THE NINTH
YOUNG ECONOMISTS'
SEMINAR

TO THE TWENTIETH DUBROVNIK ECONOMIC CONFERENCE

Organized by the Croatian National Bank

Tamara Kochubey and Dorota Kowalczyk

The Relationship between Capital, Liquidity and Risk in Commercial Banks

Hotel "Grand Villa Argentina"

Dubrovnik

June 10 -11, 2014

Draft version

Please do not quote

CROATIAN NATIONAL BANK

The relationship between capital, liquidity and risk in commercial banks*

Tamara Kochubey† and Dorota Kowalczyk‡

May 14, 2014

CERGE-EI[1], Prague

Abstract

This paper investigates capital, risk and liquidity decisions of the U.S. commercial banks during the period from 2001 till 2009. We extend the simultaneous equation model with partial adjustment introduced by Shrieves and Dahl (1992) and examine a relationship between bank liquidity, capital and risk adjustments in the presence of securitization. Our research empirically verifies the theoretical predictions of Repullo (2005). Our results indicate that banks simultaneously coordinate short-term adjustments in capital, risk and liquidity. We show that during the pre-crisis period short-term adjustments in bank capital inversely affect short-term adjustments in bank risk and vice versa. During the financial crisis, lower risk implies higher capital, however higher capital induces more risk-taking. We provide some tentative explanations for this change in sign. Next, we find a significant, negative and bidirectional relation between bank risk and liquidity adjustments. Finally, we also establish that banks increase liquidity ratios when their capital ratios decline and lower their capital when their liquidity increases. Overall, our results show that an increase in capital induces banks to reduce their liquidity position and lower risk-taking. This outcome is consistent with the findings of Repullo (2005). Banks differ in the way they adjust their capital, liquidity and risk in the regular and distress times. Rates of liquidity and risk adjustment are mostly higher during the crisis, indicating that banks were inclined to reach desired levels of liquidity and risk much faster during the crisis than in the pre-crisis period. While the rates of capital adjustment are lower during the crisis, showing that banks faced difficulties changing capital ratios to desired levels during the financial turmoil. Our results emphasize that it is critical to incorporate the liquidity ratios, in addition to capital requirements, into the banking regulations.

JEL Classification: G21, G28,

Keywords: Bank regulation, bank capital, risk-taking, bank liquidity

---

*The research is supported by the GA UK grant No. 648213.

†Correspondence address: CERGE-EI, P.O. Box 882, Politickych veznu 7, Prague, 111 21, CZ. E-mail address: Tamara.Kochubey@cerge-ei.cz

‡E-mail address: Dorota.Kowalczyk@cerge-ei.cz

[1]CERGE-EI, a joint workplace of the Center for Economic Research and Graduate Education, Charles University in Prague, and the Economics Institute of the ASCR, v. v. i.

1 Introduction

Financial supervision authorities impose regulations on banks to ensure safeness and soundness of the banking system. Unregulated banks are believed to maintain too little capital and liquidity to absorb losses. Furthermore, it has been showned[2] that the resilient banking sector facilitates proper financial intermediation and enhances capital allocation in the economy. Therefore, achieving and maintaining financial stability has been one of the main concerns of policymakers and gained attention among researchers. So did the ongoing reform process of the banking industry launched in response to the recent financial crisis. Until recently the capital requirements have been considered sufficient to curb bank risk appetite and preserve the liquidity and stability of the banking system. The liquidity regulations were absent, mostly due to a commonly shared belief that bank access to funding liquidity vitally depends on its assets quality. The recent crisis revealed a collective over-confidence in this respect. Financial innovations, deregulation and competition from the non-bank financial intermediaries leading to the 2007-2009 crisis have altered traditional roles played by banks and sources of risk to be regulated. Many banks have changed their traditional "originate and transform" *modus operandi*, where they transformed liquid deposits into illiquid loans and held loans on their books until their maturity, to a model where bank loans are sold in the secondary markets. The new "originate-to-distribute" banking model and banks' greater reliance on wholesale creditors emphasized an importance of liquidity requirements. At the same time, the "originate-to-distribute" model and securitization might have resulted in an increased interdependence of bank capital, liquidity and risk. Should a joint reshuffling of the two financial buffers and risk be confirmed by the banks' behavior, the design of banking regulations would need to account for this coordination effect. Moreover, with the rise of securitization activity there is a need to reexamine sources of banks' credit risk taking into account their on and off balance sheet activities. Therefore, traditionally accepted determinants of bank capital, risk and liquidity have to be augmented with off balance sheet exposure and, more importantly, with bank involvement in securitization activity.

This paper investigates capital, risk and liquidity decisions of the U.S. commercial banks in the period leading to the recent crisis and during the crisis itself. In particular, we examine a relationship between bank liquidity, capital and risk adjustments in the presence of securitization. Our estimations show that U.S. commercial banks simultaneously coordinate capital, risk and liquidity adjustments. We find that banks simultaneously adjust capital and risk, but the direction of these effects differs for the two analyzed periods. In the pre-crisis time, an increase in bank risk-taking reduces bank capital ratios and a decline in bank capital induces banks to increase their risk-taking even more. During the financial turmoil, banks respond to lower capital by reducing risk-taking. Whereas, a change in risk negatively affects capital adjustments. In particular, an increase in risk-taking triggers a decrease in capital ratios. Furthermore, we establish a negative relation between bank risk and liquidity adjustments, suggesting that banks increase risk by reducing their liquidity position and increase liquidity by lowering risk-taking. The sign of this effect remains the same for the two analyzed periods. Finally, our findings indicate that bank liquidity and capital adjustments are negatively related.

[2]The key role of the financial intermediation to performance of the real sector has been empirically documented for instance by Rousseau and Wachtel (1998) or Dell'Arricia, Detragiache and Rajan (2005).

Banks increase their liquidity buffer when they face lower capital ratios and lower their capital ratios when the liquidity buffers augment. These results are confirmed by a set of regressions using different measures of bank capital and risk. Our research contributes to the discussion on monitoring banks performance and ensuring the financial sector stability. Our findings suggest that bank capital and liquidity ought to be regulated jointly. In particular, they emphasize the importance of liquidity buffer as regulatory tool and support an incorporation of liquidity requirements, in addition to capital requirements, into the Basel III accord.

This paper contributes to the debate on the ongoing global banking reform process and the banking literature in several ways. First, we are the first to jointly examine capital, risk and liquidity decisions of the U.S. commercial banks. We examine a relationship between short-term adjustments in bank capital, risk and liquidity accounting for banks securitization activity. Our findings regarding a joint allocation of capital, liquidity and risk shed some light on how banks had reshuffled them, and in effect relaxed constraints of the banking regulations. The issue of how existing capital requirements proved ineffective is of critical importance to the reform of the banking regulatory framework. Second, in this study we focus on the U.S. commercial banks behavior during the period of 2001-2009. This period is of particular interest as it contains intervals of boom and bust in the securitization market. As already mentioned, an increased loan securitization changed the traditional banking model to a new one[3], where banks grant loans and then sell them in the secondary markets. It thus strengthened the banks' capacity to lend, while their incentives to screen risky borrowers and maintain adequate capital and liquidity buffers might have weakened. We find only limited evidence that securitization directly affected the capital, risk and liquidity interactions. We show that securitization increases banks' capital, and the impact of securitization on capital is significant only for the period leading to the crisis. Given the limited evidence, we cannot conclude that banks used securitization to relax constraints of existing capital requirements. Third, the examination of the U.S. bank allocation of capital, liquidity and risk over the period of 2001-2009 is fruitful because we can compare banks behavior prior to the financial crisis to their behavior during the crisis. The most noticeable difference is that banks adjusted liquidity and risk mostly much faster during the crisis than in the pre-crisis period. The capital adjustments were slower during the financial crisis, as it is more costly to raise capital during the financial turmoil. Finally, in contrast to the previous empirical studies on bank capital and portfolio risk we analyze a larger sample of U.S. commercial banks rather than focusing on a limited sample of publicly traded banks. This allows us to generalize our findings.

2 Literature Review

Among essential functions performed by banks the banking theory identifies asset transformation and liquidity creation. Banks create liquidity and transform assets by investing into illiquid loans which are financed with liquid deposits (Diamond and Dybvig, 1983). It involves risk associated with financing illiquid loans with short-term deposits. This mismatch causes

[3] As opposed to the traditional "originate-and-transform" model, a new banking firm model has been labeled "originate and distribute" or "originate, repackage and sell".

banks' vulnerability to depositors' confidence. After all, banks hold illiquid loans that are hard to sell at a short notice without incurring a loss if there is a large deposit outflow (Diamond and Rajan, 2001). To ensure against liquidity risk arising from massive deposit outflows banks can hold significant liquidity and capital buffers. The academic literature on bank capital and capital regulations in the banking system has by now grown plentiful. Liquidity, on the contrary, as a more complex concept has only recently emerged in the banking firm theory. Baltensperger (1980) is the first to draw attention to bank liquidity buffer. Both Baltensperger (1980) and Santomero (1984) analyze bank liquidity buffers from the perspective of the inventory theory. They argue that it is costly for banks to keep a stock of liquid assets, but may be also beneficiary as it reduces the probability of being 'out of stock' in case of deposit withdrawals. The inventory theory predicts that the size of liquidity buffer should reflect the cost of forgone return from holding liquid assets rather than loans, and the cost of raising funds at a short notice. Prisman, Slovin and Sushka (1986) introduce liquidity risk into liquidity management model as they allow for random deposit withdrawals. They show that the cost of bank's resources tend to increase due to the premium for the expected costs of liquidity shortage arising if the amount of deposit withdrawals is greater than bank reserves.

An insightful overview of theoretical literature on capital regulations[4] is presented in VanHoose (2007). VanHoose discusses banking models and examines the efficiency of deposit insurance and solvency ratio as disciplining tools in the frameworks ranging from pure portfolio choice to moral hazard and incentive models. VanHoose concludes that academic literature on the effects of capital regulations offers divergent predictions regarding the banks' responses to regulatory constraints. The predictions depend on what aspect of the banking framework is emphasized. The strand of literature, that treats banks primarily as portfolio managers (Kahane, 1977; Koehn and Santomero, 1980; Kim and Santomero, 1988; Rochet, 1992), indicates that as long as the risk weights are market-based the imposition of solvency ratio is likely to yield efficient and less risky asset allocation. But, otherwise the implementation of capital ratios would cause excessive risk-taking. On the other hand, the academics viewing banks mostly as monitors for moral hazard advocate that capital requirements may increase risk appetites of banks (Calem and Rob, 1999; Milne, 2002; Hellmann, Murdock and Stiglitz, 2000), because it is costly for banks to maintain higher capital ratios. Therefore, banks would incur more risk-taking in order to compensate for costs associated with maintaining higher capital ratios. These conflicting conjectures have motivated researches to empirically examine the relationship between bank capital and portfolio risk.

Several empirical studies examine the relationship between bank capital and risk under capital requirements (Shrieves and Dahl, 1992; Jacquers and Nigro, 1997; Aggarwal and Jacquers, 2001; Heid, Porath and Stolz, 2004; Jokipii and Milne, 2011). Shrieves and Dahl (1992) examine the relationship between changes in bank capital and changes in asset risk allocation for the U.S. commercial banks. They employ two-stage simultaneous equation model to take into account the simultaneity of banks' capital and risk decisions. Shrieves and Dahl document a positive relationship between changes in bank capital and changes in bank risk, which can be explained by the regulatory pressure, regulatory or bankruptcy costs avoidance

[4]See Stolz (2002) for the survey of empirical literature on bank capital.

and managerial risk aversion. Their results suggest that banks, which have to increase capital buffer due to capital regulations, tend to increase their risk levels as well. An increase in bank risk levels leads to further increases in bank capital ratios. On the contrary, Jacquers and Nigro (1997) find that risk-based capital requirements have a positive effect on bank capital and a negative effect on bank portfolio risk. As Shrieves and Dahl (1992) argue, the negative relationship may exist, if banks are seeking to exploit the deposit insurance subsidy. Using the same framework, Aggarwal and Jacquers (2001) examine how prompt corrective action imposed by FDICIA affected bank capital and risk. They find that such a regulatory action encouraged both capitalized and undercapitalized U.S. banks to increase their capital ratios and reduce their credit risk.

More recent empirical studies by Heid, Porath and Stolz (2004) and Jokipii and Milne (2011), which build on the Shrieves and Dahl (1992) framework, document a positive two-way relationship between bank capital and risk. Furthermore, they show that the capital and risk adjustments depend on the size of capital buffer, that is the amount of capital in excess of the regulatory minimum. Heid, Porath and Stolz (2004) examine risk and capital decisions of German banks, while Jokipii and Milne (2011) analyze behavior of the U.S. banks. Both studies find that when capital increases well-capitalized banks tend to maintain their capital buffers by increasing their allocation of risky assets. At the same time, low-capitalized banks prefer to rebuild their capital buffers by simultaneously increasing capital and decreasing risk. Jokipii and Milne also control for bank liquidity in the estimation, and find that more liquid banks tend to have smaller capital buffers and are more likely to increase their credit risk. However, their estimates of the liquidity are not statistically significant. Moreover, Jokipii and Milne consider bank liquidity as exogenous, while in this study we will endogenize it, because banks can simultaneously determine capital and liquidity, as well as risk and liquidity. Therefore, we account for the simultaneity of bank capital, risk and liquidity decisions in our estimation.

Until Repullo (2005) no theoretical study examined bank liquidity, capital and risk jointly. Repullo (2005) studies a strategic interaction between a bank and a lender of last resort to derive the optimal bank's levels of liquidity, capital and risk with and without capital regulation, with and without penalty rates and collateral lending. In our research, we focus on the case when a bank chooses liquidity, capital and risk under capital requirements. Under this regime, Repullo (2005) predicts that a higher capital requirement lowers the riskiness of bank loan portfolio and reduces its liquidity buffer. The work of Aspachs, Nier and Tiesset (2005) is the first to test the empirical implications of Repullo (2005). Using a sample of the UK banks, the authors investigate the determinants of bank liquidity holdings and show that a higher probability of getting a potential support from the central bank adversely affects banks liquidity buffers. Their work is, however, solely focused on the bank liquidity buffers, their determinants and the effect of macroeconomic conditions on liquidity holdings. Distinguin, Roulet and Tarazi (2013) analyze how bank capital and liquidity are related, using a simultaneous equation model. They show that banks decrease their capital ratios when there is a decline in liquidity. But the authors do not consider interrelation between bank capital, liquidity and risk. In contrast to these studies, we conduct a more comprehensive investigation and jointly analyze the possible coordination of bank's liquidity, capital and risk decisions in line with theoretical work of

Repullo (2005).

Finally, a new stream of empirical studies examines the impact of the securitization separately on bank liquidity and on bank capital. Loutskina (2011) analyzes the impact of the securitization on bank liquidity for the U.S. commercial banks. She finds that a higher involvement in the securitization activity reduces banks' holdings of liquid assets. Dionne and Harchaoui (2003) and Uzun and Webb (2007) document that securitization is negatively related to the banks' capital ratios. Banks that are involved in the securitization can hold less capital, as they may transfer assets off balance sheet to reduce capital requirements. Additionally, Dionne and Harchaoui (2003) show that securitization positively affects bank credit risk. This can occur if banks transfer only less risky loans off balance sheet, and thereby keep on balance sheet more riskier assets. To the best of our knowledge, the first study to simultaneously examine the impact of the securitization on bank liquidity, capital and credit risk is due to Kowalczyk (2012). It considers the Eurozone banks and finds that higher risk in the previous period implies greater securitization in the next period. At the same time, the study provides no significant evidence of the effect of the securitization on bank liquidity and capital for the European banks. In this research we will reinvestigate this relationship using a large sample of the U.S. commercial banks. Moreover, in contrast to Kowalczyk (2012), rather than analyzing solely the pre-crisis period, we will examine the period of 2001-2009, which contains the boom and bust times in securitization activity.

3 Methodology and Model Specification

This study examines the relationship between bank liquidity, capital and risk adjustments by employing the simultaneous equation model with partial adjustment. The simultaneous equation model accounts for a joint coordination of bank capital and risk suggested by the financial theory and emphasized in the empirical works of Shrieves and Dahl (1992), Jacquers and Nigro (1997) and Jokipii and Milne (2011) to name a few. Furthermore, the model allows us to consider the interrelation between bank capital, risk and liquidity as discussed in Repullo (2005). Under this approach, the observed changes in bank capital, risk and liquidity result from banks' discretionary behavior as well as a exogenous random shock. Formally, the model can be expressed as:

$$\triangle CAP_{it} = \triangle CAP_{it}^{bank} + \varepsilon_{it}, \tag{1}$$

$$\triangle RISK_{it} = \triangle RISK_{it}^{bank} + \epsilon_{it}, \tag{2}$$

$$\triangle LIQ_{it} = \triangle LIQ_{it}^{bank} + \nu_{it}, \tag{3}$$

where $\triangle CAP_{it}$, $\triangle RISK_{it}$ and $\triangle LIQ_{it}$ are the observed changes in bank capital, risk and liquidity, respectively, $\triangle CAP_{it}^{bank}$, $\triangle RISK_{it}^{bank}$ and $\triangle LIQ_{it}^{bank}$ are the changes in capital, risk and liquidity managed by banks, while ε_{it}, ϵ_{it} and ν_{it} are exogenous random shocks in capital, risk and liquidity levels for bank i at time t. Therefore, the observed changes in capital, risk and liquidity are modeled as the sum of a discretionary component and a random shock.

The financial theory argues that banks face financial frictions and adjustment costs which make instantaneous adjustments in bank capital, risk and liquidity unattainable. Accordingly, we model a discretionary part of the observed changes in capital, risk and liquidity using a partial adjustment framework. This approach assumes that banks choose optimal levels of capital, risk and liquidity, and then target them over time. More importantly, when actual levels depart from their targets, banks revert to the optimal levels in a gradual manner. The choice of partial adjustments over full adjustments is typically motivated by the fact that the latter are likely to be too costly or even not feasible. Consequently, the adjustments in bank capital, risk and liquidity are defined as:

$$\triangle CAP_{it}^{bank} = \alpha(CAP_{it}^{*} - CAP_{it-1}), \tag{4}$$

$$\triangle RISK_{it}^{bank} = \beta(RISK_{it}^{*} - RISK_{it-1}), \tag{5}$$

$$\triangle LIQ_{it}^{bank} = \gamma(LIQ_{it}^{*} - LIQ_{it-1}), \tag{6}$$

where α, β, and γ are the speeds of adjustments. CAP_{it}^{*}, $RISK_{it}^{*}$ and LIQ_{it}^{*} are the target levels. CAP_{it-1}, $RISK_{it-1}$ and LIQ_{it-1} are the actual levels in the previous period.

Substituting equations (4), (5) and (6) respectively into equations (1), (2) and (3) yields the following expressions for the observed changes in bank capital, risk and liquidity:

$$\triangle CAP_{it} = \alpha(CAP_{it}^{*} - CAP_{it-1}) + \varepsilon_{it}, \tag{7}$$

$$\triangle RISK_{it} = \beta(RISK_{it}^{*} - RISK_{it-1}) + \epsilon_{it}, \tag{8}$$

$$\triangle LIQ_{it} = \gamma(LIQ_{it}^{*} - LIQ_{it-1}) + \nu_{it}, \tag{9}$$

As shown above, the observed changes in capital, risk and liquidity in period t for bank i depend on deviations of its actual capital, risk and liquidity levels in the previous period $(t-1)$ from their respective targets as well as on the exogenous shocks. The target levels of capital, liquidity and risk cannot be observed and, hence, need to be proxied for. The discussion of plausible variables that capture unobservable target levels follows the examination of capital, risk and liquidity measures provided below. We complete the model by adding changes of capital, risk and liquidity to each equation, which accounts for the simultaneity of capital, risk and liquidity adjustments.

$$\triangle CAP_{it} = \alpha(CAP_{it}^{*} - CAP_{it-1}) + \varphi_1 \triangle RISK_{it} + \varphi_2 \triangle LIQ_{it} + \varepsilon_{it}, \tag{10}$$

$$\triangle RISK_{it} = \beta(RISK_{it}^{*} - RISK_{it-1}) + \phi_1 \triangle CAP_{it} + \phi_2 \triangle LIQ_{it} + \epsilon_{it}, \tag{11}$$

$$\triangle LIQ_{it} = \gamma(LIQ^{*}_{it} - LIQ_{it-1}) + \psi_1 \triangle CAP_{it} + \psi_2 \triangle RISK_{it} + \nu_{it}. \tag{12}$$

This study employs four measures of bank capital (CAP) commonly used in the empirical studies: equity capital to total assets, the risk-based capital ratio (equity capital to risk-weighted assets), the Tier 1 risk based capital ratio (Tier 1 (core) capital divided by risk-weighted assets) and the total risk-based capital ratio (total risk-based capital divided by risk-weighted assets). The use of widely acceptable measures of capital makes our results comparable to the others. There is no consensus in the literature on the measure which captures bank portfolio risk better. We utilize the two most frequently referred to measures of risk. The two risk measures are the ratio of risk-weighted assets to total assets ($RWATA$) and the ratio of nonperforming loans to total assets (NPL). Finally, the bank liquidity (LIQ) is measured by the ratio of liquid assets to total assets. The liquid assets include cash, reverse repurchase agreements, marketable securities and Federal funds sold.

As already indicated, the partial adjustment framework relies on the unobserved internal bank's target levels of capital, risk and liquidity. These internal targets need to be proxied by the observed bank specific variables describing its financial stance and the nature of its business strategy. For the sake of comparability we rely on variables typically chosen in the empirical literature. One of the commonly employed proxy, which is believed to affect the target capital, risk and liquidity, is the size of the financial institution measured by a logarithm of its total assets ($SIZE$). Among others, it accounts for the relative access to capital and liquidity, investment opportunities and diversification of business activities. Therefore, we expect a negative impact of the size on capital and liquidity. The nature of the size effect on bank risk tends to be less clear. Following Diamond (1984) and Ramakrishnan and Thakor (1984) the literature on intermediation promotes diversification as a way to minimize the risk of failure. Why doing so, it uses the argument of uncorrelated returns in line with Markowitz (1952) portfolio theory. Although the portfolio diversification is not a strategy that solely a big bank may implement, bigger banks are likely to enjoy lower diversification costs. In particular, the advantage of a considerable size is that larger banks interact with a sizable number of borrowers and have access to an ample number of investment opportunities. A larger number of investments allows a big bank to pool those investments and lower its portfolio risk. In the same spirit, larger banks might have less risky loan portfolios due to the economies of scale in screening and monitoring borrowers. On the other hand, the corporate finance literature argues that specializing may lead to improvement of bank's monitoring effectiveness and incentives, and thus is likely to reduce credit risk (Stomper, 2006). Consequently, we expect a significant size effect on the risk and leave its sign undetermined. Loan loss provisions lower a nominal amount of the risk-weighted assets and therefore it is expected to negatively affect bank risk. At the same time, banks with higher expected loan losses in order to meet capital requirements and mitigate solvency risk will tend to raise more capital. Therefore, we expect that loan loss provisions will positively affect bank capital. We measure the loan loss provisions as a ratio of new loan provisions in the current period to total assets ($LLOSS$). As long as a bank prefers to raise capital through retained earnings rather than through equity issuance, bank's profitability will positively influence the size of bank capital. Typically, the former way of raising capital is more likely to occur as it is less costly, does not affect the ownership structure and sends a positive signal to the markets. Hence, bank's profitability and capital should move in the same direction. We measure bank's profitability as a ratio of net income to total assets (ROA). Bank charter value is considered as a factor that might influence bank capital, risk and liquidity target levels. Keeley (1990) finds that the greater the charter value of a bank the greater is the incentive to keep it high. In such a case, banks tend to decrease their risk-taking, increase their liquidity buffers and maintain their capital buffers in excess of the regulatory minimum. Banks' charter value is usually measured in the literature by Tobin's Q, that is the ratio of the book value of liabilities and market value of equity to the book value of total assets. However, Jones, Miller and Yeager (2011) showed that Tobin's Q is a poor proxy for the charter value in the banking industry. They claim that this measure confuses periods of strong economic expansion with market power due to its dependence on the stock market fluctuations and business conditions. Following Jones, Miller and Yeager (2011) we employ the ratio of core deposits as a proxy for banks' charter value. Our choice is additionally justified by the fact that we analyze the large sample of U.S. commercial banks rather than solely publicly traded commercial banks and, hence, we do not limit our analysis to the use of the market data. We control for bank-specific financial constraints by incorporating bank's net interest margin (NIM) and loan growth rate ($LOAN$) in the liquidity equation. Net interest margin is defined as the ratio of quarterly annualized net interest income, that is interest income less interest expense, to average earning assets. The net interest margin and loan growth rate are expected to adversely affect the liquidity buffer.

One of the key concerns of our study is the impact of the securitization on bank capital, risk and liquidity adjustments. The immediate effect of the securitization is a reduction in the risk-weighted assets and untying regulatory capital due to a removal of the securitized loans from the bank's balance sheet. Whether or not it decreases, the overall risk exposure depends on the bank's lending and investment strategies and the competitiveness of the financial sector. Financing new assets with the released liquidity should result in an increased diversification and should lower the bank risk. While Instefjord (2005) recognize the benefits of risk sharing, they additionally show that securitization encourages more risk-taking. An increased competition in the financial markets strengthens the impact of the latter effect (Instefjord, 2005). Moreover, Greenbaum and Thakor (1987) argue that banks tend to withhold poorer quality assets. Given the benign macroeconomic conditions and the search for yield observed in the analyzed period, we expect a positive dependency between the asset quality, measured by credit risk, and the securitization activity. The predictions about the interaction of the liquidity and securitization, and bank capital and securitization are even less evident. Therefore, we simply expect to obtain a significant relation. We measure bank's involvement into the securitization activity by the ratio of assets sold and securitized with recourse and other credit enhancements to total assets (SEC).

Finally, changes in banks' liquidity, capital and risk might be influenced by individual banks' characteristics. We account for bank unobserved heterogeneity by incorporating bank fixed effects, which are designed to absorb all time invariant bank heterogeneity. To control for any regulatory or macroeconomic environment changes we include quarterly dummies. Thus, the estimated system of the equations takes the following form:

$$\begin{aligned}\triangle CAP_{it} = \alpha_0 + \alpha_1 SIZE_{it} + \alpha_2 LLOSS_{it} + \alpha_3 ROA_{it} + \alpha_4 Core\, Deposits_{it} + \alpha_5 SEC_{it} - \\ -\alpha_6 CAP_{it-1} + \alpha_7 \triangle RISK_{it} + \alpha_8 \triangle LIQ_{it} + \mu_i + \delta_t + \varepsilon_{it},\end{aligned} \tag{13}$$

$$\begin{aligned}\triangle RISK_{it} = \beta_0 + \beta_1 SIZE_{it} + \beta_2 LLOSS_{it} + \beta_3 Core\, Deposits_{it} + \beta_4 SEC_{it} - \\ -\beta_5 RISK_{it-1} + \beta_6 \triangle CAP_{it} + \beta_7 \triangle LIQ_{it} + \mu_i + \delta_t + \epsilon_{it},\end{aligned} \tag{14}$$

$$\begin{aligned}\triangle LIQ_{it} = \gamma_0 + \gamma_1 SIZE_{it} + \gamma_2 Core\, Deposits_{it} + \gamma_3 NIM_{it} + \gamma_4 LOAN_{it} + \gamma_5 SEC_{it} - \\ -\gamma_6 LIQ_{it-1} + \gamma_7 \triangle RISK_{it} + \gamma_8 \triangle CAP_{it} + \mu_i + \delta_t + \nu_{it},\end{aligned} \tag{15}$$

where μ_i and δ_t are bank and time components, respectively, and ε_{it}, ϵ_{it}, and ν_{it} are white noise processes.

The coefficients α_7, α_8, β_6, β_7, γ_7 and γ_8 are of our main interest. Their sign and significance determine the relationship between short-term adjustments in bank capital, risk and liquidity.

The presence of fixed effects in the model make lagged dependant variable endogenous. Unlike previous studies (Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 2001), we employ dynamic panel data technique to control for bank-specific heterogeneity μ_i. In particular, we use the two-step Arellano-Bond difference GMM estimator (Arellano and Bond, 1991). The Arellano-Bond procedure estimates the equation in first differences thereby removing all unobserved time invariant individual-level effects. However, the differenced lagged dependant variable is still correlated with lagged error in the differenced error term. To account for endogeneity of lagged dependant variable Arellano-Bond difference GMM estimator use instruments: available lags of lagged dependant variable in levels as instruments for the first-differenced equation. Moreover, given the simultaneous structure of our model, we need to account for the endogeneity of capital, risk and liquidity adjustments in estimation procedure. The Arellano-Bond procedure allow us to do that using GMM-type instruments for $\triangle CAP_{it}$, $\triangle RISK_{it}$ and $\triangle LIQ_{it}$. The procedure also requires that the applied instruments be exogenous. This condition can be verified by testing for the presence of autocorrelation in first-differenced residuals, where we expect to find the first order autocorrelation. A presence of higher-order autocorrelation in first-differenced residuals indicates that some lags of the variable, which are used as instruments, are endogenous. Therefore, if autocorrelation of order n is detected, only deeper lags (e.g., $n+1$) of variable can be used as instruments (Roodman, 2009). The validity of instruments as a group and correctness of model specification are checked by the Hansen J-test of overidentifying restrictions. We employ the two-step Arellano-Bond difference GMM estimator instead of the one-step due to the two-step estimator's higher efficiency. However, the two-step procedure might produce standard errors that are downward biased. To correct for that we use the finite-sample "Windmeijer correction" for the two-step covariance matrix (Baltagi, 2008).

4 Data

We use a panel dataset of U.S. commercial banks balance sheet and income statement data covering the period from 2001 Q1 to 2009 Q4. Balance sheet and income statement data for banks come from Reports of Condition and Income (Call Reports) provided by the Federal Deposit Insurance Corporation (FDIC)[5]. All commercial banks in the U.S. have to fill these reports on a quarterly basis. Many commercial banks are owned by the same bank holding company. We aggregate data for individual banks with the same owner as liquidity and equity management is performed at the bank holding company level. The bank holding company can inject liquidity and equity into its subsidiary banks as well as transfer liquidity among its subsidiaries. To account for bank mergers and acquisitions during our sample period, we exclude banks with asset growth more than 10% during that quarter. To ensure that the results are not driven by outliers we exclude banks in quarters when they had total assets in the 1st and 99th percentiles of the asset size distribution in a given quarter. Moreover, all variables are winsorized at the 1st and 99th percentiles.

Table 2 reports bank descriptive statistics. We report summary statistics for changes in bank capital, risk and liquidity and bank characteristics for the period from 2001 Q1 through 2009 Q4, and separately for the pre-crisis quarters 2001 Q1 through 2007 Q2 and the crisis quarters 2007 Q3 through 2009 Q4. Banks on average reduce their capital ratios and liquidity and increase risk-taking during the period from 2001 till 2010. Banks have, on average, core deposit ratio of 0.68, $RWATA$ of 0.68, NPL of 0.01, liquidity ratio of 0.32, return on assets of 0.002, SEC of 0.004 and loan growth of 3.1 percent. Banks' capital ratios vary from 11.3 percent for the equity capital ratio to 17 percent for the Tier 1 capital ratio, 17.6 percent for the risk-based capital ratio and 18.2 percent for the total capital ratio. On average, banks hold 379.4 million dollars in assets.

Looking at the differences in banks' behavior between the pre-crisis and crisis periods, we note that banks reduce capital ratios and increase riskiness of their loan portfolio to a higher extent, while they reduce liquidity and increase risk-weighted assets to a lower extent during the crisis. Moreover, during the crisis banks have lower core deposits ratios, return on assets, net interest margin, loan growth and they are less liquid. At the same time, the risk-taking and loan losses are larger, while risk-based capital ratios are lower during the crisis. Finally, one can observe bank enlargement and an increase in equity capital ratio during the crisis.

Tables A.1 - A.6 in Appendix show the correlations for all variables in levels and in first differences for different time periods.

5 Results

Estimation results for equations (13) $-$ (15) in the pre-crisis and crisis periods are reported in Tables 3 - 5. Figure 1 pictures and summarizes the relationship between short-term adjustments in bank capital, risk and liquidity over two time periods. The dynamic panel estimations corroborate that U.S. commercial banks simultaneously coordinate capital, risk and liquidity

[5] Call Reports are publicly available from the website of Federal Reserve Bank of Chicago.

adjustments. In all equations we have lagged dependant variables, CAP, RISK and LIQ, which are endogenous in the presence of bank fixed effects. We account for that by using GMM-type instruments of CAP, RISK and LIQ. We also account for the simultaneity of capital, risk and liquidity adjustments using GMM-type instruments. For instance, in the capital equation changes in risk and liquidity are predetermined and are instrumented by lagged first-differences of risk and liquidity adjustments. The appropriate lags of variables used as instruments are chosen based on the test for autocorrelation. The Hansen J-test in Tables 3 - 5 indicates that in most cases we cannot reject the null hypothesis of correct model specification and valid overidentifying restrictions.

5.1 The pre-crisis period

Columns (1) - (4) of Tables 3 and 5 summarize the estimation outcome for capital, risk and liquidity equations in the pre-crisis period. The results for bank risk captured by $RWATA$ are displayed in Panels A, while Panels B present the outcome for the risk measured by NPL. When bank risk is measured by $RWATA$, an impact of capital adjustments on risk adjustments and vice versa are both negative and highly significant (Tabel 3 Panel A). This means that an increase in riskiness of bank asset portfolio erodes bank capital. Therefore, banks would reduce their riskiness in order to increase capital. This outcome is in line with the empirical findings of Jacques and Nigro (1997), who find a negative influence of capital changes on risk changes when the total risk-based capital constraints are considered. Moreover, the results are consistent with the theoretical implications of Repullo (2005), who predicts that higher capital implies a lower risk. The liquidity adjustments have likewise a negative impact on both risk and capital adjustments. The inverse influence of the bank's liquidity on its riskiness suggests that banks accumulating liquid assets tend to have safer portfolios, which confirms one of the implications of Diamond and Rajan (2006). The estimates in Panel A of Table 5 suggest that this dependency is bidirectional as well. On one hand, capital adjustments negatively affect liquidity adjustments, suggesting that banks augment their capital ratios when they experience a liquidity shortage. On the other, an increase in bank capital causes a simultaneous decrease in bank liquidity buffers, which again supports the theoretical predictions of Repullo (2005). Nevertheless, this result contradicts the findings of Distinguin, Roulet and Tarazi (2013), who document a positive relationship between bank capital and liquidity for the European and US commercial banks prior to the recent financial crisis.

The results in Panels B of Tables 3 and 4 indicate that there is a positive coordination between bank capital and NPL, where NPL measures the quality of bank loan portfolio. A positive coordination of capital and risk is in accordance with the findings of Shrieves and Dahl (1992) and Jokipii and Milne (2011), and indicates that banks increase their capital ratios in response to an increase in riskiness of bank loan portfolio and vice versa. These estimates suggest that banks increase overall riskiness of their asset portfolio and decrease the riskiness of their loan portfolio when they face lower capital. Overall, such findings for the risk and capital coordination using the two risk measures seem to describe the dynamics leading to the crisis in the US banking sector. In the pre-crisis period bank' portfolios grew substantially while banks extended loans to poorer quality borrowers. Consequently, banks reported increasing

$RWATA$, even though NPL reflected a higher share of bad borrowers only later. Initially, the significant credit expansion improved banks' NPLs. When bank risk is measured by NPL, the estimation outcome presented in Panel B of Table 3 indicates a positive relationship between banks capital and liquidity. For the NPL as a risk measure, the relationship is only significant in one direction. We find no evidence that changes in capital have a significant impact on changes in liquidity.

With respect to lagged measures of capital, they all are highly significant, have expected negative signs and lie within a unit interval. The coefficient estimates vary from -0.719*** to -0.989*** for four different measures of bank capital and two different measures of bank risk. These estimates suggest that U.S. commercial banks have a relatively high speed of capital adjustment to their target levels. The estimated coefficient of *Core Deposits* (Table 3 Panel A) is negative, which indicates that the greater the charter value of a bank the lower its capital buffer. This outcome contradicts the findings of Keeley (1990) and suggests that in the pre-crisis period the US banks pursued capital strategies that could have sacrificed their values. To put it differently, banks with more stable sources of financing maintain lower capital ratios. Our result emphasizes a need to regulate both bank capital and liquidity to assure that banks concurrently maintain appropriate capital levels and stable funding sources. As such, it speaks in favor introducing the stable funding ratios in the new Basel regulations (Basel III). Furthermore, the coefficient on securitization (SEC) is positive and significant, which indicates that banks engaging in securitization activities reported increasing capital ratios. This outcome contradicts the findings of Dionne and Harchaoui (2003) and Uzun and Webb (2007). However, the anecdotal facts suggest that in the pre-crisis period banks employing securitization benefited from mounting buffers over their capital requirements. An impact of bank's size on capital adjustment (Table 3 Panel A) is negative and ranges between -0.0305*** and -0.0432**, showing that larger banks maintain smaller capital ratios. This supports the conjecture that bigger banks have an easier access to capital markets, and in general to additional funding, than smaller banks. Consequently, they can hold less capital. Finally, estimates for ROA range from 2.650*** to 6.522***. ROA positively impacts changes in capital indicating that more profitable banks tend to retain a part of their earnings to increase their capital ratios.

The estimates for the risk equation are presented in Table 4. The fitted coefficients on lagged measures of risk have expected negative signs and lie within a unit interval. The coefficient on lagged NPL vary from -0.674*** to - 0.708*** for four different measures of bank capital, while the estimate for lagged $RWATA$ is much smaller and amounts to minus 0.106*. These values imply that the U.S. commercial banks adjust their non-performing loan ratios to the target levels relatively quickly. With regard to the coordination of risk and liquidity adjustments, we find a negative and highly significant impact of liquidity adjustments on risk. The estimates for liquidity changes in the risk equation vary from -0.808*** to -0.0431** (Table 4 Panel A and B). Moreover, the outcome for the liquidity equation presented in Table 5 confirms that this relationship is bidirectional. Such a result indicates that liquidity shortages induce an increase in bank riskiness, and vice versa, banks tend to decline their liquidity buffers when they face higher risk.

Surprisingly, securitization seems to play no direct significant role in bank risk-adjustment process. Nevertheless, risk adjustments are likely to be influenced by securitization indirectly via the impact of capital on risk and securitization on capital adjustments. For most covariates, the estimation of the NPL - risk equation renders significant results. Thus, in this part we focus on results provided in Panel B Table 5. The size effect on bank risk measured by NPL is positive, which contradicts the predictions of the literature on intermediation (Diamond, 1984; Ramakrishnan and Thakor, 1984). It does not necessarily undermine the benefits of diversification. As shown by Boyd and Runkle (1993), while being better diversified, larger banks may also use excessive financial leverage. Consequently, the net effect tends to be an increase in risk. Actually, Boyd and Runkle obtain likewise the positive size effect both on risk and on capital. This is consistent with the argument that larger banks, which enjoy an easier access to investment opportunities, capital markets and funding, can maintain higher levels of risk. Providing that a large number of investment opportunities results in diversification, the positive size effect may in fact imply that specializing leads to improvement of bank's monitoring effectiveness and incentives, and thus reduces credit risk (Stomper, 2006). The impact of *Core Deposits* of around 0.04^{***} is positive, which shows that banks with more stable financing maintain riskier loan portfolios. This result suggests that banks with greater charter values incur more risk. $LLOSS$ has a negative and significant impact on changes in bank risk, measured by NPL, which indicates that banks with higher loan losses are willing to reduce riskiness of their loan portfolio.

The estimates for the liquidity equation are presented in Table 5 As expected, lagged values of liquidity have negative signs and lie within a unit interval. The coefficient estimates on lagged liquidity in Panel A vary from -0.089^{**} to -0.139^{***} for four different measures of bank capital, while the coefficient estimates on lagged LIQ in Panel B are larger and vary from -0.439^{***} to -0.638^{***}. This outcome indicates that a speed of liquidity adjustments varies significantly for the two measures of risk. *Core Deposits* positively affect liquidity adjustments, which implies that banks with higher charter values tend to keep higher liquidity buffers. The negative coefficient of bank size indicates that larger banks maintain lower liquidity buffers, which is most likely due to a better access to external funding. Surprisingly, NIM positively impacts bank changes in liquidity, indicating that more profitable banks maintain higher liquidity ratios. But the estimate of $LOAN$ has the expected negative sign, showing that banks with higher loan growth maintain lower liquidity ratios. As in case of the risk adjustments, SEC has no direct significant impact on bank liquidity changes.

All in all, our results indicate that U.S. commercial banks coordinated their capital, risk and liquidity adjustments during the pre-crisis period. This result is worth noting as it sheds light on how banks could overcome the regulations on capital and emphasizes the critical role of a joint regulation of capital ratios and liquidity ratios in relation to bank risk-taking behavior. We have established that banks with more stable sources of financing maintain lower capital ratios and tend to incur more risk. Our result emphasizes a need to regulate both bank capital and liquidity to ensure that banks simultaneously maintain appropriate capital and liquidity levels. As such, it support the idea of the stable funding ratios introduced in the new Basel regulations.

5.2 The crisis period

Tables 3, 4 and 5 confirm our key results from the pre-crisis period. In the crisis period likewise banks coordinated capital, risk and liquidity adjustments. Signs of these dependencies remain unchanged for all but the capital influence on the risk adjustment. In particular, the estimates in columns (5) - (8) of Table 3 indicate a negative coordination of capital and risk using the two risk measures. Thus, we observe that during the crisis short-term adjustments in NPL negatively impacted adjustments in bank capital, which is in contrast to the positive relationship from the pre-crisis period. The change in sign of the relationship between bank capital and NPL is reflected in the changing behavior of NPL, which dynamically rose during the financial crisis. The crisis revealed a problem of underestimated risk of banks' credit loan portfolios. The surge in NPLs has been charged against bank capital, which yielded its drop. However, the positive effect of liquidity changes (NPL) on capital adjustments detected for the pre-crisis period is also present in the crisis period (Panel B Table 3). Lagged values of capital have a significant negative impact on capital adjustments. Their estimated coefficients range from -0.505*** to -0.860***, and thus lie within a unit interval. For the risk measured by $RWATA$, their magnitudes are mostly lower than for the pre-crisis period. This outcome indicates that in the crisis period banks adjusted capital to its target levels slower. It could be explained by the fact that it is more costly to raise capital during the financial turmoil. A related research line could be a detailed analysis of effects of Troubled Asset Relief Program (TARP) and Capital Purchase Program (CPP) on the capital adjustments and coordination. We leave this research question for our further investigation. Similarly to the outcome for the pre-crisis period, bank size has a negative impact on bank capital (Table 3 Panel A). Bigger banks might tend to maintain lower capital ratios, because they have an easier access to funding, and thus do not have to build up precautionary buffers, as smaller banks do. In the crisis period, the estimates for ROA range from 1.611*** to 4.947*. Thus, the positive ROA coefficients show that more profitable banks tend to retain a part of their earnings to increase their capital ratios also in the crisis period. Not surprisingly, the magnitude of the estimates for the crisis period is smaller. Unlike in the pre-crisis period, $Core\,Deposits$ and SEC no longer play a significant role in capital-adjustment process (Table 3 Panel A). In case of securitization, one could explain this fact by the collapse of the structural finance market in the initial phase of the crisis. In the same time central banks attempted to solve the liquidity problems in banking sectors by providing cheap standby lending facilities. In addition, the US Treasure Department conducted TARP and CPP programs. We expect those the factors altogether to decrease the importance of deposits for the capital adjustments determination. $LLOSS$ has a positive impact on changes in capital, indicating that banks with higher provisions for loan losses maintain higher capital ratios in order to insure against any solvency issues.

Columns (5) - (8) of Table 4 summarize the estimation outcome for the risk equation. In the crisis period these results do not differ for two different measures of risk. There is a positive coordination of risk with capital, indicating that banks reduce their risk-taking when they face a decline in capital ratios. This outcome is in line with the empirical findings of Shrieves and Dahl (1992) as well as, partially, Jacques and Nigro (1997), but is not consistent with the theoretical implications of Repullo (2005). Since the US TARP program involved buying troubled assets from the US banks, and thus lowering their levels of risk-weighted assets, we expect this intervention to account for this shift in sign in the crisis versus the pre-crisis period. As mentioned previously, we leave this question for our further research. Contrary to the effect of capital adjustments, the liquidity adjustments in the crisis period have likewise a negative impact on both risk and capital adjustments. However, the negative coordination between bank risk and liquidity holds only for the case when bank risk is captured by $RWATA$. We find no evidence of coordination of NPL and liquidity adjustments in the crisis period. For the bank risk measured by $RWATA$, the inverse influence of the bank's liquidity on its riskiness suggests that in the crisis times banks accumulating liquid assets continues to have safer portfolios (Diamond and Rajan, 2006). The estimates in Panel A of Table 5 suggest that this dependency is bidirectional as well. The fitted coefficients on lagged measures of risk have the expected negative signs and lie within a unit interval. Not surprisingly, their magnitude is greater than in the pre-crisis period indicating that banks more actively adjusted their risk-taking during the crisis. $SIZE$ positively impacts changes in bank time. $LLOSS$ has a negative impact on changes in bank risk, showing that banks with higher loan losses are willing to reduce their riskiness.

The estimation results for the liquidity equation are presented in Columns (5) - (8) of Table 5. The results show that there is a negative coordination of liquidity and capital, suggesting that banks increase liquidity ratios when capital ratios decline. This relationship holds for two measures of risk. There is also the negative coordination between liquidity and risk. But it is statistically significant only for the case when bank risk is measured by $RWATA$. Lagged values of liquidity have significant negative impacts, and their estimated coefficients lie within a unit interval. The magnitudes of coefficients are higher for the crisis period than for the pre-crisis period, indicating that banks adjusted liquidity to the desired targets faster during the financial turmoil. The coefficient of $Core\,Deposits$ remains positive. An impact of the bank size is negative for the crisis period, which is consistent with the results for the pre-crisis period. SEC has no significant impact on bank liquidity ratios during the crisis.

6 Conclusions

In this paper, we examine how the U.S. commercial banks coordinate capital, risk and liquidity during the period leading to the recent financial crisis and during the crisis. This period is of a particular interest since it contains intervals of boom and bust in the securitization market as well as the period of financial turmoil. We employ simultaneous equation model with partial adjustment introduced by Shrieves and Dahl (1992) and extend it to model the liquidity buffers. Moreover, instead of a pooled regression approach we use a dynamic panel data technique that accounts for unobserved bank-specific effects.

The results establish that banks simultaneously coordinate capital and liquidity levels, as well as their risk exposure. Capital and risk are simultaneously adjusted by banks, however the direction of adjustments differs for the two time periods. During normal times, there is a negative coordination of bank capital and risk. Banks respond to a reduction in capital by increasing their risk-taking, while an increase in bank risk reinforces an even higher reduction of bank capital ratios. During the financial turbulence, we establish a positive influence of capital adjustments on risk adjustments, and a negative impact of risk on capital adjustments. These findings indicate that in the crisis times banks reduce their risk-taking when they face a decline in capital ratios. Nonetheless, an increase in risk induces a reduction in their capital ratios. We expect this shift in sign for the distress period to be mostly attributable to the effects of the TARP program conducted by the US Treasure Department during the recent financial crisis. When bank risk is measured by the ratio of risk-weighted assets, we find a negative coordination of bank capital and liquidity in both the pre-crisis and crisis periods. This indicates that banks increase their capital ratios when they face liquidity shortage. Liquidity and capital adjustments are negatively related for the two measures of risk, suggesting that banks increase their liquidity ratios when they face lower capital ratios. We detect a negative coordination between bank risk and liquidity, which suggests that banks lower their riskiness by increasing their liquidity position and increase risk-taking by lowering their capital buffer. These results are confirmed by the set of regressions using different measures of bank capital. The inverse influence of the bank's liquidity on its riskiness suggests that banks accumulating liquid assets tend to have safer portfolios, which confirms one of the implications of Diamond and Rajan (2006). All in all, our research empirically verifies the theoretical predictions of Repullo (2005) and shows that an increase in capital induces banks to lower risk-taking and reduce liquidity position. This outcome is consistent with the finding of Repullo (2005).

We analyze the relationship between simultaneous short-term adjustments in bank capital, risk and liquidity over the two time periods: the period leading to the recent financial crisis and during the crisis itself. It is worth noticing that rates of liquidity adjustment are higher during the crisis. It indicates that banks were willing to reach desired levels of liquidity much faster during the crisis relative to the pre-crisis period. The fitted coefficients on lagged measures of risk are also greater in the crisis versus the pre-crisis period, showing that banks more actively adjusted their risk-taking during the financial crisis. For the case when risk is measured by $RWATA$, the speeds of capital adjustments are mostly lower than those for the pre-crisis period. This outcome indicates that in the crisis period banks adjusted capital to its target levels slower, as it is more costly to raise capital during the financial distress. More generally, it shows that banks faced difficulties changing capital ratios to desired levels during the financial turmoil. Finally, this study examines a role securitization played in coordination of capital, risk and liquidity decisions. We find only limited evidence that securitization directly affected the capital, risk and liquidity interactions. We show that securitization increases banks' capital, and the impact of securitization on capital is significant only for the period leading to the crisis. This effect becomes insignificant during the crisis period. Given the limited evidence, we cannot conclude that banks used securitization to relax constraints of existing capital requirements.

Our research is instructive for the discussion on monitoring banks with instruments such as capital and liquidity ratios. All in all, our results indicate that U.S. commercial banks coordinated their capital, risk and liquidity adjustments during the pre-crisis period. This result is worth noting as it sheds light on how banks could overcome the regulations on capital and emphasizes the critical role of a joint regulation of capital ratios and liquidity ratios in relation to bank risk-taking behavior. In particular, our findings for the pre-crisis period indicate that not only do banks coordinate their risk, liquidity and capital levels, but also banks with more stable sources of financing maintain lower capital ratios and incur more risk. This outcome emphasizes the need to regulate both bank capital and liquidity to assure that banks concurrently maintain appropriate capital levels and stable funding sources. This suggests that bank liquidity is an important coordination tool and supports an implementation of the stable funding ratios in the new Basel III regulations in addition to capital requirements. As such, the study contributes to the discussion on the evaluation of Basel III and its implementation.

7 References

1. Aggarwal, R., & Jacques, K. T. (2001). The impact of FDICIA and prompt corrective action on bank capital and risk: Estimates using a simultaneous equations model. *Journal of Banking and Finance* , 25 (6), 1139–1160.

2. Arellano, M. & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58 (2), 277-297.

3. Aspachs, O., Nier, E., & Tiesset, M. (2005). Liquidity, banking regulation and the macroeconomy: Evidence on bank liquidity holdings from a panel of UK-resident banks. Working paper, Bank of England.

4. Baltagi, B.H. (2008). Econometric analysis of panel data. John Wiley and Sons Ltd.

5. Baltensperger, E. (1980). Alternative approaches to the theory of the banking firm. *Journal of Monetary Economics* , 6 (1), 1-37.

6. Boyd, J. & Runkle, D. (1993). Size and the performance of banking firms: Testing the predictions of theory. *Journal of Monetary Economics*, 31, 47–67.

7. Calem, P. & Rafael, R. (1999). The impact of capital-based regulation on bank risk-taking. *Journal of Financial Intermediation* , 8 (4), 317-352.

8. Dell'Ariccia, G., Detragiache E. & Rajan, R. (2005). The real effect of banking crises. CEPR Discussion Papers No 5088.

9. Diamond, D.W. (1984). Financial intermediation and delegated monitoring. *Review of Economic Studies* , 51, 393-414.

10. Diamond, D., & Dybvig, D. (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy* , 91, 401–419.

11. Diamond, D., & Rajan, R. G. (2001). Liquidity risk, liquidity creation, and financial fragility: A theory of banking. *Journal of Political Economy* , 109, 287–327.

12. Diamond, D., & Rajan, R. G. (2006). Money in a theory of banking. *American Economic Review*, 96 (1), 30–53.

13. Dionne, G., & Harchaoui, T. (2003). Banks' capital, securitization and credit risk: An empirical evidence for canada. HEC Working Paper No. 03-01.

14. Distinguin,I., Roulet, C., & Tarazi, A. (2013). Bank regulatory capital and liquidity: Evidence from US and European publicly traded banks. *Journal of Banking and Finance* , 37, 3295-3317.

15. Furlong, F. T., & Keeley, M. C. (1989). Capital regulation and bank risk-taking: A note. *Journal of Banking and Finance* , 13, 883-891.

16. Greenbaum, S. & Thakor, A. V. (1987). Bank funding modes: Securitization versus deposits. *Journal of Banking and Finance*, 11 (3), 379–401.

17. Heid, F., Porath, D., & Stolz, S. (2004). Does capital regulation matter for bank behaviour? Evidence for German savings banks. Discussion Paper Series 2: Banking and Financial Supervision No 03/2004, Deutsche Bundesbank

18. Hellmann, T., Murdock K. & Stiglitz, J. (2000). Liberalization, moral hazard in banking, and prudential regulation: Are capital requirements enough? *The American Economic Review* , 90 (1), 147-165.

19. Instefjord, N. (2005). Risk and hedging: Do credit derivatives increase bank risk? *Journal of Banking and Finance*, 29 (2), 333–345.

20. Jacques, K. T., & Nigro, P. (1997). Risk-based capital, portfolio risk, and bank capital: A simultaneous equations approach. *Journal of Economics and Business* , 49 (6), 533–547.

21. Jokipii, T., & Milne, A. (2011). Bank capital buffer and risk adjustment decisions. *Journal of Financial Stability* , 7, 165–178.

22. Jones, J. S., Miller, S. A., & Yeager, T. J. (2011). Charter value, Tobin's Q and bank risk during the subprime financial crisis. *Journal of Economics and Business* , 63, 372-391.

23. Kahane, Y. (1977). Capital adequacy and the regulation of financial intermediaries. *Journal of Banking and Finance* , 1, 207—218.

24. Kim, D., & Santomero, A. M. (1988). Risk in banking and capital regulation. *Journal of Finance* , 43 (5), 1219–1233.

25. Koehn, M., & Santomero, A. M. (1980). Regulation of bank capital and portfolio risk. *Journal of Finance* , 35 (5), 1235–1244.

26. Kowalczyk, D. (2012). Capital, liquidity and risk allocation in the banking Euro-zone sector. Mimeo.

27. Loutskina, E. (2011). The role of securitization in bank liquidity and funding management. *Journal of Financial Economics* , 100, 663-684.

28. Markowitz, H. M. (1952). Portfolio selection. *Journal of Finance* , 7(1), 77-91.

29. Merton, R. (1977). An analytic derivation of the cost of deposit insurance and loan guarantees. *Journal of Banking and Finance* , 1, 3-11.

30. Milne, A. (2002). Bank capital regulation as an incentive mechanism: Implications for portfolio choice. *Journal of Banking and Finance* , 26 (1), 1-23.

31. Prisman, E., Slovin, M., & Sushka, M. (1986). A general model of the banking firm under conditions of monopoly, uncertainty, and recourse. *Journal of Monetary Economics* , 17 (2), 293–304.

32. Repullo, R. (2005). Liquidity, risk taking and the lender of last resort. *International Journal of Central Banking* , 1 (2), 47–80.

33. Rochet, J. C. (1992). Capital requirement and the behaviour of commercial banks. *European Economic Review* , 36, 1137–1178.

34. Roodman, D. (2009). How to do xtabond2: An introduction to "difference" and "system" GMM in Stata. *Stata Journal* , 9 (1), 86-136.

35. Rousseau, P. L. & Wachtel, P. (1998). Financial intermediation and economic performance: Historical evidence from five industralized countries. *Journal of Money, Credit and Banking*, 30, 657-678.

36. Santomero, A. M. (1984). Modelling the banking firm: a survey. *Journal of Money, Credit and Banking* , 16, 576-602.

37. Sharpe, W. (1978). Bank capital adequacy, deposit insurance and security values. *Journal of Financial and Quantitative Analysis* , 13, 701-718.

38. Shrieves, R. E., & Dahl, D. (1992). The relationship between risk and capital in commercial banks. *Journal of Banking Finance* , 16 (2), 439–457.

39. Stomper, A. (2006). A theory of banks' industry expertise, market power, and credit risk. *Management Science* , 52 (10), 1618-1634.

40. Stolz, S. (2002). The relationship between bank capital, risk-taking, and capital regulation: A review of the literature. Kiel Working Paper № 1105.

41. Ramakrishnan, R. & Thakor, A. V. (1984). Information reliability and a theory of financial mtermediation. *Review of Economic Studies*, 51, 415-432.

42. Uzun, H., & Webb, E. (2007). Securitization and risk: Empirical evidence on US banks. *Journal of Risk Finance* , 8 (1), 11-23.

43. VanHoose, D. (2007). Theories of bank behaviour under capital regulation. *Journal of Banking and Finance* , 31 (12), 3680–3697.

Table 1: Varibles Description

Variable	Description	Call Report Data Items
SIZE	Natural logarithm of total assets	ln(rcfd2170)
Core Deposits	(Time deposits under $100,000 + transaction accounts + money market deposit accounts + + other nontransaction savings deposits)/Total assets	(rcon2215 + rcon6810 + rcon0352 + + rcon6648)/rcfd2170
EQ CAP	Total equity capital/Total assets	rcfd3210/rcfd2170
RB CAP	Total equity capital/Risk-weighted assets	rcfd3210/rcfda223
Tier1 RB CAP	Tier 1 (core) capital/Risk-weighted assets	rcfd7206
Total CAP	Total risk-based capital/Risk-weighted assets	rcfd7205
RWATA	Risk-weighted assets/Total assets	rcfda223/rcfd2170
NPL	Nonperforming loans and leases/Total loans and leases	(rcfd1403+ rcfd1407)/rcfd1400
LIQ	(Cash + securities held to maturity and available for sale + Fed Funds sold and securities purchased under agreements to resell)/Total assets	(rcfd0010 + rcfd1754 + rcfd1773 + + rcfd1350)/rcfd2170
ROA	Net income/Total assets	riad4340/rcfd2170
LLOSS	The provision for loan and lease losses/Total loans and leases	riad4230/rcfd1400
NIM	Net interest income/Average total assets	riad4074/rcfda224
LOAN	The growth rate of total loans and leases	rcfd1400
SEC	(ABS and MBS held to maturity, available for sale and held for trading + off-balance sheet assets sold and securitized with servicing retained or with recourse or other seller-provided credit enhancements)/Total assets	(rcfdb705 + rcfdb706 + rcfdb707 + rcfdb708 + + rcfdb709 + rcfdb710 + rcfdb711 + rcfdb790 + + rcfdb791 + rcfdb792 +rcfdb793 + rcfdb794 + + rcfdb795 + rcfdb796 + rcfdb776 +rcfdb777 + + rcfdb778 + rcfdb779 + rcfdb780 + rcfdb781 + + rcfdb782)/rcfd2170

Table 2: Bank Descriptive Statistics

	N	Mean	St. Dev.	Min	p25	p50	p75	Max
Full Sample								
TA (USD mln)	268248	379.4305	1185.638	5.173	56.233	119.347	272.245	26299.352
△EQ CAP	233986	-0.0016	0.015	-0.520	-0.003	-0.000	0.003	0.393
△RB CAP	233802	-0.0035	0.033	-0.874	-0.006	-0.000	0.004	0.815
△Tier1 RB CAP	233802	-0.0033	0.031	-0.806	-0.005	-0.000	0.003	0.787
△Total CAP	233802	-0.0033	0.031	-0.802	-0.005	-0.000	0.003	0.796
△RWATA	233986	0.0023	0.039	-0.885	-0.013	0.002	0.016	0.925
△NPL	232743	0.0006	0.009	-0.141	-0.002	0.000	0.002	0.141
△LIQ	233986	-0.0029	0.044	-0.876	-0.020	-0.002	0.016	0.876
SIZE	243305	11.7716	1.245	8.992	10.911	11.662	12.487	16.669
Core Deposits	243305	0.6765	0.122	0.000	0.622	0.695	0.757	0.874
EQ CAP	243305	0.1126	0.056	0.001	0.084	0.099	0.121	0.571
RB CAP	243110	0.1763	0.116	0.067	0.116	0.143	0.192	1.109
Tier1 RB CAP	243110	0.1703	0.113	0.064	0.110	0.137	0.186	1.041
Total CAP	243110	0.1815	0.113	0.078	0.122	0.148	0.197	1.045
RWATA	243305	0.6830	0.138	0.000	0.597	0.692	0.780	0.994
NPL	242017	0.0123	0.017	0.000	0.002	0.007	0.016	0.141
LIQ	243305	0.3203	0.162	0.036	0.201	0.294	0.413	0.912
ROA	243305	0.0019	0.004	-0.028	0.001	0.002	0.003	0.010
LLOSS	242017	0.0013	0.003	-0.001	0.000	0.001	0.001	0.029
NIM	243112	0.0095	0.002	0.003	0.008	0.009	0.011	0.018
LOAN	232776	3.1021	8.761	-16.485	-0.752	1.732	4.707	63.232
SEC	243305	0.0038	0.021	0.000	0.000	0.000	0.000	0.209
Pre-crisis period								
TA (USD mln)	156561	345.5289***	1079.973	5.269	53.308	111.120	251.768	21738.527
△EQ CAP	156561	0.0004***	0.008	-0.279	-0.002	0.000	0.003	0.393
△RB CAP	156447	-0.0004***	0.018	-0.767	-0.005	-0.000	0.004	0.815
△Tier1 RB CAP	156447	-0.0001***	0.017	-0.755	-0.004	0.000	0.004	0.787
△Total CAP	156447	-0.0001***	0.017	-0.761	-0.004	0.000	0.004	0.796
△RWATA	156561	0.0039***	0.034	-0.883	-0.010	0.003	0.017	0.925
△NPL	155954	0.0000***	0.007	-0.069	-0.002	0.000	0.001	0.069
△LIQ	156561	-0.0042***	0.038	-0.876	-0.021	-0.003	0.014	0.859
SIZE	156561	11.7272***	1.228	8.992	10.884	11.618	12.436	16.669
Core Deposits	156561	0.6938***	0.113	0.000	0.642	0.710	0.768	0.874
EQ CAP	156561	0.1079***	0.042	0.001	0.084	0.097	0.119	0.476
RB CAP	156448	0.1706***	0.095	0.086	0.117	0.144	0.190	0.927
Tier1 RB CAP	156448	0.1653***	0.092	0.083	0.111	0.138	0.185	0.898
Total CAP	156448	0.1767***	0.092	0.098	0.123	0.149	0.196	0.907
RWATA	156561	0.6735***	0.134	0.000	0.589	0.681	0.767	0.987
NPL	155972	0.0101***	0.012	0.000	0.002	0.006	0.013	0.069
LIQ	156561	0.3275***	0.157	0.036	0.212	0.305	0.419	0.912
ROA	156561	0.0026***	0.002	-0.013	0.002	0.003	0.004	0.010
LLOSS	155972	0.0008***	0.002	-0.001	0.000	0.000	0.001	0.012
NIM	156449	0.0097***	0.002	0.004	0.008	0.010	0.011	0.018
LOAN	155963	2.0059***	5.538	-16.485	-0.739	1.694	4.334	63.232
SEC	156561	0.0030***	0.017	0.000	0.000	0.000	0.000	0.143
Crisis period								
TA (USD mln)	59656	453.6327	1356.851	7.541	69.278	148.832	337.943	26299.352
△EQ CAP	59650	-0.0003	0.008	-0.221	-0.003	-0.000	0.003	0.290
△RB CAP	59606	-0.0007	0.018	-0.548	-0.005	0.000	0.004	0.727
△Tier1 RB CAP	59606	-0.0011	0.016	-0.556	-0.004	-0.000	0.003	0.739
△Total CAP	59606	-0.0010	0.017	-0.555	-0.004	-0.000	0.003	0.743
△RWATA	59650	0.0005	0.033	-0.623	-0.014	0.000	0.014	0.580
△NPL	59368	0.0021	0.012	-0.141	-0.002	0.000	0.004	0.141
△LIQ	59650	-0.0018	0.034	-0.796	-0.017	-0.001	0.016	0.592
SIZE	59656	12.0004	1.245	9.302	11.146	11.911	12.731	16.286
Core Deposits	59656	0.6537	0.109	0.108	0.598	0.666	0.727	0.854
EQ CAP	59656	0.1101	0.048	0.050	0.086	0.099	0.120	0.571
RB CAP	59612	0.1654	0.102	0.067	0.113	0.138	0.181	1.109
Tier1 RB CAP	59612	0.1587	0.098	0.064	0.107	0.131	0.174	1.041
Total CAP	59612	0.1698	0.097	0.078	0.119	0.142	0.184	1.045
RWATA	59656	0.7102	0.134	0.294	0.627	0.723	0.805	0.994
NPL	59378	0.0203	0.026	0.000	0.004	0.012	0.026	0.141
LIQ	59656	0.2900	0.157	0.043	0.175	0.259	0.377	0.839
ROA	59656	0.0008	0.005	-0.028	0.000	0.002	0.003	0.009
LLOSS	59378	0.0023	0.005	-0.000	0.000	0.001	0.002	0.029
NIM	59612	0.0089	0.002	0.003	0.008	0.009	0.010	0.016
LOAN	59377	1.3199	5.295	-11.669	-1.302	0.920	3.393	55.149
SEC	59656	0.0067	0.029	0.000	0.000	0.000	0.000	0.209

This table presents descriptive statistics for bank-quarters for the full sample period, for the pre-crisis period and for the crisis period. The data is taken from the Federal Reserve's Reports of Condition and Income (Call Reports) for the period from 2001 Q1 through 2009 Q4. The pre-crisis period is from 2001 Q1 through 2007 Q2 and the crisis period is from 2007 Q3 through 2009 Q4. Tests for significant differences in means between the pre-crisis and the crisis periods are based on the Welch's t-test statistics. ***, ** and * are significance levels at 1%, 5%, and 10%, respectively. See Table 1 for variables definitions.

Table 3: Capital Equation: Relationsip between changes in bank capital, risk and liquidity

	Pre-crisis period (2001 Q1 - 2007 Q2)				Crisis period (2007 Q3 - 2009 Q4)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	△EQ CAP	△RB CAP	△Tier1 RB CAP	△Total CAP	△EQ CAP	△RB CAP	△Tier1 RB CAP	△Total CAP
Panel A: Risk is measured by RWATA								
Core Deposits	-0.0935**	-0.186**	0.00457	-0.000951	0.0243 ♮	-0.212	0.0894	0.0836
	(-2.22)	(-2.38)	(0.08)	(-0.02)	(0.55)	(-0.34)	(1.22)	(1.13)
SIZE	-0.0305***	-0.0315	-0.0432**	-0.0431**	-0.0886***♮♮	-0.0375	-0.107**	-0.104**
	(-3.09)	(-1.45)	(-2.28)	(-2.24)	(-4.19)	(-0.10)	(-2.50)	(-2.40)
LLOSS	0.294	0.754	-0.976	-1.060	1.193**	-4.904	2.514**	2.601**
	(0.28)	(0.33)	(-0.46)	(-0.51)	(2.10)	(-0.45)	(1.98)	(2.05)
ROA	2.820***	6.522***	5.638***	5.697***	1.611***	-13.16	1.411 ♮♮♮	1.387 ♮♮♮
	(3.77)	(4.78)	(5.37)	(5.36)	(3.19)	(-0.78)	(1.26)	(1.24)
SEC	0.481*	1.037	-0.279	-0.133	0.180	-0.424	0.0207	0.0201
	(1.80)	(1.54)	(-0.44)	(-0.22)	(0.78)	(-0.06)	(0.04)	(0.05)
EQ CAP_{t-1}	-0.744***				-0.726***			
	(-10.53)				(-21.60)			
RB CAP_{t-1}		-0.975***				-0.860***		
		(-10.42)				(-2.95)		
Tier1 RB CAP_{t-1}			-0.915***				-0.544***♮♮♮	
			(-6.98)				(-10.73)	
Total CAP_{t-1}				-0.875***				-0.537***♮♮
				(-6.82)				(-10.80)
△RWATA	0.0145	-0.202***	-0.190***	-0.198***	-0.0321	-0.104	-0.267***	-0.274***
	(0.52)	(-2.89)	(-2.93)	(-3.15)	(-0.92)	(-0.21)	(-3.79)	(-3.83)
△LIQ	-0.0136	-0.0995**	-0.102**	-0.0992**	-0.0513**	-0.0812	-0.146***	-0.153***
	(-0.61)	(-1.96)	(-2.27)	(-2.24)	(-2.15)	(-0.28)	(-2.89)	(-2.98)
N	148227	148181	148181	148181	52849	52864	52864	52864
N of instruments	67	67	67	67	50	19	50	50
N of banks	8065	8062	8062	8062	6558	6554	6554	6554
Hansen J-test	0.116	0.000	0.083	0.078	0.622	0.440	0.235	0.217
AR(1) test	0.000	0.001	0.003	0.001	0.002	0.342	0.000	0.000
AR(2) test	0.736	0.153	0.472	0.543	0.479	0.163	0.570	0.572
Panel B: Risk is measured by NPL								
Core Deposits	-0.0996**	-0.00731	0.106**	0.112***	-0.0550	0.0761	0.0521	0.0510
	(-2.36)	(-0.15)	(2.53)	(2.63)	(-0.77)	(0.46)	(0.53)	(0.51)
SIZE	-0.0273**	0.0146	0.00674	0.00563	0.0603** ♮♮♮	-0.0762	-0.0818* ♮	-0.0826* ♮
	(-2.30)	(0.93)	(0.47)	(0.39)	(2.28)	(-1.01)	(-1.66)	(-1.67)
LLOSS	0.0601	0.833	1.133	1.230	-0.529	3.180	3.318*	3.529**
	(0.05)	(0.45)	(0.72)	(0.79)	(-0.70)	(1.51)	(1.94)	(2.09)
ROA	2.650***	4.205***	4.390***	4.469***	-0.107 ♮♮	4.947*	4.445**	4.589**
	(3.24)	(3.59)	(4.40)	(4.45)	(-0.13)	(1.86)	(2.23)	(2.32)
SEC	0.884**	1.090**	0.0657	0.104	-0.618 ♮♮	-0.249	-0.329	-0.328
	(2.30)	(2.11)	(0.14)	(0.23)	(-0.98)	(-0.17)	(-0.38)	(-0.34)
EQ CAP_{t-1}	-0.719***				-0.568***			
	(-8.41)				(-11.34)			
RB CAP_{t-1}		-0.989***				-0.528***♮♮♮		
		(-10.64)				(-5.00)		
Tier1 RB CAP_{t-1}			-0.855***				-0.505***♮♮	
			(-8.11)				(-5.30)	
Total CAP_{t-1}				-0.853***				-0.510***♮♮
				(-8.08)				(-5.34)
△NPL	0.0513	0.745***	0.389*	0.378*	-0.323*	-1.187**♮♮♮	-0.521* ♮♮	-0.524* ♮♮
	(0.32)	(3.48)	(1.95)	(1.90)	(-1.78)	(-2.26)	(-1.78)	(-1.79)
△LIQ	-0.0159	0.0968***	0.0835***	0.0845***	0.0191	0.126*	0.113**	0.115**
	(-1.13)	(3.74)	(3.63)	(3.66)	(0.43)	(1.84)	(2.03)	(2.10)
N	148210	148164	148164	148164	52839	52855	52855	52855
N of instruments	67	113	113	113	32	26	31	31
N of banks	8063	8060	8060	8060	6557	6553	6553	6553
Hansen J-test	0.194	0.000	0.238	0.223	0.099	0.541	0.804	0.750
AR(1) test	0.000	0.002	0.00171	0.00143	0.000	0.003	0.000	0.000
AR(2) test	0.535	0.128	0.168	0.183	0.193	0.718	0.613	0.671

This table reports estimation results using the Arellano-Bond Two-Step GMM procedure. GMM-type instruments for $\triangle RISK_{it}$ and $\triangle LIQ_{it}$ are used to account for simultaneity of capital, risk and liquidity adjustments. All regressions include bank fixed effects and time dummies. t- values are presented in parentheses. They are calculated using Windmeijer's corrected standard errors. Hansen J-test reports a p-value for the Hansen test of overidentifying restrictions. AR(n) tests present p-values for the test of no n-order autocorrelation in residuals. ***, ** and * are significance levels at 1%, 5%, and 10%, respectively. Tests for significant differences in regression coefficients between the pre-crisis and the crisis periods are based on the t-test statistics. ♮♮♮, ♮♮ and ♮ are significance levels at 1%, 5%, and 10%, respectively.

Table 4: Risk Equation: Relationship between changes in bank risk, capital and liquidity

	Pre-crisis period (2001 Q1 - 2007 Q2)				Crisis period (2007 Q3 - 2009 Q4)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	△RWATA	△RWATA	△RWATA	△RWATA	△RWATA	△RWATA	△RWATA	△RWATA
Panel A: Risk is measured by RWATA								
Core Deposits	0.0860	-0.0304	-0.0584	-0.0643	0.0800	0.00523	0.0224	0.0142
	(0.99)	(-0.29)	(-0.54)	(-0.59)	(0.97)	(0.06)	(0.13)	(0.08)
SIZE	0.00344	0.0121	0.0277	0.0252	0.0756**	0.0996***	0.0695	0.0624
	(0.08)	(0.27)	(0.56)	(0.51)	(1.97)	(2.84)	(0.79)	(0.71)
LLOSS	0.0102	-3.848	-3.871	-3.934	-0.457	-0.702	-1.104	-1.154
	(0.00)	(-1.07)	(-1.10)	(-1.10)	(-0.78)	(-1.28)	(-1.15)	(-1.22)
SEC	0.711	0.473	0.773	0.771	-0.402	-0.393	-1.529	-1.411
	(0.76)	(0.43)	(0.71)	(0.70)	(-0.53)	(-0.56)	(-1.02)	(-0.96)
RWATA$_{t-1}$	-0.106*	0.0535	0.0688	0.0667	-0.149***	-0.164***♮♮♮	-0.180** ♮♮	-0.185** ♮♮
	(-1.86)	(0.95)	(1.10)	(1.06)	(-2.67)	(-3.05)	(-2.03)	(-2.09)
△EQ CAP	0.0444				0.310***			
	(0.37)				(2.68)			
△RB CAP		-0.141**				0.0392 ♮♮		
		(-2.25)				(0.64)		
△Tier1 RB CAP			-0.190**				0.304♮♮	
			(-2.00)				(1.63)	
△Total CAP				-0.190**				0.309* ♮♮
				(-1.99)				(1.67)
△LIQ	-0.808***	-0.703***	-0.718***	-0.715***	-0.635***♮♮	-0.673***	-0.703***	-0.700***
	(-14.40)	(-15.87)	(-14.13)	(-14.05)	(-14.87)	(-19.47)	(-9.70)	(-9.62)
N	148227	148181	148181	148181	52849	52864	52864	52864
N of instruments	70	73	73	73	74	74	39	39
N of banks	8065	8062	8062	8062	6558	6554	6554	6554
Hansen J-test	0.114	0.425	0.374	0.371	0.649	0.510	0.785	0.757
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.000	0.000	0.000	0.000	0.097	0.095	0.093	0.087
AR(3) test	0.159	0.212	0.212	0.212	0.316	0.385	0.346	0.312
Panel B: Risk is measured by NPL								
	△NPL	△NPL	△NPL	△NPL	△NPL	△NPL	△NPL	△NPL
Core Deposits	0.0594*	0.0546*	0.0532	0.0551	-0.00298	-0.00499	0.00273	0.00338
	(1.76)	(1.74)	(1.57)	(1.64)	(-0.04)	(-0.04)	(0.06)	(0.07)
SIZE	0.0426***	0.0404***	0.0406***	0.0416***	0.03039**	0.0434	0.0280***	0.0277***
	(3.00)	(2.97)	(2.90)	(2.90)	(1.98)	(1.47)	(2.59)	(2.58)
LLOSS	-1.583***	-1.512**	-1.543**	-1.596**	-0.404** ♮	-0.788	-0.3769** ♮	-0.387** ♮
	(-2.62)	(-2.36)	(-2.26)	(-2.36)	(-2.02)	(-1.57)	(-2.00)	(-2.04)
SEC	0.229	0.285	0.446	0.421	1.178*	1.514	0.266	0.248
	(0.35)	(0.50)	(0.72)	(0.67)	(1.79)	(1.52)	(0.83)	(0.78)
NPL$_{t-1}$	-0.684***	-0.672***	-0.708***	-0.708***	-0.859***	-0.783**	-0.899***	-0.891***
	(-6.10)	(-6.45)	(-6.70)	(-6.62)	(-2.82)	(-2.46)	(-5.26)	(-5.28)
△EQ CAP	0.0643				0.266**			
	(1.13)				(2.00)			
△RB CAP		0.0571**				-0.114		
		(2.02)				(-0.61)		
△Tier1 RB CAP			0.0895**				0.106*	
			(2.29)				(1.85)	
△Total CAP				0.0814**				0.102*
				(2.13)				(1.82)
△LIQ	-0.0431**	-0.0562***	-0.0602***	-0.0595***	0.0123	-0.0568	-0.0166 ♮	-0.0164 ♮
	(-2.43)	(-3.25)	(-3.27)	(-3.23)	(0.35)	(-1.36)	(-1.10)	(-1.09)
N	148205	148159	148159	148159	52837	52853	52853	52853
N of instruments	70	70	70	70	28	26	44	44
N of banks	8058	8055	8055	8055	6556	6552	6552	6552
Hansen J-test	0.160	0.408	0.603	0.579	0.170	0.297	0.0964	0.110
AR(1) test	0.000	0.000	0.000	0.000	0.446	0.334	0.306	0.285
AR(2) test	0.927	0.741	0.914	0.914	0.571	0.389	0.877	0.862

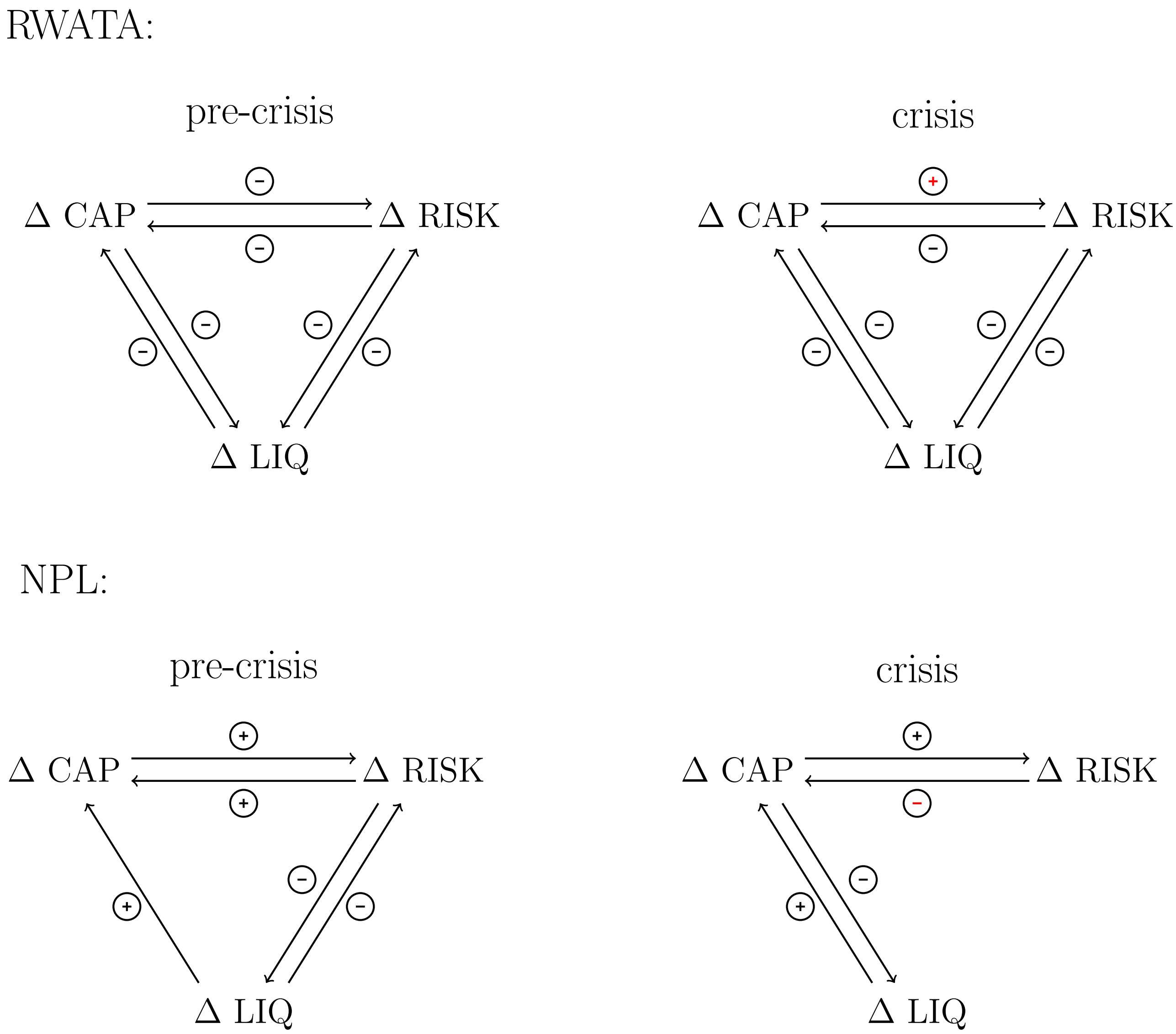
This table reports estimation results using the Arellano-Bond Two-Step GMM procedure. GMM-type instruments for $\triangle CAP_{it}$ and $\triangle LIQ_{it}$ are used to account for simultaneity of risk, capital and liquidity adjustments. All regressions include bank fixed effects and time dummies. t- values are presented in parentheses. They are calculated using Windmeijer's corrected standard errors. Hansen J-test reports a p-value for the Hansen test of overidentifying restrictions. AR(n) tests present p-values for the test of no n-order autocorrelation in residuals. ***, ** and * are significance levels at 1%, 5%, and 10%, respectively. Tests for significant differences in regression coefficients between the pre-crisis and the crisis periods are based on the t-test statistics. ♮♮♮, ♮♮ and ♮ are significance levels at 1%, 5%, and 10%, respectively.

Table 5: Liquidity Equation: Relationship between changes in bank liquidity, capital and risk

	Pre-crisis period (2001 Q1 - 2007 Q2)				Crisis period (2007 Q3 - 2009 Q4)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	△LIQ	△LIQ	△LIQ	△LIQ	△LIQ	△LIQ	△LIQ	△LIQ
Panel A: Risk is measured by RWATA								
Core Deposits	0.146**	0.137*	0.109*	0.0987*	0.734*	0.457**	0.537***♮♮	0.542***♮♮
	(2.04)	(1.85)	(1.90)	(1.72)	(1.89)	(2.00)	(3.03)	(3.04)
SIZE	-0.0647***	-0.0803***	-0.0506***	-0.0540***	-0.234	-0.236**	-0.237***♮♮	-0.244***♮♮
	(-2.73)	(-3.04)	(-2.87)	(-2.97)	(-1.52)	(-2.24)	(-2.59)	(-2.66)
NIM	3.955*	4.468*	3.335*	3.165*	-1.570	3.806	-5.864 ♮	-6.243 ♮
	(1.71)	(1.91)	(1.76)	(1.67)	(-0.24)	(0.75)	(-1.25)	(-1.33)
LOAN	-0.000965***	-0.00125***	-0.00116***	-0.00120***	-0.00135*	-0.00172***	-0.00286***	-0.00296***
	(-2.77)	(-3.43)	(-3.82)	(-3.90)	(-1.90)	(-2.63)	(-3.91)	(-3.98)
SEC	0.373	0.755	0.468	0.602	-0.854	0.473	-0.0761	-0.143
	(0.39)	(0.80)	(0.64)	(0.85)	(-0.49)	(0.46)	(-0.07)	(-0.14)
LIQ$_{t-1}$	-0.0667	-0.0899**	-0.138***	-0.139***	-0.310*	-0.262**	-0.353***♮	-0.367***♮
	(-1.45)	(-1.99)	(-4.44)	(-4.44)	(-1.68)	(-2.05)	(-3.03)	(-3.15)
△RWATA	-0.943***	-0.947***	-0.995***	-0.994***	-0.841***	-0.984***	-0.743***♮	-0.728***♮♮
	(-14.53)	(-15.26)	(-21.64)	(-21.61)	(-6.16)	(-8.17)	(-6.02)	(-5.83)
△EQ CAP	-0.217*				-0.461			
	(-1.93)				(-1.45)			
△RB CAP		-0.112**				-0.422***♮♮		
		(-1.98)				(-3.09)		
△Tier1 RB CAP			-0.266***				-0.909***♮♮♮	
			(-2.84)				(-4.04)	
△Total CAP				-0.273***				-0.922***♮♮♮
				(-2.88)				(-4.13)
N	148167	148171	148171	148171	52813	52857	52857	52857
N of instruments	113	113	153	153	25	38	38	38
N of banks	8060	8060	8060	8060	6553	6553	6553	6553
Hansen J-test	0.262	0.106	0.183	0.156	0.117	0.232	0.306	0.320
AR(1) test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2) test	0.000	0.000	0.000	0.000	0.187	0.258	0.090	0.087
AR(3) test	0.105	0.102	0.163	0.166	0.554	0.920	0.289	0.225
Panel B: Risk is measured by NPL								
Core Deposits	0.0724	0.0956	0.0596	0.0614	1.062	1.742** ♮	-0.0651	-0.0503
	(0.63)	(0.86)	(0.54)	(0.55)	(1.52)	(2.04)	(-0.20)	(-0.15)
SIZE	-0.172***	-0.0942*	-0.125**	-0.119**	0.267	0.238	-0.0341	-0.0316
	(-3.36)	(-1.86)	(-2.27)	(-2.15)	(0.86)	(0.42)	(-0.38)	(-0.35)
NIM	8.831**	12.87***	12.55***	12.43***	-5.889	-16.69	0.763 ♮	0.794 ♮
	(2.26)	(3.00)	(3.05)	(3.02)	(-0.43)	(-0.82)	(0.16)	(0.17)
LOAN	-0.00284***	-0.00200***	-0.00236***	-0.00233***	0.00156	0.00137	-0.00326***	-0.00323***
	(-4.38)	(-3.48)	(-3.54)	(-3.49)	(0.60)	(0.49)	(-3.21)	(-3.20)
SEC	1.124	1.037	1.592	1.539	-9.347	-10.13	1.157	1.292
	(0.57)	(0.72)	(1.07)	(1.03)	(-0.82)	(-0.86)	(0.35)	(0.38)
LIQ$_{t-1}$	-0.439***	-0.638***	-0.598***	-0.613***	-0.418	-0.794***	-0.329***♮	-0.334***♮
	(-4.52)	(-6.44)	(-5.48)	(-5.58)	(-1.47)	(-2.72)	(-3.24)	(-3.32)
△NPL	-0.918	-0.997**	-1.057**	-1.067**	-2.047	-1.533	-0.0324	-0.0230
	(-1.49)	(-2.12)	(-2.18)	(-2.21)	(-0.99)	(-0.40)	(-0.05)	(-0.03)
△EQ CAP	-0.305**				-0.494			
	(-2.25)				(-0.44)			
△RB CAP		0.0211				0.452		
		(0.34)				(0.71)		
△Tier1 RB CAP			-0.0486				-1.712***♮♮♮	
			(-0.34)				(-5.28)	
△Total CAP				-0.0460				-1.680***♮♮♮
				(-0.32)				(-5.21)
N	148160	148164	148164	148164	52811	52855	52855	52855
N of instruments	70	70	70	70	22	22	31	31
N of banks	8060	8060	8060	8060	6553	6553	6553	6553
Hansen J-test	0.002	0.379	0.460	0.438	0.399	0.520	0.316	0.273
AR(1) test	0.000	0.000	0.000	0.000	0.138	0.494	0.000	0.000
AR(2) test	0.000	0.161	0.074	0.099	0.477	0.678	0.857	0.859

This table reports estimation results using the Arellano-Bond Two-Step GMM procedure. GMM-type instruments for $\triangle RISK_{it}$ and $\triangle CAP_{it}$ are used to account for simultaneity of liquidity, risk and capital adjustments. All regressions include bank fixed effects and time dummies. t- values are presented in parentheses. They are calculated using Windmeijer's corrected standard errors. Hansen J-test reports a p-value for the Hansen test of overidentifying restrictions. AR(n) tests present p-values for the test of no n-order autocorrelation in residuals. ***, ** and * are significance levels at 1%, 5%, and 10%, respectively. Tests for significant differences in regression coefficients between the pre-crisis and the crisis periods are based on the t-test statistics. ♮♮♮, ♮♮ and ♮ are significance levels at 1%, 5%, and 10%, respectively.

Figure 1: Banks' coordination of capital, risk and liquidity



Appendix

Table A.1: Correlation matrix of independent variables for the full sample period

	SIZE	Core Deposits	EQ CAP	RB CAP	Tier1 RB CAP	Total CAP	RWATA	NPL	LIQ	ROA	LLOSS	NIM	LOAN
SIZE	1.000												
Core Deposits	-0.199	1.000											
EQ CAP	-0.252	-0.398	1.000										
RB CAP	-0.288	-0.292	0.880	1.000									
Tier1 RB CAP	-0.320	-0.282	0.866	0.987	1.000								
Total CAP	-0.316	-0.284	0.867	0.987	0.999	1.000							
RWATA	0.246	-0.092	-0.194	-0.547	-0.545	-0.544	1.000						
NPL	0.011	-0.034	-0.064	-0.074	-0.074	-0.070	0.061	1.000					
LIQ	-0.251	0.057	0.301	0.571	0.578	0.576	-0.792	-0.049	1.000				
ROA	0.082	0.151	-0.195	-0.173	-0.172	-0.172	0.007	-0.316	-0.018	1.000			
LLOSS	0.057	-0.175	0.129	0.070	0.067	0.070	0.115	0.414	-0.064	-0.642	1.000		
NIM	-0.094	0.145	0.007	-0.133	-0.129	-0.127	0.290	-0.124	-0.276	0.316	-0.032	1.000	
LOAN	-0.050	-0.191	0.340	0.229	0.228	0.225	0.094	-0.187	-0.047	-0.203	0.072	0.031	1.000
SEC	0.089	-0.045	-0.009	-0.047	-0.050	-0.049	0.097	0.025	-0.064	0.011	0.034	-0.031	-0.022

Table A.2: Variable correlation matrix for the full sample period

	△EQ CAP	△RB CAP	△Tier1 RB CAP	△Total CAP	△RWATA	△NPL	△LIQ
Correlation coefficients between dependent variables							
△EQ CAP	1.000						
△RB CAP	0.756	1.000					
△Tier1 RB CAP	0.737	0.974	1.000				
△Total CAP	0.736	0.973	0.998	1.000			
△RWATA	-0.007	-0.438	-0.428	-0.431	1.000		
△NPL	-0.010	0.003	0.002	0.005	-0.022	1.000	
△LIQ	0.023	0.300	0.289	0.287	-0.622	0.026	1.000
Correlation coefficients of independent variables with dependent variables							
SIZE	0.076	0.087	0.085	0.085	-0.047	0.044	0.054
Core Deposits	0.086	0.102	0.100	0.099	-0.060	-0.039	0.071
EQ CAP	-0.189	-0.263	-0.258	-0.257	0.167	-0.014	-0.190
RB CAP	-0.153	-0.164	-0.157	-0.156	0.083	-0.028	-0.119
Tier1 RB CAP	-0.163	-0.176	-0.163	-0.162	0.088	-0.028	-0.124
Total CAP	-0.161	-0.174	-0.161	-0.160	0.086	-0.027	-0.123
RWATA	0.005	-0.029	-0.034	-0.033	0.115	0.054	-0.073
NPL	0.030	0.056	0.056	0.057	-0.077	0.364	0.074
LIQ	-0.044	-0.029	-0.027	-0.028	-0.047	-0.050	0.098
ROA	0.333	0.302	0.298	0.294	-0.066	-0.112	0.094
LLOSS	-0.190	-0.159	-0.160	-0.155	0.010	0.127	-0.029
NIM	0.061	0.041	0.041	0.041	0.024	-0.070	-0.014
LOAN	-0.452	-0.565	-0.578	-0.576	0.381	-0.026	-0.489
SEC	0.016	0.013	0.013	0.013	0.003	0.005	0.013

Table A.3: Correlation matrix of independent variables for the pre-crisis period

	SIZE	Core Deposits	EQ CAP	RB CAP	Tier1 RB CAP	Total CAP	RWATA	NPL	LIQ	ROA	LLOSS	NIM	LOAN
SIZE	1.000												
Core Deposits	-0.260	1.000											
EQ CAP	-0.213	-0.297	1.000										
RB CAP	-0.252	-0.175	0.839	1.000									
Tier1 RB CAP	-0.288	-0.164	0.818	0.984	1.000								
Total CAP	-0.284	-0.167	0.820	0.984	0.998	1.000							
RWATA	0.225	-0.110	-0.194	-0.598	-0.597	-0.594	1.000						
NPL	-0.139	-0.009	0.054	0.044	0.045	0.050	-0.039	1.000					
LIQ	-0.220	0.088	0.294	0.598	0.606	0.602	-0.781	0.058	1.000				
ROA	0.120	-0.016	0.080	0.014	0.014	0.015	0.102	-0.162	-0.054	1.000			
LLOSS	0.011	-0.114	0.027	-0.031	-0.034	-0.031	0.098	0.260	-0.061	-0.371	1.000		
NIM	-0.073	0.123	0.026	-0.173	-0.170	-0.167	0.379	0.025	-0.359	0.331	0.151	1.000	
LOAN	0.037	-0.096	0.041	-0.033	-0.030	-0.032	0.153	-0.167	-0.132	-0.037	0.003	0.045	1.000
SEC	0.105	-0.073	0.011	-0.038	-0.042	-0.039	0.091	-0.004	-0.062	0.020	0.026	-0.025	-0.005

Table A.4: Variable correlation matrix for the pre-crisis period

	△EQ CAP	△RB CAP	△Tier1 RB CAP	△Total CAP	△RWATA	△NPL	△LIQ
Correlation coefficients between dependent variables							
△EQ CAP	1.000						
△RB CAP	0.553	1.000					
△Tier1 RB CAP	0.505	0.948	1.000				
△Total CAP	0.501	0.947	0.996	1.000			
△RWATA	0.146	-0.501	-0.506	-0.510	1.000		
△NPL	0.007	0.011	0.010	0.014	-0.006	1.000	
△LIQ	-0.152	0.196	0.181	0.179	-0.517	0.012	1.000
Correlation coefficients of independent variables with dependent variables							
SIZE	0.003	0.017	0.018	0.018	-0.006	0.005	0.021
Core Deposits	-0.063	-0.020	-0.022	-0.021	-0.037	-0.011	0.036
EQ CAP	0.123	0.020	0.021	0.021	0.046	-0.005	-0.055
RB CAP	0.087	0.073	0.077	0.076	-0.032	-0.010	0.002
Tier1 RB CAP	0.081	0.066	0.077	0.076	-0.030	-0.010	-0.002
Total CAP	0.082	0.067	0.078	0.077	-0.032	-0.010	-0.001
RWATA	0.010	-0.064	-0.075	-0.075	0.149	0.018	-0.093
NPL	0.023	0.046	0.045	0.046	-0.054	0.290	0.062
LIQ	-0.004	0.027	0.035	0.034	-0.080	-0.021	0.129
ROA	0.197	0.154	0.161	0.156	-0.021	-0.029	0.026
LLOSS	-0.073	-0.056	-0.062	-0.054	-0.002	0.019	0.003
NIM	0.032	0.016	0.009	0.010	0.017	-0.023	-0.011
LOAN	-0.092	-0.369	-0.381	-0.380	0.426	-0.027	-0.540
SEC	0.019	0.004	0.007	0.005	0.016	0.004	0.004

Table A.5: Correlation matrix of independent variables for the crisis period

	SIZE	Core Deposits	EQ CAP	RB CAP	Tier1 RB CAP	Total CAP	RWATA	NPL	LIQ	ROA	LLOSS	NIM	LOAN
SIZE	1.000												
Core Deposits	-0.216	1.000											
EQ CAP	-0.232	-0.294	1.000										
RB CAP	-0.288	-0.193	0.871	1.000									
Tier1 RB CAP	-0.329	-0.180	0.847	0.981	1.000								
Total CAP	-0.324	-0.181	0.847	0.980	0.999	1.000							
RWATA	0.285	-0.124	-0.198	-0.561	-0.561	-0.558	1.000						
NPL	0.104	-0.048	-0.129	-0.150	-0.148	-0.140	0.142	1.000					
LIQ	-0.289	0.124	0.270	0.556	0.570	0.566	-0.798	-0.123	1.000				
ROA	-0.055	0.075	0.084	0.098	0.101	0.096	-0.134	-0.502	0.133	1.000			
LLOSS	0.151	-0.085	-0.083	-0.127	-0.133	-0.126	0.174	0.508	-0.134	-0.743	1.000		
NIM	-0.160	0.215	0.062	-0.068	-0.063	-0.062	0.167	-0.284	-0.148	0.350	-0.149	1.000	
LOAN	-0.051	-0.102	0.206	0.133	0.134	0.130	0.055	-0.251	-0.028	0.092	-0.161	0.091	1.000
SEC	0.041	0.017	-0.025	-0.060	-0.064	-0.065	0.101	0.003	-0.055	0.015	0.013	-0.024	-0.025

Table A.6: Variable correlation matrix for the crisis period

	△EQ CAP	△RB CAP	△Tier1 RB CAP	△Total CAP	△RWATA	△NPL	△LIQ
Correlation coefficients between dependent variables							
△EQ CAP	1.000						
△RB CAP	0.619	1.000					
△Tier1 RB CAP	0.525	0.895	1.000				
△Total CAP	0.520	0.893	0.996	1.000			
△RWATA	0.153	-0.409	-0.376	-0.381	1.000		
△NPL	-0.060	-0.022	-0.020	-0.012	-0.027	1.000	
△LIQ	-0.198	0.243	0.229	0.228	-0.694	0.043	1.000
Correlation coefficients of independent variables with dependent variables							
SIZE	-0.010	0.029	0.045	0.048	-0.052	0.078	0.057
Core Deposits	-0.009	0.039	0.032	0.030	-0.045	-0.053	0.064
EQ CAP	0.073	-0.082	-0.083	-0.084	0.110	-0.037	-0.131
RB CAP	0.080	0.007	-0.001	-0.003	0.045	-0.059	-0.066
Tier1 RB CAP	0.074	-0.005	-0.002	-0.005	0.052	-0.059	-0.071
Total CAP	0.072	-0.005	-0.002	-0.004	0.050	-0.056	-0.070
RWATA	-0.053	-0.079	-0.057	-0.054	0.097	0.090	-0.083
NPL	-0.132	-0.041	-0.036	-0.033	-0.085	0.398	0.081
LIQ	0.050	0.040	0.014	0.010	-0.023	-0.078	0.081
ROA	0.381	0.263	0.239	0.231	0.024	-0.153	0.007
LLOSS	-0.288	-0.166	-0.169	-0.157	-0.069	0.158	0.059
NIM	0.087	0.038	0.035	0.034	0.040	-0.107	-0.041
LOAN	-0.085	-0.416	-0.415	-0.414	0.441	-0.033	-0.625
SEC	0.010	0.003	0.007	0.006	0.008	-0.010	0.021