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2009-9

Swiss National Bank Working Papers

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ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

Bank Capital Buffer and Risk Adjustment Decisions*

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October, 2009

Abstract

Building an unbalanced panel of United States (US) bank holding company (BHC) and commercial bank balance sheet data from 1986 to 2006, we examine the relationship between short-term capital buffer and portfolio risk adjustments. Our estimations indicate that the relationship over the sample period is a positive two-way relationship. Moreover, we show that the management of such adjustments is dependent on the degree of bank capitalization. Further investigation through time-varying analysis reveals a cyclical pattern in the uncovered relationship: *negative* after the 1991/1992 crisis, and *positive* before 1991 and after 1997.

JEL Codes: G21, G28, G32
Key words: Bank capital, Portfolio Risk, Regulation

1 Introduction

Capital requirements have become one of the key instruments of modern day banking regulation providing both a cushion during adverse economic conditions and a mechanism for preventing excessive risk taking

*The opinions expressed herein are those of the authors and do not necessarily reflect the views of the Swiss National Bank. We would like to thank Antonello D'Agostino, Geraldo Cequeiro, an anonymous referee as well as the audiences of the Swiss Conference on Banking and Financial Intermediation and the European Financial Management Association 2008 for their valuable comments and suggestions.

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ex ante (see Rochet, 1992a; Dewatripont and Tirole, 1994). Theoretical work focusing on the effects of capital requirements on bank risk appetite is dominated by a theory of moral hazard, in which information asymmetries and deposit insurance shield banks from the disciplining control of depositors. Taking capital as exogenous, this strand of literature analyzes incentives in asset risk choice. These studies show that capital adequacy regulation may reduce the total volume of risky assets (see Merton, 1977; Sharpe, 1978; Furlong and Keeley, 1989). This literature however, has also shown that with the further assumption of a risk averse bank utility function [1], bank portfolio composition may be distorted in the direction of more risky assets. As a consequence, average risk may increase and risk consistent weights are required to correct for moral hazard.[2] The theoretical literature is thus ambiguous about the relationship between bank capital and bank risk.

A broader view, moving beyond the theory of moral hazard, is provided by the charter value theory.[3] This theory argues that banks have something to lose since bankruptcy leads to a loss of future profits. Two further possible characterizations of the relationship between bank capital and risk thus exist (see Calomiris and Kahn, 1991; Diamond and Rajan, 2000). In contrast to the predictions of the moral hazard theory, banks therefore no longer hold the minimum allowable amount of capital, rather, they have their own preferred (target) level of capitalization. If this level is exceeded by regulatory requirements, then there is no longer a relationship between capital and risk taking. To our knowledge, there is no theoretical analysis exploring the resulting relationship between capital and risk, which appears to be ambiguous. The following possible outcomes exist: (i) higher risk can increase the probability of default and encourage banks to increase capital, and (ii) higher systematic risk can reduce charter value and lower capital holdings. If however, regulatory capital requirements exceed the banks target level of capital, then a higher degree of capitalization will lead to a reduction in risk appetite whereby the charter effects become less important. The quantitative magnitude of this effect however, may be relatively small.

Within the charter value literature, attention has more recently shifted towards the capital buffer theory[4], a dynamic version of the charter value

[1]A risk averse utility function is usually justified as reflecting the divergence of interest between managers and shareholders inducing risk averse behavior.

[2]Koehn and Santomero, 1980; Kim and Santomero, 1988; Rochet, 1992; and Freixas and Rochet 1997.

[3]Also referred to as the franchise value (see Marcus, 1984; Boot and Greenbaum, 1993; Demsetz et. al, 1997; Hellman, Murdoch, and Stiglitz 2000, Matutes and Vives 2000), charter value is the value that would be foregone if the bank closes.

[4]See among others Milne and Whalley, 2001; Peura and Keppo, 2006; VanHoose,

models in which there are costs both of altering the level of capital and allowing capital to fall below the minimum required levels. The buffer theory predicts that banks will maintain a level of capital above the required minimum (a buffer of capital). The costs of falling below the minimum required level of capital are both explicit and implicit. Buser et al. (1981) argue that implicit costs of regulation may arise from regulatory interference designed to control excess demand for insurance (eg. expanding risk taking). Explicit costs relate to penalties and/or restrictions imposed by the supervisor triggered by a breach of the regulation, possibly even leading to bank closure. The novel contributions of the capital buffer theory are to distinguish the long from the short run relationships between capital and risk taking and the impact of regulatory capital from observed bank capital. Here, regulatory capital will have a limited long run impact on bank risk choice, regardless of risk weighting. The long run relationship between the capital buffer and risk is similar to that predicted by the charter value theory, and can therefore be either positive or negative. The short run relationship between capital buffer and risk on the other hand, will depend on the degree of bank capitalization. For banks near their desired level (highly capitalized banks), we would expect a positive relationship. However, for banks approaching the regulatory required level, the relationship should be negative. An increase in regulatory capital requirements, in the short run, will reduce the buffer of capital and so has the same impact as a direct reduction in the capital buffer.

Several empirical papers have focused on understanding the relationship between risk and capital, testing whether increases in capital requirements force banks to increase or decrease their risk (see Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 2001; Rime, 2001). Most of these studies have confirmed the positive relationship between capital and risk adjustments predicted by theory, indicating that banks that have increased their capital levels over time, have also increased their risk appetite. Shrieves and Dahl (1992) argue that a positive relationship between the key variables is in line with several hypotheses which include the unintended effect of minimum capital requirements, regulatory costs, bankruptcy cost avoidance as well as managerial risk aversion. Jacques and Nigro (1997) on the other hand find a negative relationship between changes in capital and risk levels. They note that such a finding may be attributable to methodological flaws in the risk based guidelines.[5] Alternatively, as suggested by Shrieves and

2007a&b.

[5]Avery and Berger (1991) suggest that while the risk weights constitute a significant improvement over the old capital standards, several instances in which the

Dahl (1992), a negative relationship may exist between capital and risk adjustments if banks seek to exploit the deposit insurance subsidy.

Evidence on the capital buffer theory is however more limited. For a set of German savings banks, Heid et. al (2004) suggest that the coordination of capital and risk adjustments depends on the amount of capital the bank holds in excess of the regulation. Banks with low capital buffers try to rebuild an appropriate buffer by raising capital while simultaneously lowering risk. In contrast, banks with large buffers maintain their capital buffer by increasing risk when capital increases. These findings are in line with the predictions of the capital buffer theory.

The relationship between risk and capital has several important policy implications. The recent modification in the capital requirement regulation (Basel II) is a structural change that places far more emphasis on the range of capital that may be required given the specific risks faced by each bank. It has been argued that a more risk sensitive capital adequacy regulation may reduce banks' willingness to take risk. However, if banks already risk adjust their total capital, ie. minimum capital plus buffer capital, more than implied by Basel I, then replacing Basel I with Basel II may not affect the capital to asset ratio or risk profile of banks' portfolio as much as feared. It is therefore clearly of interest to understand the relationship between risk and capital buffer formation.

For a sample of publicly traded US bank holding companies (BHCs) we investigate the relationship between short run capital and risk adjustments. Our estimations show that the management of short term adjustments in capital and risk are dependent on the size of the buffer. For banks with capital buffers approaching the minimum requirement, the relationship between adjustments in capital and risk are negative. That is that low capital banks either (i) increase their buffers by reducing their risk, or (ii) gamble for resurrection by taking more risk as a means to rebuild the buffer. In contrast, the relationship between capital and risk adjustments for well capitalized banks is positive, indicating that they maintain their target level of capital by increasing *(decreasing)* risk when capital increases *(decreases)*. Allowing for the speed at which banks adjust towards their target capital and risk levels to be bank specific, we show that small buffer banks adjust to their target capital level significantly faster than their better capitalized counterparts. We are however, unable to find significant evidence of a similar trend for adjustments in risk. We additionally investigate the time varying nature of the relationship between capital and risk adjustments, which appears to exhibit a cyclical pattern: *negative* after the 1991/1992 crisis, and *positive* before 1991 and after 1997.

weights assigned to specific categories are too crude to reflect true risk.

The rest of the paper is organized as follows: Section 2 outlines the empirical framework adopted. Section 3 describes the data and defines the hypotheses to be tested. Section 4 presents our empirical estimations and results. Section 5 briefly discusses our findings and concludes.

2 Empirical Framework

In order to investigate the short run relationship between capital buffer and risk adjustments, we acknowledge that banks will manage their capital buffer by accounting primarily for the risk of default. Similarly, risk taking will depend on how close the capital buffer is to the minimum requirement. Moreover, in this framework, observed changes in a banks' capital buffer and its portfolio risk can be thought of as a function of two components; one part which is managed internally by the bank plus an exogenous random shock. Building on previous work[6], our model, with simultaneously determined variables, can be written as follows:

$$\Delta buf_{it} = \Delta buf_{it}^{bank} + \varepsilon_{it} \quad (1)$$

$$\Delta risk_{it} = \Delta risk_{it}^{bank} + \mu_{it} \quad (2)$$

where Δbuf_{it} and $\Delta risk_{it}$ are the observed changes in the capital buffer and risk respectively. Δbuf_{it}^{bank} and $\Delta risk_{it}^{bank}$ are the changes in the capital buffer and risk that are managed internally by the bank. ε_{it} and μ_i and are the exogenously determined random shocks for bank i at time t.

The framework outlined above further assumes that banks will establish an internally optimal capital buffer and risk level that they will target over time. The long run level of target capital and risk are given by:

$$buf_{it}^{*} = \xi z_{it} + \eta_{it} \quad (3)$$

$$risk_{it}^{*} = \varphi u_{it} + \omega_{it} \quad (4)$$

Here z_{it} and u_{it} capture all variables (including Δbuf_{it} in the risk equation and $\Delta risk_{it}$ in the buffer capital equation) that determine the banks' target level of capital buffer and risk. ξ and φ are the vectors of coefficients to be estimated. Δbuf_{it} is assumed to impact the target level of risk since any short term change in the capital of the bank will affect the banks' probability of default. Similarly a shift in the banks' risk profile will alter the banks distance from the regulatory minimum.

[6] See Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 2001.

Over time, exogenous shocks will drive actual levels away from or toward, target levels. Banks will therefore need to adjust both the capital buffer and risk taking to revert back to their internally optimal level. This adjustment is depicted by Δbuf_{it}^{bank} and $\Delta risk_{it}^{bank}$. Full adjustment to the target level however, may be too costly or infeasible. Our model therefore assumes partial, rather than complete, adjustment in each period.

We can then think of the bank managed adjustment as:

$$\Delta buf_{it}^{bank} = \xi_0(buf_{it}^{*} - buf_{it-1}) \tag{5}$$

$$\Delta risk_{it}^{bank} = \varphi_0(risk_{it}^{*} - risk_{it-1}) \tag{6}$$

Here ξ_0 and φ_0 are the speeds of adjustment of the capital buffer and risk respectively; buf_{it}^{*} and $risk_{it}^{*}$ are the target levels of capital buffer and risk; and buf_{it-1} and $risk_{it-1}$ capture the actual levels of buffer capital and risk in the previous period. $buf_{it} - buf_{it-1}$ and $risk_{it} - risk_{it-1}$ then represent the actual change in capital and risk between two periods, while $buf_{it}^{*} - buf_{it-1}$ and $risk_{it}^{*} - risk_{it-1}$ denote the desired long run change. These equations highlight the fact that observed changes in the buffer and risk levels in period t are a function of the differences between the target level of capital and risk in period t and previous period's actual capital and risk, and any exogenous shock.

Substituting equations (5.) and (6.) into equations (1.) and (2.) we then have:

$$\Delta buf_{it} = \xi_0(buf_{it}^{*} - buf_{it-1}) + \kappa_{it} \tag{7}$$

$$\Delta risk_{it} = \varphi_0(risk_{it}^{*} - risk_{it-1}) + \phi_{it} \tag{8}$$

We note that the observed changes in capital and risk in any given time period t is some fraction ξ_0 or φ_0 of the desired change for that period. If ξ_0 (φ_0)= 1, then the actual buffer (risk) level will be equal to the desired buffer (risk) level. That is, adjustment to the target level is instantaneous. If on the other hand, ξ_0 (φ_0)= 0, nothing changes, since the actual level of buffer (risk) at time t is the same as that observed in the previous period. Typically then, ξ_0 and φ_0 will lie between these extremes since adjustment to the desired stock of capital is likely to be incomplete for several reasons.

3 Hypotheses and Data

To determine how observed short run fluctuations of the capital buffer (Δbuf_{it}) impact on short run changes in bank risk ($\Delta risk_{it}$), we estimate our model derived in the previous section. It is important to note that the target levels of capital (buf^*_{it}) and risk ($risk^*_{it}$) cannot be observed and hence are approximated by various cost and revenue variables discussed in detail in Section 5.3.1 below.

$$\Delta buf_{it} = \alpha_1 - \xi_0 buf_{it-1} + \xi_1 Y_{it} + \xi_2 \Delta risk_{it} + \kappa_{it} \tag{9}$$

$$\Delta risk_{it} = \alpha_2 - \varphi_0 risk_{it-1} + \varphi_1 Z_{it} + \varphi_2 \Delta buf_{it} + \phi_{it} \tag{10}$$

where Δbuf_{it} and $\Delta risk_{it}$ are the observed changes in capital buffers and risk respectively, $i = 1,2\ldots N$ is an index of banks and $t = 1,2,\ldots T$, is the index of time observation for bank i at time t. The Y_{it} and Z_{it} vectors capture the bank specific variables that determine the target buffer and risk levels respectively. κ_{it} and ϕ_{it} are assumed to consist of a bank specific component and white noise.

Our null hypothesis can be presented as:

H_0 : *Short term adjustments in the capital buffer and bank risk have no impact on one another.* The alternative hypotheses to be tested are then as follows:

H_{1A}: *The coefficients ξ_2, and φ_2, are positive and significant. Adjustments in capital buffer and risk are positively related for banks with large capital buffers. This hypothesis is in line with the theory that well capitalized banks will manage their desired probability of default, by maintaining an target capital buffer through positive adjustments in risk.*

and

H_{1B}: *The coefficients ξ_2, and φ_2, are negative and significant. The adjustments of buffer capital varies systematically, but negatively, with adjustments in risk taking. ie. Riskier banks will hold less capital in their buffer stock. This hypothesis is in line with the notion that banks with buffers near the regulatory minimum will build up their buffers of capital by reducing risk taking.*

3.1 Sample Selection

We create an unbalanced panel of US commercial bank and bank holding companies (BHCs) balance sheet data covering the period between 1986 and 2006. All commercial bank data is obtained from the Consolidated Report of Condition and Income (referred to as the Call Reports) published by the Federal Reserve Bank of Chicago.[7] Since all insured banks are required to submit Call Report data to the Federal Reserve each quarter we are able to extract income statement and balance sheet data for a large number of commercial banks.[8] In addition, we obtain balance

[7]This data is publicly available at www.chicagofed.org.

[8]In 1976 we have data for 14,000 banks which diminishes to around 8,000 banks by the end of the sample.

sheet data for BHCs from the Fed Funds Y-9 form. By identifying the high holder to which the individual commercial banks belong, we merge the two datasets to obtain balance sheet, income as well as risk based variables for publicly traded bank holding companies.[9] See Appendix for further information on data manipulations.

In general the BHCs in the sample have been well capitalized throughout the sample. The average bank has exceeded the minimum required capital ratio by a comfortable margin. The average[10] tier one (total) capital stood at 7.55(9.55) percent of risk weighted assets[11] in 1986 but reached 9.88(13.44) percent by 1994 and has remained relatively stable since.

Figure 1 documents the evolution of both tier one and total capital ratios over time. In 1992 both tier one and total capital ratios rose substantially. Several reasons can be put forward as possible explanations of this. First, this may simply reflect an unusual period of inflated bank profitability and share price appreciation during the 1990s. BHC capital ratios might thus have risen passively, simply because bank managers failed to raise dividends or repurchase shares. Second, this was around the time that the Basel I rules were introduced in the US. The Federal Deposit Insurance Committee Improvement Act (FDICIA) subsequently sought to impose greater credit risk on uninsured bank liability holders and consequently introduced a mandatory set of prompt corrective actions (PCA) that increased the cost of violating the capital standard. Hence, direct supervisory pressure may have contributed to the capital buildup. Although PCA does not directly apply to BHCs, it is relevant, because it applies to their bank subsidiaries and therefore may affect the amount of excess capital held at the holding company level.

Dependent and Explanatory Variables

Bank Capital Buffers In this paper, we acknowledge that the capital to asset ratio that regulators define and monitor is the ratio of regulatory capital to risk weighted assets. There is however, no reason to expect that this is the same ratio that banks target internally when making risk decisions. Banks for example might consider the market value of capital, targeting a market value of equity below which the bond market starts charging a risk premium. Alternatively, banks may actively manage capital so as to remain within a desired range of eco-

[9] Once the initial dataset is obtained, we further clean the data by keeping only those bank holding companies for which we have three consecutive quarters of data.

[10] Weighted by market capitalization.

[11] Risk weighted assets are defined as the total of all assets held by the bank, weighted for credit risk according to a formula determined by the countries regulator.

nomic capital[12] hence targeting the level of either book or market equity needed to carry our future acquisition strategies.

We define dependent variable Δbuf_{it}, as the observed change in the amount of capital the bank holds in excess of that required by the regulator. We adopt this measure of capital since we assume that banks will manage their capital in such a way as to avoid, or minimize, costs associated with a breach of regulatory requirements. Since individual subsidiary banks seldom issue independent equity and are rather wholly owned by a holding company, equity financing generally occurs at the BHC level. To capture changes in the buffer of capital, we focus solely on the BHCs.

Regulatory requirements placed on banks have undergone several changes throughout the sample period. At the beginning of our sample, US regulators employed a simple leverage ratio to assess capital adequacy: primary capital had to exceed 5.5 percent of assets, while the total amount of primary plus secondary capital had to exceed six percent of assets. Consequently, in the period between 1986 and the end of 1990, we consider a ratio of total capital equal to seven percent as the regulatory minimum with which we calculate the capital buffer. This criterion is based on the Federal Reserve Boards definition of zones for classifying banks with respect to supervisory action.

Effective December 31, 1990, banks were required to hold at least 3.25 percent of their risk weighted assets as tier one capital and a minimum of 7.25 percent of their risk weighted assets in the form of total capital (tier one + tier two). Finally, Basel I was introduced at the end of 1992. The minimum tier one and total capital ratios were subsequently raised to four and eight percent respectively. In addition to the Basel regulations, US banks are restricted by an additional leverage ratio of primary capital to total capital requirement imposed by the FDICIA. Current regulations therefore state that in order to be *adequately capitalized*, a BHC must have a tier one capital ratio of at least four percent, a total capital ratio of at least eight percent and a leverage ratio of at least four percent.

The tier one ratio of a bank is defined as tier one capital over the banks total assets, where tier one capital gives the ratio of a banks' core equity capital to its total risk weighted assets. Due to reporting changes, data on risk weighted assets are not available as far back as 1986. We therefore create proxy series for these variables prior to this time.

We adopt the methodology put forward by Beatty and Gron (2001) to

[12]Economic capital is the amount of risk capital, assessed on a realistic basis, which a firm requires to cover the risks that it is running or collecting as a going concern, such as market risk, credit risk, and operational risk. It is the amount of money which is needed to secure survival in a worst case scenario.

estimate risk weighted assets prior to 1990. Our estimated risk weighted assets variable, (*erwa*) is calculated as follows:

$total\ loans + (0.2 * agency\ securities) + (0.5 * municipal\ securities) + (corporate\ securities)$

Moreover, we proxy missing values of tier one capital with the series for total equity. We can then compare pre- and post- Basel periods. The correlations for both series are good. We find that between 1990 and 2006, the correlation between the *erwa* to total assets series and the true risk weighted assets to total assets is around 83 percent. The correlation between the ratio of common equity to total assets and the tier one capital to total assets ratio is around 97 percent.

Risk From a regulators point of view, banks with a relatively risky portfolio, ie. with a high credit risk, should hold a larger capital buffer. Otherwise, these banks will be more likely to fall below the minimum capital ratio, increasing the probability of bankruptcy and likelihood of facing costs associated with failure.[13] Measuring bank risk is not a simple task since each alternate proxy has its own characteristics and limitations. Consequently no single proxy provides a perfect measure of bank risk. Several varying measures of risk have been adopted in the literature however, no consensus on which is most suitable exists.

In this study we are concerned with portfolio risk, the proportion of risky assets in the bank's portfolio. This is the measure of risk on which bank regulators base their capital guidelines. Even though the proportion of certain risky assets in a bank's portfolio may not exactly reflect the overall asset risk of a bank, it may reflect project choice by bank managers and, thus, to some degree the overall asset risk. Several authors have therefore used the composition of a bank's portfolio to capture asset risk (See Godlewski, 2004; Berger, 1995; McManus and Rosen, 1991; Gorton and Rosen, 1995). Recent literature has shown that banks are steadily moving towards reliance on non traditional business activities that generate fee income, trading income and other types of non interest income and that consequently, bank risk is now largely found off balance sheet (DeYoung and Roland, 2001; Stiroh, 2004). Given the objective of this study, our aim is to correctly estimate risk in a manner that captures changes in management policy with regard to the risk profile of the bank over a twenty year history. Therefore, several asset based measures centered on existing literature are adopted, all of which come from the commercial bank side of the balance sheet of the unbalanced panel created in Section 5.3.1.

[13] See Ancharya (1996).

For our first measure of risk ($risk$) we create an index as per Chessen (1987), Keeton (1989) and Shrieves and Dahl (1992). The index, constructed from accounting data, is calculated as follows:

$$(0.25 * interest\ bearing\ balances) + (0.10 * shortterm\ US\ treasury\ and\ government\ agency\ debt\ securities) + (0.50 * state\ and\ local\ government\ securities) + (0.25 * bank\ acceptances) + (0.25 * fed\ funds\ sold\ and\ securities\ purchased\ under\ agreements\ to\ resell) + (0.75 * standby\ letters\ of\ credit\ and\ foreign\ office\ guarantees) + (0.25 * loan\ and\ lease\ financing\ commitments) + (0.50 * commercial\ letters\ of\ credit) + (all\ other\ assets)$$

The weighted sum of these asset amounts is then divided by total assets.

In addition to the $risk$ measure described above, we consider the risk weighted assets to total assets ratio rwa/ta. The risk weighted assets are calculated in accordance with the Basel I rules. The rationale for this proxy is that the allocation of bank assets among risk categories is the major determinant of a bank's risk.[14] This measure of risk however does not account for market risk and therefore serves to capture credit risk only. As a consequence, it captures only one part of the true asset risk. Moreover, the relative weights assigned to each portfolio category may not correspond to the actual risk involved. Since there are only four kinds of relative weights (0, 20, 50 and 100 percent), each category within the portfolio may consist of assets with varying levels of risk.[15] Therefore, it is likely that two banks with the same rwa/ta ratio in fact have different levels of risk exposure.

An additional proxy for risk adopted is the ratio of non-performing loans[16] to total loans and credits, npl. This measure of loan portfolio quality is an ex-post measure of risk since banks with non-performing loans are obliged to make provisions for loan losses. In order to affectively capture risk through this methodology, we need to acknowledge that the risk of loans originated in a given year will not be reflected in past due and non accrual classifications until the subsequent period. Therefore the quality of loans must be measured as those past due or

[14] See Chessen (1987) and Keeton (1989). Jacques and Nigro (1997) argue that the rwa/ta captures the allocation as well as the quality aspect of portfolio risk. Avery and Berger (1991) and Berger (1995) show that this ratio is positively correlated with risk.

[15] For instance, all commercial loans have the same weight (100 percent) regardless of the creditworthiness of the borrower.

[16] Non-performing loans are those that are 90 days or more past due or not accruing interest.

non accruals recorded the following year. Finally, we calculate the ratio of commercial and industrial loans to total assets (*c&iratio*). This measure is adopted since commercial and industrial loans are generally riskier than the other categories of loans.[17] Empirical studies (Gorton and Rosen, 1995; Samolyk, 1994) find evidence that banks with a *c&iratio* also have higher levels of non performing assets.

The rwa/ta ratio is generally considered to be a better ex-ante indicator of overall risk than the *c&iatio*, since it is a more comprehensive measure. Thus, while the *c&iratio* focuses only on a specific portfolio item, the Basel Accord guidelines group all assets into different portfolio categories and assign different risk weights according to the perceived riskiness of all of the portfolio categories. In contrast to the other two measures (the *c&iratio* and the rwa/ta), the *npl* ratio is an ex-post measure of risk. Thus, the *npl* ratio inherently depends on luck or chance in addition to other factors, in addition to ex-ante risk. The *npl* ratio may contain information on risk differences between banks not caught by the rwa/ta ratio, and thus is used as a complementary risk measure to the rwa/ta ratio.

If banks consider the true credit risk of their portfolios when deciding on the total amount of capital, one would expect the buffer capital to vary positively with any risk measure included as a regressor. Essentially replicating the true risk profile of banks' portfolios rather than the risk weights in Basel I.

In addition to the influence that risk will have on the capital buffer formation, and vice verse, our model assumes that the target levels of both risk and capital will depend on a set of bank specific characteristics, captured in equations (9.) and (10.) by the X_{it} and Y_{it} vectors respectively. Different corporate finance theories produce a long list of factors that drive non-financial firms' capital structures (see Harris and Raviv, 1991; Frank and Goyal, 2003; Frank and Goyal, 2007). The empirical corporate finance literature has converged towards a set of variables that reliably predict leverage of non-financial firms in the cross section.[18] Recently, a set of authors developing models of target bank capital have confirmed the validity of these variables for a set of firms in a slightly different legal and institutional environment (Diamond and Rajan, 2000;

[17] The major loans made by U.S. commercial bank lending activities can be segregated into four broad categories. These are real estate, commercial and industrial, individual, and others. Commercial and industrial loans includes credit to construct business plants and equipment, loans for business operating expenses, and loans for other business uses. It is the second largest loan category in dollar volume among the loan portfolio of U.S. commercial banks.

[18] See Titman and Wessels, 1988; Rajan and Zingales, 1995; and more recently Frank and Goyal, 2007.

Allen et al., 2006; and Gropp and Heider, 2008). Hence, variables included in the X_{it} and Y_{it} vectors above are drawn from the corporate finance literature and can be defined as follows:

Charter value: A more satisfactory account of bank risk taking emerges when allowance is made for the charter value of the bank. The larger the charter value, the greater the incentive to reduce risk taking and to maintain a capital buffer that is not in danger of falling below the regulatory minimum.[19] The charter value thus acts as a restraint against moral hazard in banking (Marcus, 1984; Keeley, 1990; Demsetz et al., 1997) and can explain the relationship between capitalization and risk appetite (Demsetz et al., 1997).

Defined as the net present value of its future rents, the charter value can hence be thought of as being the market value of assets, minus the replacement cost of the bank (Keeley, 1990; Demsetz et. al., 1997 and Gropp and Vesala, 2001). As is commonly done in the literature, we proxy the charter value of the bank by calculating Tobins q as follows:

$$q = \frac{bvl + mve}{bva} \tag{11}$$

Where bva, bvl and mve depict the book value of assets, the book value of liabilities and the market value of equity respectively. The benefit of using Tobins q to capture charter value is that it is a market based measure meaning greater market power in both asset and deposit markets are reflected in a higher q value. Moreover, it allows for comparability among banks of varying sizes in our analysis.

All market data is obtained from the Center for Research on Securities Prices (CRSP). We would expect to observe a positive relationship between q and the capital buffer; such that banks with higher charter values will hold larger capital buffers as a means to protect the valuable charter. Moreover a negative relationship between q and risk is expected, indicating that banks with higher charter values have a greater incentive to reduce their risk. Moreover, we would expect to observe a positive relationship between q and the capital buffer; such that banks with higher charter values will hold larger capital buffers as a means to protect the valuable charter.

Bank size: It is usually argued that larger firms are safer, better known in the market, and more exposed to agency problems (Jensen and Meckling, 1976) explaining why larger firms generally have lower degrees of capitalization. The size of a bank may additionally play a role in de-

[19] Banks with larger charter values will want to protect this value by lowering their risk taking.

termining risk appetite through its impact on investment opportunities and diversification possibilities as well as access to equity capital. Large banks might be covered by the too-big-to-fail phenomenon whereby any distress will be bailed out by government assistance. Therefore, to capture size effects on both buffer and risk adjustments, we include the log of total assets (*size*) with an ambiguous expected sign in both cases.

Return on assets: Bank profitability may have a positive effect on bank capital if the bank prefers to increase capital through retained earnings rather than through equity issues. This might be the case since equity issues may convey negative information to the market about the banks value in the presence of asymmetric information. Return on assets (*roa*) is included as a measure of bank profits. The expected sign on the coefficient is positive since the level of buffer capital would, in this case, be expected to move in line with the level of bank profitability.

Loan loss provisions: A bank's current loan losses will have an impact on the risk level of a bank since a bank with a higher level of loan losses will tend to exhibit lower levels of risk adjusted assets in the future. We proxy these losses (*loanloss*), by the ratio of new provisions to total assets. The effect of loan losses on the capital buffer is expected to be positive since banks with greater expected losses can be assumed to raise their capital levels in order to comply with regulatory requirement and to mitigate solvency risk. We include the *loanloss* variable in the risk equation based on the assumption that banks with higher level of loan losses will exhibit lower future levels of risk adjusted assets. As a result, a negative relation should exist between target risk and loan loss provisions.

Liquidity: Banks with more liquid assets need less insurance against a possible breach of the minimum capital requirements. Moreover, the non zero risk weight associated with liquid assets means that banks can increase their capital buffers by liquidating assets. Therefore banks with more liquid assets generally have smaller target capital buffers and may also be willing to increase their levels of risk. We therefore expect a negative relationship between *liquidity*, calculated as the ratio of bond holdings, share holdings, and interbank assets to total assets, and the bank's capital buffer.

Dummy variables: The model presented in equations (9.) and (10.) assumes that the target level of both capital and risk depends on a set of bank specific characteristics including its charter value, size, profitability and liquidity. The speed at which the bank adjusts back to the target level however is assumed to be constant.

The capital buffer theory predicts that banks with small capital buffers will try to build capital towards an internally defined target buffer while banks with large buffers will maintain their buffer at the target level. Hence, adjustments in capital buffers and risk are expected to be positively *(negatively)* related for banks with larger *(smaller)* than average capital buffers. Moreover, banks with smaller *(larger)* capital buffers are expected to adjust both capital and risk faster *(slower)* than than well capitalized banks.

To allow for variations in capital and risk management to depend on the degree of bank capitalization, we create a set of dummy variables $Dcap_l$ and $Dcap_h$. The dummy $Dcap_l$ is set equal to one if the capital buffer of a bank is *less* than two percent; and zero otherwise. Similarly, the dummy $Dcap_h$ is equal to one if the capital buffer of a bank is greater than three percent; and zero otherwise.[20]

To test the predictions outlined above, we interact the *Dcap* dummy variables with the variables of interest. For example, in order to capture differences in the speeds of adjustment of low and high buffer banks, we interact $Dcap_l$ and $Dcap_h$ with the lagged dependent variables buf_{it-1} and $risk_{it-1}$. Moreover, to assess differences in short term adjustments of capital and risk that depend on the degree of capitalization, we interact the dummy variables with $\Delta risk_{it}$ and Δbuf_{it} in the capital and risk equations respectively. Bank fixed effects and a full set of time dummies are included in all the regressions.[21]

4 Estimation: Methodology and Results

Our model, as outlined in equations (9.) and (10.) is estimated for a variety of combinations of risk measures outlined in Section 5.3.1. All variables adopted in the study are defined in Table 1. Table 2 presents correlations of our main variables in levels and in differences. Since theory suggests that banks with low risk aversion will choose high leverage *(low capital)* and high asset risk (see Kim and Santomero, 1988), we would expect to find a negative correlation between the level of portfolio risk and and bank capital ratios simply due to the cross sectional variation in risk preferences. The capital buffer theory suggests that there will be a positive time series correlation between adjustments in capital and risk. Banks with larger capital buffers reduce their endogenous risk aversion and increasing risk taking while increased opportunities to take

[20]The three percent threshold is consistent with the 25th percentile of buffer capital in the sample. It also corresponds to the FDIC definitions of *adequately* and *well* capitalized banks.

[21]Most important determinants of capital ratios are time invariant firm specific characteristics according to recent research (see Lemmon, Roberts, and Zender, 2008).

on risky exposures lead banks to increase capital. Only the correlation between buf_{it} and $risk_{it}$ is negative. All other measures of risk appear to be positively correlated with the capital buffer.

The observed negative relationship is in line with previous findings. However, most of the authors to date have proxied risk by non performing loans (see Shrieves and Dahl, 1992; Jacques and Nigro, 2001 and Aggarwal and Jaques, 1998 for evidence of this for the US market). We are unable to replicate this negative finding with our npl_{it} measure of risk. By calculating correlations in various time periods, we are however, able to show that the correlations between the buffer of capital and most risk variables are negative prior to 1993. This relationship becomes positive after this time, driving the complete sample correlation presented in Table 2.

These simple correlation studies do not allow other variables to affect the relationship and therefore do not clarify whether the correlations noted are due to simultaneous changes in the variables. Moreover, they do not allow for the numerator/denominator interactions in buf_{it}. Our dynamic estimations therefore serve to account for various additional factors that could affect the level of capital and risk held to provide a deeper understanding of the relationships.

Since we estimate a dynamic model, including the lagged endogenous variables, we employ the the one and two step Blundell-Bond system GMM estimators (Blundell and Bond ,1998). However, since they produce quite similar estimates, we present only the (asymptotically) more efficient two step estimates. However, the two step estimates of the standard errors tend to be severely downward biased (Arellano and Bond, 1991; Blundell and Bond, 1998). To compensate, we use the finite sample correction to the two step covariance matrix derived by Windmeijer (2005). Applying this methodology rather than the three stage least squares (3SLS) approach that is common in this literature[22], allows us to account for possible bank specific effects, providing unbiased estimates.[23] The methodology uses lagged levels as instruments in the first difference equations and lagged first differences (Δbuf_{it} *(*$\Delta risk_{it}$*))* in the levels equations. Moreover, in the simultaneous equations estimation, we include lags of $risk_{it}$ *(*buf_{it}*)* as instruments for $\Delta risk_{it}$ *(*Δbuf_{it}*)* to account for the simultaneity of capital and risk adjustments in the buf_{it} *(*$risk_{it}$*)* equation. The number of instruments chosen in each model was

[22]see among others Schrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 2001; Rime, 2001; and Heid et al., 2004.

[23]As a robustness check, we additionally pool the cross sectional data over the entire sample and estimate using the 3SLS methodology. For our key variables, the findings are unchanged and are therefore not presented here for the sake of brevity.

the largest possible, for which the Sargan -statistic for over identification restrictions was still satisfied.

4.1 Full Sample GMM:

We begin by estimating our model with different risk measures outlined above. As a first step, equations (9.) and (10.) are estimated as separate equations.

4.1.1 Single equation estimations

Capital equation: The results from estimating variations of equation (9.) are presented in Table 3. $\Delta risk_{it}$, $\Delta rwa/ta_{it}$, Δnpl_{it}, $\Delta c\&iratio_{it}$ are adopted as the risk measures in *Model I, Model II, Model III and Model IV* respectively. *Model V*, introduces a combination of Δnpl_{it} and $\Delta rwa/ta_{it}$. *Model VI* uses the risk index, $\Delta risk_{it}$, together with $\Delta rwa/ta_{it}$. Finally, in *Model VII*, $\Delta risk_{it}$ and Δnpl_{it} are considered together. In each case, the risk measure is taken to be the observed change in risk as discussed in detail in Section 5.3.

In general, observed changes in buffer capital are positively related to changes in risk. We do however, observe a negative relationship when $\Delta c\&iratio_{it}$ is included. The positive finding indicates that the target capital buffer is adjusted in accordance to the varying risk profile of the bank. A bank experiencing a positive *(negative)* shock to risk will therefore respond by increasing *(reducing)* its capital buffer.

In addition to the risk variables, the estimated coefficients for the bank specific variables generally carry the expected sign with mostly significant coefficients. The reported coefficients on the lagged dependent variable buf_{it-1} are highly significant. They show the expected positive signs and lie within the required interval $[0; 1]$. Hence they can be interpreted as speeds of capital adjustment. The significance of the speeds of adjustment are in line with the view that the costs of capital adjustment are an important explanation of the holding of large capital buffers. The fastest speed of adjustment is noted in *Model I*, where the composite $\Delta risk_{it}$ measure is adopted. Here on average banks close the gap between their actual and desired level of capital by around nine percent each quarter, corresponding to a 36 percent adjustment in the year period following a shock. This speed of adjustment is in line with findings of Flannery and Rangan (2006) who show that the mean firm acts to close its gap at the rate of more than 30 percent per year.

The expected positive sign on the q_{it} coefficient is found in all of the six models indicating that banks with higher charter values hold larger capital buffers. $size_{it}$ is consistently negative, but only significant in two of the seven cases *Model II* and *Model VI*. The negative coefficient is in line with the too-big-to-fail hypothesis as well as with the notion that smaller banks experience greater difficulty in accessing the capital markets. Furthermore, this finding could provide evidence in favor of scale economies whereby larger banks will generally enjoy a higher level of screening and monitoring than their smaller counterparts resulting in a reduction excess capital held as insurance. Moreover, the negative coefficient is consistent with the notion that smaller banks are less diversified than their larger counterparts and therefore hold larger capital buffers. roa_{it} is consistently positive and mostly significant, indicating the importance that BHCs place on retained earnings to increase their capital buffers. $loanloss_{it}$ is positive and significant in five of the seven cases, indicative that banks with greater expected losses raise capital buffers in order to comply with regulatory requirements and to mitigate solvency risk. Finally, the $liquidity_{it}$ variable shows that banks with higher liquidity ratios generally hold less capital. While the estimates have the correct sign, the results are only significant in two of the seven models *Model I and Model VII*.

Risk equation: Similarly to above, equation (10.) is estimated as a single equation, in this case varying the dependent variable. $\Delta risk_{it}$, $\Delta rwa/ta_{it}$, Δnpl_{it}, $\Delta c\&iratio_{it}$ are adopted for *Model I, Model II, Model III* and *Model IV* respectively.

The coefficients on Δbuf_{it} are generally positive and highly significant. The only exception being the coefficient associated with *Model IV*, where we observe a negative coefficient significant at the ten percent level. The positive relationship indicates that BHCs respond to a positive *(negative)* capital shock by increasing *(reducing)* risk taking. This finding is in line with the notion that banks aim to maintain an internally defined level of risk by either increasing or decreasing the size of the capital buffer.

The speed of adjustment captured by $risk_{it-1}$ is substantially slower than that noted in the buffer equation above. Again, we find that the speed of adjustment for *Model I* is the fastest. Here, banks generally close around three percent of the gap between desired and actual risk each quarter. This is equivalent to a reduction of around twelve percent of the gap within the year following an exogenous shock.

q_{it} is negative and significant for all of the models. This is in line with our expectations and with previous studies showing that charter values act as a disciplining mechanism with regard to risk taking. Similarly, banks with low charter values have little to lose and therefore may adopt riskier strategies. $size_{it}$ is positive in all case but significant only for *Model III* and *Model IV*. As above, this is consistent with the notion that larger banks have higher target levels of risk than smaller banks.

The $loanloss_{it}$ coefficients are positive and significant indicating that contrary to expectations, banks with higher loan losses are riskier. Finally, the $liquidity_{it}$ coefficient is positive as expected, but not significant in any of the four cases.

Our findings indicate that the relationship between observed changes in capital and risk appears to be positive. BHC's that have increased their risk taking over our sample period, have similarly increased their capital buffers and vice verse. These estimations have however failed to account for the fact that short term adjustments to capital and risk are simultaneously determined and therefore should be interpreted with caution. The main purpose of these estimations was rather to determine how the relationships change with the various measures of risk used. In general, we see that regardless of the risk measure adopted, except for $\Delta c\&iratio_{it}$, the results are qualitatively unchanged. For the rest of this paper, we therefore adopt $\Delta risk_{it}$ as our measure of risk. We chose the composite risk index $\Delta risk_{it}$ for several reasons. First, it appears to be the most accurate measure of risk for this study since it estimates risk in a manner that captures changes in management policy with regard to the risk profile of the bank at any point in time. Moreover, the expected negative correlation between risk and capital (see Table 2) is only evident when the $\Delta risk_{it}$ measure is adopted. Hence, we assume that this measure dominates others as discussed previously.

We therefore proceed to estimate equations (9.) and (10.) as a system of equations, acknowledging the simultaneity associated with decisions taken in this regard.

4.1.2 Simultaneous equation estimations

For the simultaneous estimations of equations (9.) and (10.), three varying specifications are considered. *Specification I*, is our baseline model defined in equations (9.) and (10.). *Specification II* allows the speed of adjustment back to the target level to interact with the degree of bank capitalization. Finally, *Specification III* allows for further interaction between capital and risk management and bank specific characteristics. In this specification, both the speed of adjustment, together with the management of short term adjustments in capital and risk interact with the size of the capital buffer. The results are presented in Table 5.

Under *Specification I*, the impact of capital buffer adjustments on risk and vice verse are both positive and highly significant. This is in line with the results obtained for the single equation estimations. The fact that simultaneous adjustments of capital and risk are positively related to each other can be associated with a number of theories of bank behavior. First, if banks manage their capital in such a way as to avoid, or minimize, costs associated with a breach of regulatory requirements, then banks would tend to increase *(decrease)* capital when they increase *(decrease)* portfolio risk, and conversely. This is the case since the value of expected bankruptcy costs increase with the probability of bankruptcy (see Orgler and Taggart, 1983). Through simultaneous adjustments of both capital and risk, banks are able to manage an internally optimal probability of default, defined as a function of both capital and risk. Moreover, the theory of managerial risk aversion in the context of banking (Saunders et al., 1990) views managers as agents of stockholders that may have an incentive to reduce the risk of bank insolvency below the level desired by stockholders. Managers, who are assumed to be compensated with risky fixed claims on the bank, and who have firm and industry specific human capital, have a great deal to lose personally in the event of a bank failure. In this case, the marginal cost associated with increases in risk or decreases in capital, is the incremental disutility experienced by bank managers. Thus, banks that have high risk portfolios may compensate for increases in risk by increasing capital and vice verse. Each case gives rise to a positive relationship between adjustments in risk and capital; and adjustments in capital and risk. The positive relationships between capital and risk are noted under all three specifications. The speeds of risk and capital adjustment under *Specification I* are in both cases positive and highly significant. As per the single equation estimations, the speed of risk adjustment is significantly slower than the capital adjustment over the sample period.

The interaction terms, $Dcapxbuf_{it-1}$ and $Dcapxrisk_{it-1}$ introduced in *Specification II*, shed further light on how the speed of adjustment towards the target level depends on the size of the capital buffer. Coefficients for both $Dcap_lxbuf_{it-1}$ and $Dcap_hxbuf_{it-1}$ are positive as expected. The magnitudes of the coefficients, together with their degree of significance imply that banks with small capital buffers, those with capital buffers *not* larger than two percent, adjust their buffers faster than their better capitalized counterparts. This is in line with the recent literature which allows the speed of adjustment towards targets to vary with firm specific characteristics (see Berger at al., 2008).[24] For the risk equation, coefficients, and degrees of significance, of $DCAP_lxrisk_{it-1}$ and $DCAP_hxrisk_{it-1}$ indicate that low buffer banks do not adjust their risk any faster than highly capitalized banks.

Under *Specification III*, we introduce a further interaction between the degree of bank capitalization and management of short term risk and

[24]Their findings suggest that BHCs adjust toward their target levels of capital relatively quickly; and that adjustment speeds are faster for poorly capitalized BHCs, but slower (ceteris paribus) for BHCs under severe regulatory pressure.

buffer adjustments. Both $Dcap_l x \Delta risk_{it}$ and $Dcap_l x \Delta buf_{it}$ are negative and highly significant. This finding has two possible interpretations (i) lower capitalized banks reduce their risk taking *(capital buffers)* when capital *(risk)* is increased, thereby moving towards their target probability of default in the long run; or alternatively, (ii) banks with capital approaching the regulatory minimum will increase risk taking, gambling for resurrection in order to rebuild their capital buffer. As a consequence, buffers may temporarily fall even further. Both versions are consistent with the capital buffer theory. In contrast, banks with capital buffers substantially above the requirement increase *(reduce)* risk taking when capital increases *(falls)*, thereby maintaining a target probability of regulatory breach as predicted by theory. Our findings with regard to interacted speeds of adjustment confirm those noted under *Specification II.*

With regards to the bank specific variables, q_{it} is consistently highly significant in all cases, regardless of the specification adopted. This is in line with predictions made by the capital buffer theory. Banks with a relatively high charter value will hold a larger capital buffer and will have a greater incentive to reduce risk taking. As per the single equations, larger banks will hold less capital and take more risk. The effect of $size$ on risk is however, insignificant.

In addition, we note that BHCs will generally rely heavily on retained earnings in order to increase their capital buffers. This is in line with Aggarwal and Jacques (2001) who conduct a similar study for the US, however their sample is limited to commercial banks as well as to a much shorter time frame. Banks with greater expected losses appear to raise their capital buffers to comply with regulatory requirements and to mitigate solvency risk, while banks with higher loan losses, surprisingly, tend to exhibit higher levels of portfolio risk. The coefficients on the $liquidity_{it}$ variables carry the expected signs but are not significant at any level.

The most important findings can be outlined as follows: Short term adjustments in capital and risk are positively related and the relationship appears to be two way ie. large buffer banks maintain a target probability of default through positive adjustments in both capital and risk taking. Small buffer banks on the other hand, reach a target probability of default through negative adjustments. This finding is in line with the notion that banks with capital buffers approaching the regulatory minimum either (i) reduce their risk taking until the target capital level is reached or (ii) increase risk taking as a means to gamble for resurrection consequently reducing the capital buffer even further. Moreover, we find that BHCs adjust their capital buffers towards a target level faster than they adjust their risk. Banks with smaller capital buffers adjust significantly faster than larger buffer banks.

4.2 Further Investigation

Our findings above indicate that observed short term capital buffer and risk adjustments is a positive and significant two way relationship throughout the sample period. While these findings are broadly in line with previous research in this field (see Shrieves and Dahl, 1992; Jacques and Nigro, 1997; Aggarwal and Jacques, 2001; Rime, 2001; Heid et al., 2004) the driving force behind this relationship still remains unclear. It is not clear whether simultaneous adjustments in risk and capital is a universally adopted phenomenon among banks in the sample, neither can we be sure whether that relationship remains consistent over time. The remainder of the analysis therefore focuses on determining whether simultaneous adjustments are dependent on institutional characteristics among banks in our sample, and whether or not the relationship uncovered above has varied significantly over time.

4.2.1 Sub sample Approach

The effect that loan loss provisions has on adjustments in capital buffers and risks has largely varied between studies undertaken. One group of authors, (see among others Rime, 2001 and Heid et. al, 2004) are able to uncover only very little significant impact of loan losses on these variables of interest. Other authors, for example Aggerwal and Jacques (2001), find that US commercial banks with higher loan loss provisions have higher risk weighted assets. Moreover, Peura and Keppo (2006) show that for a sample of US banks between 1983 and 2002[25], those banks with higher than average loan loss provisions have; (i) on average lower expected returns; (ii) on average higher standard deviations in expected returns; (iii) a positive and highly significant correlation between capital levels and the standard deviations of returns. The last observation is important since the standard deviations of returns should be the key parameter driving capital levels in the model. Their analysis suggests that for banks that have suffered below average loan losses, the capital buffer theory seems irrelevant. We test this finding here empirically by splitting our sample into two groups. Those banks with above average loan losses and those with below average loan losses. For each quarter, we take the mean value of loan loss provisions as a threshold and separate the sample accordingly.

Results for estimating equations (9.) and (10.) by these sub samples are presented in Table 7 and 8. Empirical results for those banks

[25] Particularly in the years 1987, 1990, and 1991.

with above average loan loss provisions are broadly unchanged from the full sample GMM estimations presented above. Here we see that adjustments in capital and risk remain positively related. For banks with lower than average loan losses however, adjustments do not appear to have any significant impact on one another. This is verified through the insignificant coefficients on $\Delta risk_{it}$ in the buffer equation, and on Δbuf_{it} in the risk equation. With respect to the interaction terms, we are able to confirm the findings from our previous estimations. Banks with low buffers of capital appear to adjust their capital towards the target level significantly faster than higher buffer banks. Moreover, the coordination of short term adjustments in capital and risk is dependent on the size of the buffer of capital. Small capital buffer banks rebuild an appropriate capital buffer by raising capital while simultaneously lowering risk. In contrast, larger buffer banks try to maintain their capital buffer by increasing risk when capital increases.

4.2.2 Rolling GMM

Under the GMM approach adopted above, fixed coefficients are estimated so as to capture an average effect that each regressor will have on the dependent variable over the time period analyzed. Here, any changes to economic structure, such as changes in a policy regime etc. will not be captured directly, but rather effects will be averaged out to provide a single estimate over time. During much of the 1990s, (a large portion of the time frame during which we conduct this analysis), the regulatory restrictions imposed on BHC's underwent significant transformation. Basel I was initially introduced in 1990 which, for the first time in history, defined a numerical minimum amount of capital that banks were required to hold. These rules were subsequently amended slightly in 1992. Moreover, the FDIC improvement act came into force in 1991 which included a set of correctative actions that increased the cost of violating the regulatory minimum. Moreover, restrictions on permissible bank activities were removed allowing BHC's to select from a broader array of potential risk exposures. The typical BHC's risk exposure consequently increased, as the diversification effects of new business activities were outweighed by the higher risks associated with the new lines of business.

In addition, the US economy faced several periods of change in terms of economic growth and prosperity as well the removal of restrictions placed on permissible bank activities, increasing the array of potential risk exposures. Therefore, to capture the changing environment in which BHCs have been operating and to assess the effects on the capital buffer risk relationship, we obtain a set of rolling coefficients for equations (9.)

and (10.). We achieve this by estimating a series of rolling GMM equations over our sample period providing a continuous picture of the buffer risk relationship. We begin with windows of one year, including four time period observations in each window.[26] This gives us one coefficient for each year. These estimations are conducted only on the above average loan loss provision banks.

Results for the buffer and risk equations under *Specification I* are presented in Tables 9 and 10 respectively.[27] The relationship between risk and capital adjustments appears to have changed significantly over time.

In particular, the relationship between buffer and risk adjustments appears to be driven by the management of shocks to the capital buffer. Banks have consistently maintained their desired probability of default by reducing *(increasing)* risk taking following a negative capital *(positive)* shock. We do however see a slight shift in the relationship in the years directly post regulation. Between 1994 and 1997, we note that a capital shock has a negative impact on the adjustment of risk. Banks with an increase in capital reacted by reducing their risk taking, building up their capital buffers to meet requirements by adjusting their risk taking downwards. This build up of capital is reflected in Figure 2.

On the other hand, shocks to risk have started significantly influencing capital buffer adjustments only since 1999. Banks faced with riskier portfolios reacted by simultaneously increasing their capital buffers. Similarly, banks that experienced a decline in portfolio risk reduced their capital buffer in order to maintain their internally defined target probability of default. Interestingly, we do see a change in this relationship too, after 1993. Moreover, in the three years between 1993 and 1997, an increase in risk taking induced a build up of capital. Here it seems that banks tried to build up their capital buffers to new target levels through a positive risk capital strategy. That is, by increasing capital when risk was high, and reducing capital when risks were low. The coefficients of interest are presented in Figure 2.

From the time varying analysis conducted, it seems that from around 1999, banks have started to manage an internally optimal probability of default defined as a function of both capital and risk. Several theories can be put forward to try to explain the visibly increased importance that risk adjustments have on capital adjustments. First, the removal

[26]Both 1986 and 2008 are dropped from the sample since we only have two quarterly observations in each of these years.

[27]We additionally estimate time varying equations for *Specification II* and *II* however, we do not report the results here for the sake of brevity since they are qualitatively unchanged from those observed for the previous estimations.

of restrictions on permissible bank activities, allowing BHC's to select from a broader array of potential risk exposures,[28] has consequently increased BHC's risk exposures. Moreover, as regulation moves towards becoming more risk sensitive, it is possible that banks merely recognize the increased importance to be placed on managing risk taking.

4.2.3 Robustness

In order to verify the results obtained, several additional robustness tests have been conducted. First, we re-estimate equations (9.) and (10.), substituting Δbuf_{it} with total capital over total assets (Δcap_{it}). The results are qualitatively unchanged from the findings presented. The only notable difference is the speed of adjustment which appears much slower than the adjustment back to the target buffer level. When Δcap_{it} is estimated as the dependent variable, we find the gap between actual and target capital is closed by around two percent per quarter, when compared to nine percent for the buffer. In this framework, the gap between actual and target risk is closed by around one percent per quarter compared to three percent under the buffer capital framework. The speed of adjustment of Δcap_{it} is therefore still significantly faster than that of $\Delta risk_{it}$, but the difference is not as extreme as in the results presented. Second, we estimate equations (9.) and (10.), substituting $\Delta risk_{it}$ (Δbuf_{it}) with a lagged $\Delta risk_{it-1}(\Delta buf_{it-1})$. While the effects of the control variables do change somewhat, the sign and the magnitude of the key variables remain unchanged. Third, we experimented with the use of buf as an absolute level, again without qualitative changes to the relationships of key variables. Other tests involved including additional lags of $\Delta risk_{it}$ and Δbuf_{it} in equations (9.) and (10.) respectively. Furthermore, we adopted different thresholds of low versus high capital. Finally, we introduce a saw tooth in the capital ratios by allowing for the fact that dividend payments are made only every second quarter. This was done by introducing a dummy variable set equal to one when dividends were paid and zero otherwise.

5 Discussion

Building an unbalanced panel of US commercial bank and BHC data between 1986 and 2008, this paper examines the relationship between short term adjustments in bank capital buffers and risk. Controlling for various determinants of capital buffers and risk levels put forward by the theoretical and empirical literature in this field, we find that the relationship appears to be positive and two way during the sample period. Moreover, we show that the management of short term adjustments to

[28]see Stiroh (2004).

capital and risk is dependent on the degree of bank capitalization.

Our results identify a positive and significant relationship between capital buffer and risk adjustments over time. Our findings are broadly in line with the capital buffer theory, predicting that well capitalized banks adjust their buffer capital and risk positively. The relationship is negative for low buffer banks. These results are confirmed by a set of single equations as well as by simultaneous GMM equations. In addition, we note that the management of short term adjustments in capital and risk are dependent on the amount of capital the bank holds in excess of the required minimum. Banks with small capital buffers rebuild an appropriate capital buffer by raising capital while simultaneously lowering risk. In contrast, well capitalized banks maintain their capital buffers by increasing risk when capital increases. Our estimations further indicate that the speed with which banks adjust towards the desired level is also dependent on the size of the buffer. We show that small buffer banks adjust capital buffers significantly faster than their better capitalized counterparts. However, we are unable to find significant evidence of a similar trend for risk adjustment.

By splitting the sample and analyzing banks by degree of loan loss provisions, we show that the buffer theory holds only for high loan loss banks. Capital and risk adjustments for low loan loss banks on the other hand, do not appear to impact one another significantly. In addition, the relationship between capital and risk appears to have changed significantly over time. Shocks to the capital buffer have consistently, positively, affected adjustments in risk. For example, a bank faced with a reduced capital ratio (for example resulting from the recent collapse of the asset backed commercial paper as a source of funding), have reacted with a simultaneous reduction in their risk taking. On the other hand, short term shocks to risk have only really become important for buffer capital adjustments post-1999.

Despite the lack of parameters capturing the return towards the long run equilibrium, our results do provide substantial support for the buffer view that capital is not an exogenous decision, but rather determined simultaneously with internal risk choices. Moreover, we find that the relationship between capital and risk is not stable over time. Rather, it can be driven by either exogenous changes to risk aversion or, by shocks to either capital or to risk opportunities. Both of these underlying factors may have a cyclical component. In economic upturns, banks become more risk loving as they understate their risk relative to the objective measure of risk. Moreover, shocks to either capital or risk can also have a cyclical component, however this should not affect the buffer risk relationship significantly.

6 Tables and Figures

Figure 1: *US BHC Tier One and Total Capital Evolution.*

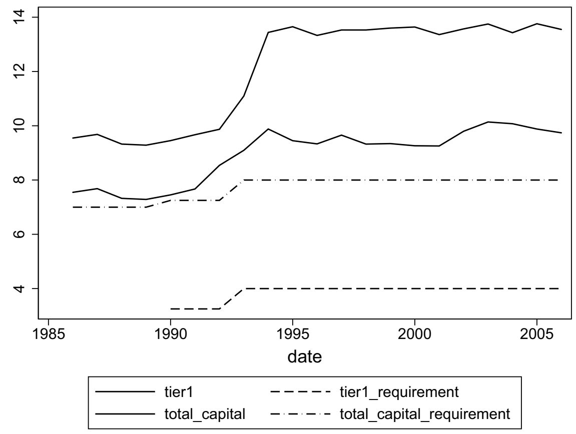


Table 1: Variable Descriptions.

		Expected sign	
Variable	Description	Buffer capital equation	Risk equation
Δbuf	Change in the total capital ratio minus regulatory required minimum.		
Δrisk	Change in the weighted sum of assets amounts as defined in Section		
Δrwa/ta	Change in the ratio of risk weighted asets to total assets.		
Δnpl	Change in the ratio of non-performing loans to total loans and credits.		
Δc&iratio	Change in the ratio of commercial and industrial loans to total loans.		
q	Tobins *q*.	+	-
size	Log of total assets.	ambiguous	ambiguous
roa	Return on assets.	+	
loanloss	Ratio of new provisions to total assets.	+	-
liquidity	Ratio of bond holdings + share holdings + interbank assets to total assets.	-	+
$\mathbf{Dcap}_l$	Dummy variable equal to 1 for low buffer banks and 0 otherwise .	ambiguous	ambiguous
$\mathbf{Dcap}_h$	Dummy variable equal to 1 for high buffer banks and 0 otherwise .	ambiguous	ambiguous

Table 2: Correlation Matrix.

	buf	risk	rwa/ta	npl	c&iratio	Δbuf	Δrisk	Δrwa/ta	Δnpl	Δc&iratio
buf	1									
risk	-0.29***	1								
rwa/ta	0.21**	0.42***	1							
npl	0.17**	0.39*	0.33***	1						
c&iratio	0.12**	0.37**	0.29***	0.22***	1					
Δbuf	-0.12***	0.27***	-0.25***	-0.14**	-0.22***	1				
Δrisk	0.34*	0.13***	0.41***	0.41**	0.36***	0.26***	1			
Δrwa/ta	0.25	0.22***	0.43**	0.22**	0.38*	0.19*	0.34*	1		
Δnpl	0.19**	0.19***	0.34**	0.34***	0.24**	0.23***	0.23***	0.38**	1	
Δc&iratio	0.45*	0.25***	-0.44***	-0.33***	0.21***	0.18*	0.19**	0.29**	0.27*	1

Note: *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 3: Single Equation GMM: Capital Buffer Equation.

	Model I	*Model II*	*Model III*	*Model IV*	*Model V*	*Model VI*	*Model VII*
buf_{it-1}	0.09 (9.74)***	0.05 (9.56)***	0.04 (12.99)***	0.06 (13.22)***	0.06 (12.96)***	0.07 (10.73)***	0.08 (17.94)***
$\Delta risk_{it}$	0.55 (14.76)***					0.65 (10.11)***	0.55 (12.76)***
$\Delta rwa/ta_{it}$		0.34 (2.98)***			0.27 (1.97)**	0.29 (0.95)	
Δnpl_{it}			0.24 (2.14)**		0.19 (1.95)**		-0.11 (4.87)***
$\Delta c\&iatio_{it}$				-0.28 (2.87)***			
q_{it}	0.34 (1.23)	0.46 (3.23)***	0.34 (2.06)**	0.32 (3.09)***	0.29 (1.98)**	0.39 (2.18)**	0.35 (2.79)***
$size_{it}$	-0.22 (1.10)	-0.35 (1.74)*	-0.29 (0.99)	0.33 (1.06)	-0.34 (1.16)	-0.18 (2.32)**	0.45(0.88)
roa_{it}	0.18 (1.96)**	0.12 (2.11)**	0.16 (3.42)***	0.14 (0.99)	0.12 (2.76)***	0.15 (2.49)**	0.16 (2.01)**
$loanloss_{it}$	-0.43 (1.88)*	0.23 (2.01)**	0.19 (1.93)*	0.22 (0.93)	-0.42 (2.00)**	0.19 (1.14)	0.40 (2.34)**
$liquidity_{it}$	-0.32 (1.99)**	-0.42 (0.09)	-0.33 (0.58)	-0.56 (1.20)	-0.55 (0.73)	-0.45 (1.32)	-0.33 (5.11)***
Sargan	19.87 (1.77)	25.73 (2.89)	54.78 (2.74)	16.79 (1.37)	27.77 (1.66)	31.51 (2.33)	22.06 (2.98)
a(1)	-1.97 (0.00)	-1.02 (0.00)	2.34 (0.00)	-1.43 (0.00)	2.04 (0.00)	-3.22 (0.00)	-1.20 (0.00)
a(2)	-2.01 (0.99)	1.92 (0.83)	1.23 (1.12)	2.65 (0.52)	1.02 (0.23)	-1.05 (0.68)	-1.18 (0.87)

Note: All regressions include bank fixed effects together with a full set of time dummies as control variables (not reported here). Dependent variable is $\Delta \mathrm{buf}_{it}$. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 4: Single Equation GMM: Risk Equation.

	Model I	*Model II*	*Model III*	*Model IV*
$risk_{it-1}$	0.03 (5.55)***	0.01 (10.34)***	0.02 (9.45)***	0.02 (9.34)***
Δbuf_{it}	0.55 (10.23)***	0.65 (7.04)***	0.48 (5.33)***	-0.77 (1.66)*
q_{it}	-0.44 (4.34)***	-0.61 (2.31)**	-0.34 (2.49)**	-0.48 (6.99)***
$size_{it}$	0.22 (1.02)	0.19 (0.63)	0.21 (1.92)*	0.26 (2.07)**
$loanloss_{it}$	0.14 (1.00)	0.25 (2.28)**	0.24 (3.96)***	0.10 (3.02)***
$liquidity_{it}$	0.19 (0.34)	0.14 (0.41)	0.15 (1.99)**	0.15 (1.73)*
Sargan	15.34 (0.92)	32.34 (0.83)	21.31 (0.79)	12.43 (0.68)
a(1)	-1.32 (0.00)	1.23(0.00)	2.12 (0.00)	2.30 (0.00)
a(2)	1.21 (0.87)	-2.12(0.64)	1.98 (0.92)	-2.34 (0.76)

Note: All regressions include bank fixed effects together with a full set of time dummies as control variables (not reported here). Dependent variable is Δrisk$_{it}$ Δrwa/ta$_{it}$, Δnpl$_{it}$ and Δc&iratio$_{it}$ for Model I, II,III and IV respectively. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 5: Simultaneous Equation GMM Estimations.

	Specification I		*Specification II*		*Specification III*	
	ceofficient	t-value	coefficient	t-value	coefficient	t-value
Buffer capital equation						
buf_{it-1}	0.09	(10.87)***				
$Dcap_l \Delta buf_{it-1}$			0.09	(12.87)***	0.08	(7.98)***
$Dcap_h \Delta buf_{it-1}$			0.14	(2.51)**	0.12	(4.87)***
$\Delta risk_{it}$	0.42	(9.54)***	0.35	(8.54)***	0.38	(11.86)***
$Dcap_l \Delta risk_{it}$					-0.15	(2.50)**
$Dcap_h \Delta risk_{it}$					0.50	(7.52)***
q_{it}	0.32	(4.87)***	0.27	(1.72)*	0.42	(3.08)***
$size_{it}$	-0.39	(1.91)*	-0.44	(1.69)*	-0.37	(1.83)*
roa_{it}	0.09	(2.01)**	0.10	(2.19)**	0.09	(1.82)*
$loanloss_{it}$	0.05	(2.47)**	0.12	(2.49)**	0.09	(4.87)***
$liquidity_{it}$	-0.45	(1.42)	-0.37	(1.56)	-0.42	(0.98)
Sargan	27.79	(2.99)	29.78	(3.45)	17.79	(2.87)
a(1)	2.15	(0.00)	1.98	(0.00)	-2.65	(0.00)
a(2)	1.11	(0.54)	2.65	(0.21)	2.88	(1.05)
Risk equation						
$risk_{it-1}$	0.02	(7.54)***				
$Dcap_l \Delta risk_{it-1}$			0.05	(1.98)**	0.04	(2.03)**
$Dcap_h \Delta risk_{it-1}$			0.06	(3.68)***	0.05	(2.48)**
Δbuf_{it}	0.43	(13.46)***	0.48	(4.27)***	0.51	(12.45)***
$Dcap_l \Delta buf_{it}$					-0.22	(5.24)***
$Dcap_h \Delta buf_{it}$					0.36	(8.35)***
q_{it}	-0.21	(3.98)***	-0.13	(4.98)***	-0.15	(6.87)***
$size_{it}$	0.25	(0.85)	0.26	(1.02)	0.32	(0.84)
$loanloss_{it}$	0.21	(1.75)*	0.15	(1.23)	0.25	(2.47)**
$liquidity_{it}$	0.67	(0.96)	0.47	(1.21)	0.44	(2.52)**
Sargan	26.87	(3.28)	32.15	(3.11)	16.98	(2.55)
a(1)	2.30	(0.00)	-1.98	(0.00)	-2.15	(0.00)
a(2)	-2.05	(1.05)	1.98	(0.98)	1.87	(1.12)

Note: All regressions include bank fixed effects together with a full set of time dummies as control variables (not reported here). Dependent variables are Δbuf_{it} and Δrisk_{it} for the buffer and risk equations respectively. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 6: Summary Statistics and Correlations by Sub-Sample.

	Total Sample			*BHCs with above-avg loan loses*			*BHCs with below-avg loan loses*		
	buf	roa	std. dev roa	buf	roa	std. dev roa	buf	roa	std. dev roa
Minimum	2.55	0.00	0.47	3.32	0.00	0.29	2.46	0.00	0.45
Median	6.11	0.03	0.68	5.61	0.04	0.95	6.37	0.98	0.58
Maximum	11.29	0.07	1.11	8.35	0.09	1.01	11.52	0.08	0.86
variable correlations									
	buf	roa	std. dev roa	buf	ROA	std. dev roa	buf	ROA	std. dev roa
buf	1	0.23***	0.19***	1	-0.32***	0.25	1	0.42***	0.10***
roa		1	-0.29***		1	-0.38***		1	-0.23
std. dev roa			1			1			1

Table 7: Sub-Sample Estimations: Capital Buffer Equation.

	BHCs with above-avg loan loss provisions			*BHCs with below-avg loan loss provisions*		
	Specification I	*Specification II*	*Specification III*	*Specification I*	*Specification II*	*Specification III*
buf_{it-1}	0.05 (4.87)***			0.09 (1.99)**		
$Dcap_l \Delta buf_{it-1}$		0.05 (9.54)***	0.06 (8.79)***		0.07 (1.24)	0.08(1.92)*
$Dcap_h \Delta buf_{it-1}$		0.10 (4.78)***	0.11 (2.53)**		0.17 (1.35)	0.11 (0.95)
$\Delta risk_{it}$	0.64 (7.87)***			0.35 (0.35)		
$Dcap_l \Delta risk_{it}$		-0.29 (1.69)*	-0.31 (3.15)***		-0.10 (0.95)	-0.32 (1.21)
$Dcap_h \Delta risk_{it}$		0.39 (8.44)***	0.29 (3.05)***		-0.09 (1.24)	0.21 (1.79)*
q_{it}	0.33 (4.80)***	0.39 (5.78)***	0.36 (2.87)***	0.29 (1.84)**	0.30 (1.99)**	0.42 (2.07)**
$size_{it}$	-0.35 (1.54)	0.22 (0.64)	-0.35 (1.97)**	-0.28 (2.98)***	-0.15 (3.12)***	-0.28 (4.15)***
roa_{it}	0.11 (2.01)**	0.14 (1.71)*	0.13 (1.97)**	0.11 (2.05)**	0.14 (1.84)*	0.09 (0.95)
$liquidity_{it}$	-0.34 (1.25)	-0.36 (0.98)	-0.38 (1.06)	-0.35 (1.75)*	-0.40 (1.87)*	-0.52 (2.01)**
Sargan	25.78 (2.98)	15.97 (4.50)	29.87 (3.02)	16.87 (9.78)	29.78 (3.60)	32.55 (5.54)
a(1)	-1.57 (0.00)	1.98 (0.00)	2.36 (0.00)	2.98 (0.00)	2.78 (0.00)	3.05 (0.00)
a(2)	-2.36 (0.97)	1.54 (1.11)	-2.05 (0.85)	1.87 (0.88)	1.78 (1.02)	-2.45 (0.78)

Note: All regressions include bank fixed effects together with a full set of time dummies as control variables (not reported here). Dependent variable in buffer equation is Δbuf_{it}. For the risk equation we make use of Δrisk_{it}. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 8: Sub-Sample Estimations: Risk Equation.

	BHCs with above-avg loan loss provisions			*BHCs with below-avg loan loss provisions*		
	Specification I	*Specification II*	*Specification III*	*Specification I*	*Specification II*	*Specification III*
$risk_{it-1}$	0.03 (7.87)***			0.01 (1.74)*		
$Dcap_l \Delta risk_{it-1}$		0.05 (1.96)**	0.01 (2.50)**		0.04 (1.11)	0.06 (1.52)
$Dcap_h \Delta risk_{it-1}$		0.06 (2.45)***	0.05 (3.23)***		0.07 (1.96)**	0.09 (2.01)**
Δbuf_{it}	0.56 (6.78)**			0.74 (8.62)***		
$Dcap_l \Delta buf_{it-1}$		-0.15 (3.64)***	-0.12 (2.35)**		-0.19 (1.24)	-0.20 (1.97)**
$Dcap_h \Delta buf_{it-1}$		0.30 (2.27)**	0.27 (5.78)***		0.34 (1.23)	0.39 (2.41)**
q_{it}	-0.32 (3.78)***	-0.57 (4.78)***	-0.39 (2.13)**	-0.42 (1.66)*	-0.44 (2.37)**	-0.28 (0.93)
$size_{it}$	0.25 (1.85)*	0.32 (2.25)**	0.19 (1.02)	0.36 (0.88)	0.18 (0.96)	0.29 (1.34)
$liquidity_{it}$	0.21 (1.04)	0.23 (1.15)	0.31 (0.95)	0.32 (1.26)	0.26 (1.96)**	0.23 (1.23)
Sargan	19.87 (2.65)	26.87 (2.68)	27.89 (4.11)	25.69 (2.94)	15.87 (4.87)	19.87 (3.63)
a(1)	-1.25 (0.00)	2.65 (0.00)	1.68 (0.00)	-1.58 (0.00)	2.69 (0.00)	-3.02 (0.00)
a(2)	-1.64 (0.77)	1.47 (0.32)	-1.78 (0.54)	2.02 (0.69)	-1.06 (0.61)	-2.23 (0.94)

Note: All regressions include bank fixed effects together with a full set of time dummies as control variables (not reported here). Dependent variable in buffer equation is Δbuf_{it}. For the risk equation we make use of $\Delta risk_{it}$. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 9: Time Varying Coefficients Estimation: Capital Buffer Equation (Specification I).

	buf_{it-1}	$\Delta risk_{it}$	q_{it}	$size_{it}$	roa_{it}	$liquidity_{it}$	Sargan	a(1)	a(2)
1987	0.15 (1.02)	0.47 (0.96)	0.42 (1.02)	-0.49 (1.80)*	0.04 (1.34)	-0.23 (1.64)*	32.45 (2.36)	-2.55 (0.00)	-1.98 (1.02)
1988	0.12 (1.64)*	0.63 (0.74)	0.43 (1.73)*	0.32 (1.04)	0.02 (1.23)	-0.32 (1.70)*	27.89 (3.54)	1.25 (0.00)	-2.36 (1.05)
1989	0.14 (0.69)	0.62 (1.20)	0.39 (2.34)**	0.38 (0.84)	0.07 (2.24)**	-0.28 (1.96)**	19.56 (2.98)	-1.23 (0.00)	-2.56 (1.11)
1990	0.13 (1.11)	0.79 (0.83)	0.32 (2.01)**	-0.25 (1.48)	0.10 (1.87)*	-0.24 (1.75)*	32.45 (1.87)	-3.54 (0.00)	3.05 (0.87)
1991	0.12 (1.72)*	0.30 (0.85)	0.34 (1.84)*	-0.22 (1.73)*	0.01 (1.94)*	-0.29 (1.76)*	27.65 (2.69)	-2.00 (0.00)	-2.11 (1.15)
1992	0.11 (1.74)*	0.54 (0.56)	0.49 (2.10)**	-0.19 (0.75)	0.12 (2.23)**	-0.33 (1.67)*	33.33 (2.86)	1.67 (0.00)	-2.08 (0.86)
1993	0.09 (2.00)**	-0.31 (1.06)	0.49 (3.03)***	-0.19 (1.74)*	0.04 (0.64)	-0.03 (1.15)	41.32 (3.05)	-4.03 (0.00)	2.00 (1.67)
1994	0.05 (2.97)***	-0.29 (1.77)*	0.32 (2.39)**	-0.26 (1.89)*	-0.05 (0.79)	-0.21 (1.26)	52.78 (2.89)	3.15 (0.00)	-2.78 (1.14)
1995	0.07 (2.85)***	-0.12 (2.76)***	0.27 (0.85)	-0.25 (1.85)*	0.04 (1.99)**	-0.30 (1.92)*	42.45 (3.05)	-3.21 (0.00)	-2.99 (0.96)
1996	0.06 (1.77)*	-0.13 (1.64)*	0.29 (1.11)	0.23 (0.99)	-0.11 (0.94)	-0.35 (2.00)**	32.12 (4.56)	2.05 (0.00)	-1.69 (0.36)
1997	0.09 (2.76)***	-0.25 (1.96)**	0.36 (2.32)**	0.28 (0.86)	0.08 (1.78)*	-0.29 (1.99)**	19.87 (3.68)	-2.58 (0.00)	-2.45 (1.00)
1998	0.09 (2.13)**	-0.15 (1.03)	0.30 (2.01)**	-0.19 (1.69)*	0.11 (1.95)*	-0.27 (1.65)*	19.87 (3.78)	-2.12 (0.00)	-2.65 (0.96)
1999	0.07 (2.18)**	-0.12 (1.30)	0.32 (3.59)***	-0.31 (2.03)**	0.10 (1.74)*	0.34 (1.79)*	35.69 (5.45)	-3.25 (0.00)	-12.64 (0.61)
2000	0.08 (4.30)***	0.14 (0.39)	0.25 (5.00)***	-0.16 (1.51)	0.08 (2.10)**	-0.18 (0.88)	16.55 (2.14)	-2.54 (0.00)	2.68 (1.06)
2001	0.09 (2.97)***	0.29 (1.95)*	0.37 (4.30)***	-0.18 (1.71)*	0.10 (1.37)	-0.16 (1.86)*	18.66 (6.54)	1.96 (0.00)	-3.02 (1.11)
2002	0.08 (3.12)***	0.44 (2.17)**	0.20 (1.99)**	0.19 (0.99)	0.06 (1.94)*	-0.26 (1.78)*	17.68 (3.25)	2.55 (0.00)	1.25 (0.34)
2003	0.07 (2.94)***	0.36 (4.30)***	0.48 (1.86)*	0.19 (0.67)	0.06 (1.79)*	-0.21 (1.07)	32.56 (4.25)	1.25 (0.00)	-1.26 (0.65)
2004	0.06 (4.12)***	0.30 (5.40)***	0.36 (5.40)***	0.29 (0.22)	0.03 (2.19)**	-0.25 (2.62)***	35.68 (3.36)	2.65 (0.00)	-3.22 (0.87)
2005	0.09 (3.85)***	0.32 (3.11)***	0.30(5.30)***	0.29 (0.75)	0.05 (1.78)*	-0.32 (2.47)**	37.25 (4.87)	2.65 (0.00)	-1.87 (1.19)
2006	0.07 (4.02)***	0.33(1.99)**	0.59 (3.99)***	0.32 (0.84)	0.06 (1.52)	-0.26 (1.09)	16.87 (5.47)	-3.65 (0.00)	-3.25 (1.23)
2007	0.06 (3.13)***	0.43(5.34)***	0.45 (4.23)***	0.31 (0.12)	0.02 (1.82)*	-0.18 (1.98)**	25.65 (3.02)	2.65 (0.00)	-2.56 (0.87)

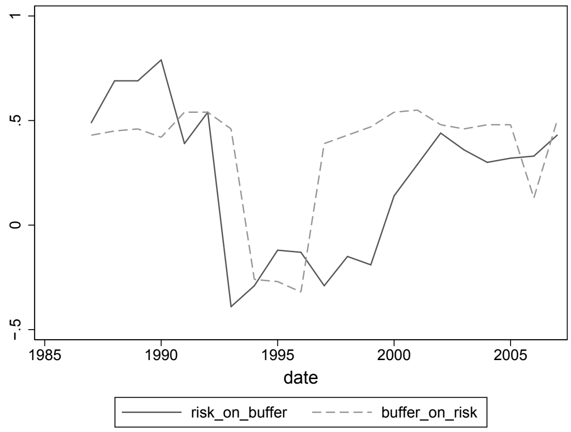
Note: All regressions include bank fixed effects. Dependent variable is Δbuf_{it}. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Table 10: GMM Time Varying Coefficients Estimation: Risk Equation (Specification I).

	$risk_{it-1}$	Δbuf_{it}	q_{it}	$size_{it}$	$liquidity_{it}$	Sargan	a(1)	a(2)
1987	0.02 (2.01)**	0.43 (1.73)*	-0.25 (1.73)*	0.22 (0.96)	0.32 (0.98)	19.64 (3.98)	-1.54 (0.00)	-2.45 (1.06)
1988	0.01 (2.11)**	0.45 (2.23)**	-0.29 (2.11)**	0.15 (0.98)	0.21 (1.86)*	32.15 (4.55)	-3.25 (0.00)	-2.15 (0.96)
1989	0.00 (1.11)	0.46 (3.05)***	-0.23 (1.03)	0.22 (1.06)	0.25 (1.52)	27.89 (3.58)	-2.36 (0.00)	-1.58 (0.86)
1990	0.01 (1.99)**	0.42 (0.95)	-0.27 (1.05)	0.21 (2.11)**	0.27 (1.68)*	19.58 (6.54)	-1.99 (0.00)	2.54 (1.17)
1991	0.04 (3.00)***	0.54 (1.99)**	-0.24 (1.85)*	0.28 (1.64)*	-0.27 (0.85)	35.68 (3.69)	4.12 (0.00)	-2.67 (1.19)
1992	0.03 (2.49)**	0.55 (4.13)***	-0.23 (2.74)***	0.27 (2.27)**	0.26 (0.95)	35.65 (2.98)	1.15 (0.00)	-1.99 (0.98)
1993	0.04 (1.98)**	0.46 (2.06)**	-0.26 (3.11)***	0.27 (1.15)	0.26 (1.23)	36.89 (2.98)	1.59 (0.00)	2.64 (1.00)
1994	0.02 (2.31)**	-0.26 (2.38)**	-0.23 (2.07)**	0.26 (1.09)	0.35 (1.69)*	237.89 (6.25)	-2.13 (0.00)	-2.98 (0.96)
1995	0.03 (1.83)*	-0.27 (4.95)***	0.25 (0.98)	0.29 (1.95)*	0.36 (1.67)*	19.78 (7.86)	-2.21 (0.00)	3.25 (0.96)
1996	0.02 (1.86)*	-0.32 (5.72)***	0.24 (0.74)	0.24 (1.73)*	0.29 (0.94)	26.98 (4.68)	1.56 (0.00)	-1.98 (1.04)
1997	0.03 (4.00)***	0.39 (2.01)**	-0.25 (0.84)	0.32 (2.22)**	0.31 (0.74)	26.56 (2.89)	-2.69 (0.00)	-1.98 (1.22)
1998	0.05 (3.96)***	0.43 (3.63)***	-0.26 (1.20)	0.35 (1.96)**	0.34 (1.85)*	39.68 (6.54)	2.33 (0.00)	-2.36 (0.96)
1999	0.04 (5.93)***	0.47 (2.96)***	-0.28 (1.78)*	0.27 (1.55)	0.37 (1.73)*	35.68 (6.87)	-3.25 (0.00)	-2.11 (0.68)
2000	0.03 (2.99)***	0.53 (1.06)	-0.25 (1.99)**	0.27 (1.64)*	0.34 (2.39)**	52.14 (2.88)	-1.54 (0.00)	-2.56 (1.06)
2001	0.06 (2.38)**	0.55 (6.94)***	-0.25 (2.04)**	0.26 (1.63)	0.26 (3.07)***	19.86 (3.67)	2.65 (0.00)	-1.56 (0.96)
2002	0.04 (1.84)*	0.48 (3.74)***	-0.31 (2.23)**	0.25 (1.13)	0.26 (7.96)***	38.97 (5.64)	1.89 (0.00)	-2.45 (0.67)
2003	0.02 (3.06)***	0.46 (3.85)***	-0.36 (1.85)*	0.14 (1.33)	0.31 (3.97)***	17.89 (3.62)	-1.68 (0.00)	-3.02 (1.01)
2004	0.01 (7.05)***	0.48 (6.00)***	-0.37 (2.00)**	0.19 (1.99)**	0.34 (4.97)***	44.56 (3.68)	-2.69 (0.00)	-2.56 (1.03)
2005	0.03 (6.14)***	0.48 (7.94)***	-0.36 (3.48)***	0.24 (1.74)*	0.38 (8.64)***	56.98 (4.65)	2.68 (0.00)	2.06 (0.86)
2006	0.01 (5.96)***	0.43 (3.07)***	-0.36 (1.97)**	0.25 (2.01)**	0.35 (4.23)***	29.87 (2.78)	1.26 (0.00)	-1.25 (0.73)
2007	0.02 (2.94)***	0.50 (4.33)***	-0.33 (2.50)**	0.26 (1.78)*	0.34 (7.87)***	29.45 (6.45)	4.32 (0.00)	1.26 (0.93)

Note: All regressions include bank fixed effects. Dependent variable is Δrisk_{it}. Other variables as defined in Table 5.2. t-values presented in parentheses. a(1) and a(2) represent first and second order residual tests. *, **, *** denote significance at the ten, five and one percent levels of significance respectively.

Figure 2: *Time Varying Coefficients.*



7 Data Manipulations

7.1 Commercial bank dataset

All bank level data is obtained from the Consolidated Report of Condition and Income (referred to as the Call Reports) published by the Federal Reserve Bank of Chicago. Since all insured banks are required to submit Call Report data to the Federal Reserve each quarter we are able to extract income statement and balance sheet data for around 14,000 commercial banks. The dataset spans from $1976Q1 - 2006Q2$.

This particular dataset poses several problems for us to deal with in terms of cleaning the data and obtaining a consistent set of data series. There are several reasons for this. First, through time, definitions change for some of the variables of interest, therefore, looking merely at the Report documentation that that banks are required to fill in is not always sufficient. Therefore it is necessary, on some occasions, to join series together in order to yield sensible series through time. Moreover, most of the large banks only provide data on a consolidated foreign and domestic basis requiring the exploration of which series to use.

RCON vs. RCFD series In general, larger banks only provide data on a consolidated foreign and domestic basis. Therefore, it is necessary to use the $RCFD$ series rather than the $RCON$ series for each variable. For banks that do not have foreign operations however, it is possible to assume that the two series ($RCON$ and $RCFD$) will be identical, although it is necessary to bear in mind that foreign deposits in this case are not available.

The definition for total securities changes several times through our sample. It is therefore necessary for us to combine various individual series through time to create a consistent variable to work with. Prior to 1984, it is not possible to combine all of the items that are now considered as investment securities. We therefore need to approximate the securities variable. Pre-1984 we combine $RCFD0400$ (US Treasury securities), $RCFD0600$ (US Government agency and corporation obligations), $RCFD0900$ (obligations of states & political subdivisions) and $RCFD0380$ (other bonds, stocks and securities). In 1984q1 however, we are able to separately add up the items making up investment securities because a) trading account securities for sale at book value ($RCFD1000$) is replaced by *securities for sale at market value* ($RCFD2146$) and b) there is no guarantee that the securities are held to maturity match across the break in 1984. i.e. there is no guarantee that $RCFD0402$ (securities issued by states and political subdivisions in the US) + $RCFD0421$ (other domestic securities) + $RCFD0413$(foreign securities) = $RCFD0900$ (obligations of states and political subdivisions) + $RCFD0950$(other securities). For the pre and post 1984 series to be consistent, these two summations must be equal. We therefore combine the series $RCFD0390$ (book value of securities) and $RCFD2146$ (assets held in the trading account) for the period 19841 to 1993q4. After this time, $RCFD0390$ (book value of securities) is no longer available. From 1994q1 we therefore proceed by summing up $RCFD1754$ (total securities held to maturity), and $RCFD1773$ (total securities available for sale). Moreover, $RCFD1754$ (total securities held to maturity), and $RCFD1773$ (total securities available for sale) excludes securities held in the trading account, which is part of $RCFD3545$ (total trading assets). We therefore create an additional securities variable (securties2) which is the summation of $RCFD1754$ (total securities held to maturity), $RCFD1773$ (total securities available for sale) and $RCFD2146$ (assets held in trading accounts). We generally make use of the securities2 variable since this eliminates a break in the series in 1993.

For total loans, we again see that there is a break in the series in March 1984. In the third quarter of 1984, the series includes the variable $RCFD2165$ (lease financing receivables). From March 1984 we adopt $RCFD1400$ (total loans & leases, gross) as our total loans variable. Prior to this however, we replace the series with a sum of $RCFD1400$ (total loans & leases) and $RCFD2165$ (lease financing receivables). Similarly for net loans we have $RCFD2122$ (total loans, net of unearned income) for the period between 1984q1 and 2006q2. Prior to this, we again combine $RCFD2122$ (total loans, net of unearned income) with $RCFD2165$ (lease financing receivables).

Commercial and Industrial loans has a change in definition as well. From 1976 until 1984q3, we make use of the $RCFD1600$ (commercial and industrial loans). Here, each bank's own acceptances are included. From 1984q3 however, the series starts to include holdings of bankers' acceptances which are accepted by other banks. We therefore replace this series with a combination of the $RCFD1755$ (acceptances of other banks) and $RCFD1766$ (commercial and industrial loans, other). It remains impossible to create a consistent series here that would exclude banker's acceptances.

A further change in definition occurs with the Fed Funds series. Considering first the Fed Funds Sold series. From 1976 until 2002q1 we are able to make use of $RCFD1350$ (Fed Funds Sold). However, the series discontinues thereafter. We subsequently form a continuation by summing $RCONb987$ (Fed Funds sold in domestic offices) and RCFDb989 (securities purchased under agreement to sell).

Similarly, for Fed Funds Purchased, the series $RCFD2800$ (Fed Funds

Purchased) discontinues at the end of 2001. We are then able to replace the series in 2002q2 with $RCFDb993$ (Fed Funds purchased in domestic offices) summed with RCFDb995 (securities sold under agreement to repurchase).

Other issues in the commercial bank dataset In most of the graphical analysis we find a kink in the series in 1997q1. Looking closer at the cause of this disturbance in the data, we find that the number of institutions falls in 1997q1 to 8,648 from 9,772 in 1996q4. The number subsequently rises again in 1997q2 when the number of reporting institutions jumps again to 9,248. Investigating the issue further, we find that there appears to be a fault in the dataset for this period. It seems that information reported for around 800 banks are all returned with 0 values. We therefore correct the data by setting values equal to those of the previous period where data is missing.

Dealing with mergers With respect to the treatment of bank mergers in the data, several possible alternative approaches are considered: *Option 0*: All observations affected by a merger are simply dropped from the sample. Note however,if using any lagged growth rates or differences in the model, this means dropping future observations as well as the observation when the merger takes place. This option is applied by many existing studies in the banking literature (see for example Kashyap and Stein, 2000). *Option 1*: This option is preferable when a large bank acquires a very much smaller bank. Here, all past balance sheet and income observations are rescaled, using a constant ratio, from the beginning of the sample up to the quarter preceding the merger. This ratio is equal to the increase in total assets triggered by the merger. *Option 2*: This option is preferable to Option 1 when two merging banks are of similar size. Here, the merged entities are reconstructed backwards as the sum of the merging banks. In this case a new new bank id, different from any existing id, is created and applied to all subsequent observations.

In this chapter, we adopt a mixture of Options 1 and 2; When merging banks are of different sizes we adopt Option 1 while for a small number of mergers where the merging banks are of similar size, we create a new bank id as per Option 2.

Merging the Commercial and BHC datasets The following steps were undertaken to merge the holding company data with with commercial bank data from the Federal Reserve Bank of Chicago. We start with the commercial bank data set and start by identifying those banks that belong to foreign call family:

1.

We start by generating a foreign call identity as follows:

gen fgncall_ind = 0

replace fgncall_ind = 1 if fgncallfamily > 0 & fgncallfamily ~ = .

We then created a variable called *identifier* which tells us the name of the financial high holder. (this is equal to the rssd9348 variable in the dataset:

gen identifier = high holder $/* = rssd9348 * /$

If however, the high holder is a foreign call family, the variable gives the number of it instead:

replace identifier = $fgncallfamily$ if $fgncall\_ind == 1$

2.

We then make use of the *identifier* variable to collect holding company data from the BHC data.

By changing the name of $rssd9001$ to identifier in BHC data. Moreover, we drop all observations equal to 0.

3.

Finally we merge this dataset back to the commercial bank data. First we copy the commercial bank dataset and the BHC data into the same directory. Opening the commercial bank data, we type the following:

$$\text{merge } rssd9001 \text{ dateq using BHCpanel, unique sort}$$
$$update\_merge(\_mergeBHC)$$

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