a different intercept across the two groups (UK- vs. foreign-owned). In addition we allow the slope terms to vary across groups, by interacting the NUK dummy with all of support, interest rate and GDP growth. Finally, we allow for bank fixed effects (η_i). If left uncontrolled, the presence of heterogeneity across banks might bias our estimates. In order to treat individual fixed effects we therefore pursue a General Methods of Moments (GMM) procedure that involves taking first differences and using the lags of the explanatory variables as instruments. In order to gauge the success of this procedure we use two tests as guidelines for the goodness of our estimates: the Hansen test for the validity of the instruments, and a test for the autocorrelation in the error term. The estimation procedure then consists of finding the set of instruments that gives us the best Hansen test (checking that the coefficients are stable to different instrument specifications), and checking that the error term has only a first-order autocorrelation.

Results

Table 5 presents the main results. The first two columns show the baseline regression for the two alternative dependent variables. It turns out that the results do not change materially

whether we use ratio of liquidity over assets ratio, or the ratio of liquidity over deposits. In interpreting the results further, note that, since we have introduced interaction terms relating to foreign-owned banks, the simple slope coefficients apply to the UK owned sub-sample of banks. As regards this sub-sample, the results are statistically strong and support a number of the predictions outlined above. First, the amount of liquidity banks hold as insurance against liquidity shortages does appear to depend on the support that they are expected to receive from the LOLR in case of shortage. In particular, as predicted by Repullo (2003), for UK-owned banks, the strength of LOLR support has a negative effect on banks' liquidity holdings. That is, the higher (lower) the probability of being bailed out, the lower (higher) banks' liquidity holdings. Second, monetary policy, proxied by the short-term interest rate, appears to affect liquidity buffers. The negative coefficient on the short interest rate suggests that when policy rates are high (low) UK banks respond by holding a smaller (larger) amount of liquid assets, relative to both total assets and total deposits. This suggests that when the central bank attempts to stimulate the economy with a reduction in the interest rate and a corresponding increase in the monetary base, the effects are only transmitted with a lag, since banks appear to keep the additional liquidity on their balance sheets[13]. Finally, real GDP growth does appear to affect banks' liquidity holdings. As indicated by the negative coefficient on GDP growth, banks appear to hold smaller (larger) amounts of liquidity, relative to both total assets and total deposits, in periods of stronger (weaker) economic growth. In other words, banks appear to build up their liquidity buffers during economic downturns and draw them down in economic upturns.

The results are somewhat different for the foreign-owned banks. In table 5, the reported coefficient relates to the overall coefficient for the foreign-owned subgroup that was computed by adding the difference in the marginal effect across the two groups onto the benchmark effect for the UK group. The P-value shown beneath the coefficient indicates whether this coefficient is different from zero. It turns out that as regards LOLR support, there is a significant difference between the foreign-owned banks when compared to UK-owned banks resulting in a slope coefficient for foreign banks (of 0.63 and 0.57 respectively in columns 1 and 2), that is not significantly different from zero (P-values 0.55 and 0.63). In other words, LOLR support for foreign-owned banks does not appear to affect their holdings of liquid assets. One reason

[13] Whether this is due to banks lending being capacity constrained or due to the demand for lending being subdued in these instances is difficult to decide and a question outside of the scope of this paper. A related literature analyses whether bank loan supply shifts in response to changes in central bank policy rates, eg Kashyap and Stein (2000) and Kishan and Opiela (2000).

could be that the expectation of LOLR support as measured relates to the group as a whole and is expected to be provided by the home central bank, rather than by the UK authorities. As regards the effect of the short-term interest rate, the effect on foreign bank liquidity holdings is negative and statistically significant (with P-values of 0.01 and 0.02), as it is for the UK owned banks. However, at -0.06 the size of the effect is only about half that for the UK banks and it turns out that this difference in size is statistically significant (with a P-value of 0.05). In response to an increase in the short-term interest rate, foreign-owned institutions appear to reduce their liquidity holdings, as do UK owned banks. However, the reduction is smaller and amounts to about half the reduction seen for the UK banks. Finally, liquidity holdings at foreign-owned banks appear to respond less to variations in UK GDP growth than is the case for UK-owned banks (a finding that turns out to be significant at the 5% level). Indeed the reduction in liquidity in response to stronger growth appears to be only marginally significantly different from zero (in colum 2) if at all (in column 1) for the foreign-owned banks.

Robustness checks

As a robustness check we expand the list of regressors to include a number of further control variables that might affect the banks' liquidity buffer. In particular, we include a bank-level measure of the bank's size, the net interest margin on loans (opportunity cost of holding liquid assets), a measure of a bank's profitability and a measure of a bank's loan growth. As regards the impact of these control variables, we check again whether foreign-owned banks are different from the UK owned group and have found this to be the case as regards the interest margin, but not with respect to the other control variables introduced.

As can be seen from columns 3 and 4 of table 5, the main results as regards the effect of support, short term interest rate and GDP growth prevail and are little changed when compared with the baseline regression. As regards the additional controls, we find plausible results overall. First, it turns out that for the UK owned banks the interest margin - a proxy for the opportunity cost of holding liquid funds - has a negative effect on liquidity holdings, as predicted by inventory models of optimal liquidity holdings. For foreign owned banks, by contrast, the interest margin appears to have the opposite effect on liquidity, perhaps reflecting remittances of liquidity from the centre of the group when UK interest margins are high. We also find that more profitable banks appear to hold larger buffers on average, even though this result is not significant at conventional levels. Similarly, we find that larger banks tend to hold larger buffers, but again this result is not significant at conventional levels. Finally, as one

might expect, we find banks that experience stronger loan growth to reduce their liquidity holdings, a result that is significant at the 5% level in column 3. This is consistent with the results of Kashyap and Stein [2000], and suggests that banks adjust their liquidity according to their current lending opportunities, increasing liquidity when lending opportunities are poor and decreasing liquidity when lending opportunities improve. This in turn suggests that banks cannot fully rely on external funding, and therefore have to manage their internal funds to optimally invest (lend) over time.

As a further check on the results we include a number of dummy variables that are related to potential regime changes over our sample period, Table 5, columns 5 and 6. First we include a dummy for deregulation of the Gilt-edged money market in the UK. This occurred in January 1996, when obstacles to the sale and repurchase of Gilts were removed and a Gilt repo market was established, that might have resulted in additional incentives to hold liquid assets (Repos). Second we include a dummy that relates to the introduction of the Sterling Stock Liquidity Regime in the UK. This is a quantitative liquidity requirement that from 1996 has been applied to the ten largest UK banks. To account for potential effects of this regulation, we introduce a dummy that is equal to 1 for all banks subject to this regulation from 1996. Moreover, we include a dummy variable that indicates whether subsidiaries have been added to a banking group over the course of the sample period and a further dummy variable that takes account of the date of any merger between firms in our sample.

It turns out that the deregulation of the gilt-edged repo market did lead to an increase in liquidity held by banks in our sample, a result that is statistically significant at the 1% level. Moreover, banks that are subject to SSLR requirements appear to hold larger liquidity buffers, all else equal, even though this result is only marginally significant, if at all. On the other hand, changes in group composition and merger activity do not appear to affect bank liquidity buffers. Controlling for these additional considerations, the baseline results regarding the effects of LOLR, interest rate and GDP growth appear to prevail.

6. Analysis of the Change in Liquidity

Econometric Specification

We next turn to the analysis of changes in liquidity with a view of testing more directly whether some of the results of the levels regressions relate to financial frictions that might impact liquidity policy at banks.

Following Almeida *et al* (2004), the estimated equation is:

$$\Delta Liq_{it} = c + \beta_{11}\pi_{it} + \beta_{21}TQ_{it} + \eta_i + \varepsilon_{it}$$

where *Liq* is the liquidity ratio, *c* is a constant, π is the profitability of bank i at time t and *TQ* (Tobin's q) is the ratio of the market value of equity and the book value of other liabilities to the book value of total assets of bank i at time t.

The regression specification is designed to test whether the change of the liquidity ratio can be explained by the banks' current profits (π) and its future lending opportunities (*TQ*). As for the levels regression, we treat fixed effects using the GMM procedure outlined above. However, for the changes regressions we do not attempt to compare UK owned banks with the foreign-owned institutions and instead focus on the UK owned sub-sample. The main reason is that foreign-owned institutions operating in the UK typically do not have a separate listing, but tend to be branches or else subsidiaries of larger groups, making it difficult to measure Tobin's Q for the UK operations of these groups.

Results

The coefficients on both profit and Tobin's q in Column 1 of Table 6 support the notion that UK banks are subject to financial constraints. In particular, liquidity ratios respond positively to increases in current profits (cash flows). They also respond positively to increases in future lending opportunities, as measured by Tobin's q. In other words, UK banks appear to hoard liquidity when cash flows are high and when future investment opportunity are favourable. Both results are statistically strong and suggest that banks behave in a way that is consistent with the Almeida *et al* model. The results thus provide prima facie evidence that banks are financially constrained in the sense that it is costly for banks to raise external funds as and when they are needed to finance lending opportunities.

Extension

As a check on this interpretation, we inter-act those variables that we use to test for financial constraints with variables that are traditionally associated with the existence of financial constraints. In particular, the literature on the bank lending channel argues that smaller banks are more financially constrained than large banks, since smaller banks would tend to have a more limited access to capital markets. The bank lending channel is thus hypothesed to be stronger for smaller banks. Kashyap and Stein (2000), Kishan and Opiela (2000). This literature typically also argues that for those banks that have a less liquid balance sheet the effect of the bank lending channel should be stronger, since these banks are more financially constrained in the sense that they have less scope to run down their liquid assets in response to an adverse monetary policy shock.

Columns 3 and 4 of Table 6 show the results of regressions that interact both current profit and Tobin's Q with a dummy that identifies those banks with relatively liquid balance sheets. The results suggest that for liquid banks, the effect of current profit on the change in liquidity is less pronounced than it is for illiquid banks and overall not significantly different from zero. The effect of lending opportunities, on the other hand is associated with larger increases in liquidity even for the more liquid banks, with the overall effect only marginally smaller for the liquid banks than for the relatively illiquid banks.

Columns 5 and 6 of Table 6 report regressions that contain interactions with a dummy that indicates relatively large banks. The results suggest that larger banks do not change their liquidity in response to higher current profits, with the coefficient positive, but not significantly different from zero. On the other hand, again, future lending opportunities appear to lead to increases in liquidity of similar magnitude for both large and small banks.

Overall, our results are in line with the arguments advanced in the bank lending channel literature. In particular, the results in Table 6 are consistent with the interpretation that overall, banks are financially constrained, but that this is not the case for banks that are large or those banks that have liquid balance sheets.

7. Conclusion

The main contribution of this paper is to formally test for the existence of liquidity moral hazard at banking firms, as described in Repullo (2003). This form of moral hazard arises when banks hold lower liquidity buffers than they otherwise would when they expect to receive

emergency liquidity assistance from the LOLR. Using a measure of support expectations based on the Fitch support rating, we find strong evidence of the existence of such an effect, which may point to a rationale for regulatory liquidity requirements as a quid pro quo for LOLR support.

A further contribution of this paper is to analyse in detail the interplay between macroeconomic conditions and bank liquidity buffers. We find that bank liquidity buffers are countercyclical. In other words, banks appear to build up liquidity buffers in periods of weak economic growth and draw buffers down in periods of strong economic growth. In addition, using micro-data we find that banks appear to hold larger buffers when short term rates are low and smaller buffers when short term rates are high.

The fact that liquidity buffers behave in countercyclical fashion may be related to financing constraints at the individual bank level. Indeed, much of the theoretical literature on bank capital and bank capital regulation assumes that banks can issue new equity only at a cost. The standard argument as regards the source of these costs is asymmetric information on the quality of the bank's existing assets, Myers and Majluf (1984). To the best of our knowledge, this is the first paper that explicitly tests for financial frictions of this kind for banking firms. We find, using a test based on changes in liquidity at banking firms, that banks are financially constrained, inducing them to hoard funds when current profits are high and future lending opportunities are good.

Financial constraints that arise from asymmetric information as regards asset quality contribute to concerns about procyclicality of banking capital regulation. When raising equity is costly, and risk-based requirements rise in recessions, banks may respond to increases in requirements by cutting their lending. Capital requirements, when risk-based, may thus exacerbate procyclicality of bank lending. The evidence presented here suggests that, as regards liquidity requirements, the presence of financing constraints works the other way. In the presence of financing constraints banks have an incentive to increase their liquidity holdings in recessions and to decreases liquidity holdings in booms. And our evidence does indeed suggest that this is what they do. A liquidity requirement imposed on banking firms is thus likely to bite in economic upturns and to be slack in economic downturns, potentially reducing procyclicality of bank lending.

Finally, we present evidence that foreign-owned banks appear to be subject to a different set of constraints when managing their liquidity, perhaps indicating that liquidity is managed

centrally and that UK branches and subsidiaries can use the group-internal internal capital market to raise funding as and when needed to finance investment or underwriting opportunities. As regards policy implications, it is not easy to draw any firm conclusions from this evidence. Perhaps one concern is that, when subsidiaries and branches rely on the centre of the group for financing, they may be hard hit by any liquidity problem that might arise at the centre.

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Appendix: Charts and Tables

Chart 1
Average liquidity ratio (1)

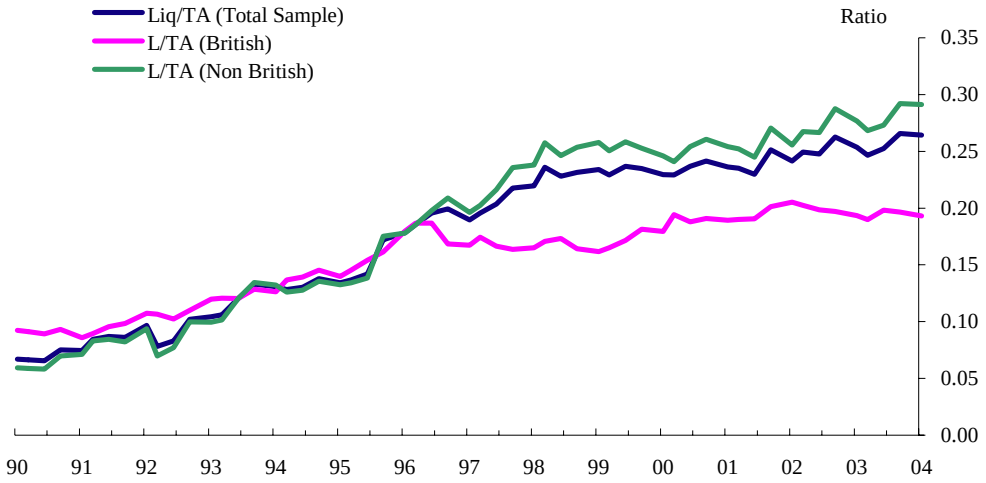

Chart 2
Average liquidity ratio (2)

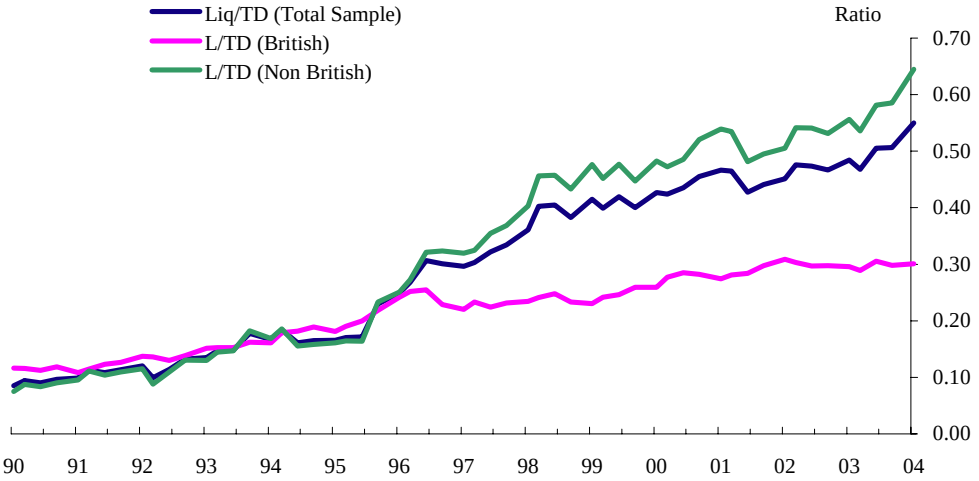

Chart 3
Distribution of banks according to total assets

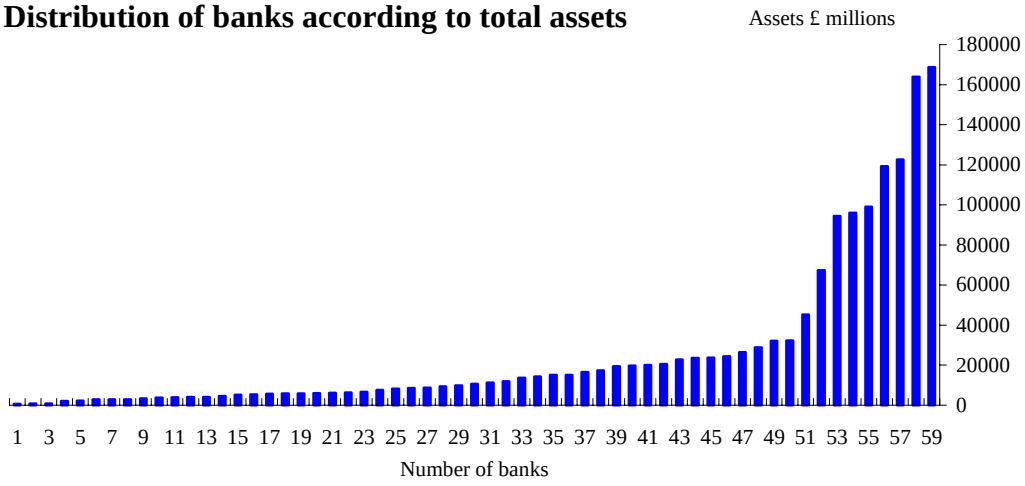

Table 2: Balance sheet composition, 1990

Average for 1990	UK	Non-UK	Total
Average Assets	77120.3	21414.0	27375.4
Liabilities (in per cent of total)			
Sight Deposits	0.31	0.11	0.16
Time Deposits	0.49	0.71	0.66
CD issued	0.04	0.13	0.11
Capital	0.13	0.03	0.05
Other Liabilities	0.03	0.02	0.02
	1.00	1.00	1.00
Assets (in per cent of total)			
Cash	0.00	0.00	0.00
Market Loans	0.35	0.61	0.55
CD	0.04	0.02	0.02
CP	0.00	0.00	0.00
Bills	0.02	0.01	0.01
Treasury Bills	0.00	0.00	0.00
BoE euro bills	0.00	0.00	0.00
Loans	0.50	0.31	0.36
Gilt reverse Repos	0.00	0.00	0.00
Non Gilt reverse Repos	0.00	0.00	0.00
Investments	0.07	0.05	0.05
Other Assets	0.03	0.01	0.01
	1.00	1.00	1.00

Table 3: Balance sheet composition, 2003

Average for 2003	UK	Non-UK	Total
Average Assets	**99974.9**	**30939.2**	**27375.4**
Liabilities (in per cent of total)			
Sight Deposits	**0.33**	**0.18**	**0.22**
Time Deposits	**0.37**	**0.48**	**0.45**
CD issued	**0.05**	**0.13**	**0.11**
Capital	**0.14**	**0.04**	**0.06**
Other Liabilities	**0.11**	**0.18**	**0.16**
	1.00	**1.00**	**1.00**
Assets (in per cent of total)			
Cash	**0.00**	**0.00**	**0.00**
Market Loans	**0.26**	**0.46**	**0.41**
CD	**0.09**	**0.02**	**0.04**
CP	**0.00**	**0.00**	**0.00**
Bills	**0.01**	**0.01**	**0.01**
Treasury Bills	**0.00**	**0.00**	**0.00**
BoE euro bills	**0.00**	**0.00**	**0.00**
Loans	**0.51**	**0.20**	**0.29**
Gilt reverse Repos	**0.01**	**0.02**	**0.01**
Non Gilt reverse Repos	**0.02**	**0.11**	**0.09**
Investments	**0.14**	**0.14**	**0.14**
Other Assets	**0.00**	**0.04**	**0.01**
	1.00	**1.00**	**1.00**

Table 4: Descriptive statistics

Variable Name	Mean	Std. Dev	Min	Max	Observations
LR1	0.1545	0.1581	0.0000	0.8358	4018
LR2	0.2533	0.3820	0.0000	4.6335	4017
∆LR1	0.0046	0.6448	-10.7902	11.5320	4001
∆LR2	0.0049	0.6627	-11.2148	11.5333	4001
Support	0.3631	0.2059	0.2000	1.0000	3328
Interest	7.5697	3.1729	3.4100	14.5515	4018
Profit	0.0010	0.0050	-0.0842	0.0571	2280
Loan growth	0.0049	0.4601	-9.9628	4.1997	4011
GDP growth	0.0064	0.0050	-0.0093	0.0219	3915
Interest margin	0.0025	0.0036	-0.0158	0.0462	2182
Tobin's Q	1.0820	0.2759	0.7880	3.5017	677

Table 5: Regressions in levels

Dependent variable	(1) Liq. / Assets (p-value)	(2) Liq. / Dep. (p-value)	(3) Liq. / Assets (p-value)	(4) Liq. / Dep. (p-value)	(5) Liq. / Assets (p-value)	(6) Liq. / Dep. (p-value)
(1)Support	**-3.89** **(0.02)**	**-4.33** **(0.01)**	**-2.01** **(0.07)**	**-2.26** **(0.06)**	**-2.03** **(0.05)**	**-1.88** **(0.09)**
(2)Support *NUK	**0.63** **(0.55)**	**0.57** **(0.63)**	**0.20** **(0.79)**	**-0.25** **(0.75)**	**0.04** **(0.95)**	**-0.19** **(0.82)**
(3)Interest	**-0.12** **(0.00)**	**-0.14** **(0.00)**	**-0.05** **(0.09)**	**-0.05** **(0.10)**	**-0.06** **(0.00)**	**-0.07** **(0.00)**
(4)Interest *NUK	**-0.06** **(0.01)**	**-0.06** **(0.02)**	**-0.06** **(0.06)**	**-0.06** **(0.05)**	**-0.04** **(0.09)**	**-0.05** **(0.06)**
(5)GDP growth	**-17.65** **(0.00)**	**-19.75** **(0.00)**	**-7.66** **(0.04)**	**-6.93** **(0.08)**	**-8.53** **(0.01)**	**-8.84** **(0.04)**
(6)GDP growth *NUK	**-3.38** **(0.30)**	**-5.52** **(0.10)**	**-1.96** **(0.57)**	**-2.13** **(0.57)**	**-1.46** **(0.64)**	**-2.64** **(0.43)**
Interest Margin			**-8.61** **(0.04)**	**-10.47** **(0.02)**	**-6.50** **(0.11)**	**-8.93** **(0.05)**
Interest Margin *NUK			**11.25** **(0.07)**	**8.48** **(0.20)**	**4.52** **(0.28)**	**2.63** **(0.51)**
Profit			**1.88** **(0.21)**	**2.89** **(0.10)**	**1.68** **(0.31)**	**2.07** **(0.27)**
Loan growth			**-0.12** **(0.02)**	**-0.11** **(0.03)**	**-0.09** **(0.03)**	**-0.08** **(0.08)**
Log(assets)			**0.13** **(0.38)**	**0.24** **(0.11)**	**-0.04** **(0.71)**	**0.05** **(0.76)**
Dum Deregulation					**0.13** **(0.01)**	**0.18** **(0.00)**
Dum SSLR					**0.12** **(0.11)**	**0.07** **(0.23)**
Dum Group					**-0.10** **(0.71)**	**-0.11** **(0.70)**
Dum Merge					**-0.12** **(0.19)**	**-0.16** **(0.24)**
Sargan Test	**0.53**	**0.27**	**0.92**	**0.95**	**0.95**	**0.98**
Number of Observations	**2558**	**2558**	**1675**	**1675**	**1772**	**1772**

Table 6: Regressions in changes

Dependent variable	(1) D(Liq./Assets) (p-value)	(2) D(Liq./Dep.) (p-value)	(3) D(Liq./Assets) (p-value)	(4) D(Liq./Dep.) (p-value)	(5) D(Liq./Assets) (p-value)	(6) D(Liq./Dep.) (p-value)
Profit	1.09 (0.01)	1.24 (0.00)	0.72 (0.01)	0.73 (0.06)	0.87 (0.01)	1.02 (0.01)
Tobin's Q	0.32 (0.07)	0.35 (0.06)	0.29 (0.03)	0.39 (0.07)	0.27 (0.02)	0.34 (0.07)
Profit Liquid			-0.45 (0.50)	0.41 (0.63)		
Profit Large					0.10 (0.96)	1.43 (0.59)
Tobin's Q Liquid			0.27 (0.04)	0.32 (0.06)		
Tobin's Q Large					0.30 (0.01)	0.42 (0.03)
log(assets)	0.02 (0.75)	0.05 (0.53)	0.05 (0.45)	0.12 (0.36)	-0.01 (0.89)	0.01 (0.92)
Number of Observations	338	318	325	325	318	318
Hansen test	0.85	0.83	0.82	0.88	0.85	0.96