Bank Accounting Ratios, Interbank Lending, and Liquidity Hoarding During Financial Crisis 2007/08

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BANK ACCOUNTING RATIOS, INTERBANK LENDING, AND LIQUIDITY HOARDING DURING FINANCIAL CRISIS 2007/08

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Abstract

Although a large body of literature has proposed various models to identify an impending financial crisis by studying systemic risk and contagion, scarce previous research has considered the possibility that banks can protect themselves during a financial crisis and therefore affect the propagation of losses through financial linkages, such as the interbank market. Drawing upon a subset of U.S. bank accounting ratios from 1992Q4 to 2011Q4, the thesis investigates banks' preemptive actions by analysing significant structural shifts in response to crises at the aggregated bank level. We've found Bank size does matter in context of applicability of banking accounting ratios serve as early warning signals. The results show that certain indicators such as 'leverage' and 'coverage' ratios are appropriate indicators for the detection of banking system vulnerabilities all banks. And nonperforming loans ratio (NPLs) additionally serves as an indicator for the timing of a crisis. The thesis also finds that whereas capital levels were closely monitored, heavy reliance of banks on wholesale funding is often overlooked. Banks accumulate liquidity to protect themselves from liquidity shocks and therefore contribute to (or mitigate) the onset of a crisis. Therefore, the impact of bank size and interbank lending on bank risk-taking are carefully examined; and a nonlinear (U-shaped) relationship is found. It adds empirical weights to the 'too big to fail' phenomenon. In addition to this, preemptive actions of large banks are found in the interbank market during the financial crisis. In other words, interbank lending is associated with substantially lower risk taking by borrowing banks in financial crisis, which are consistent with monitoring by lending banks. Finally, the thesis considers banks' liquidity creation during the interbank lending crunch. The author finds those same factors leading to precautionary liquidity hoarding also contributed to a decline in interbank lending: banks with net interbank borrowing positions rationed lending due to self-insurance motives and they offered higher rates to attract external funding; net lenders hoarded liquidity due to heightened counterparty risk. The author also proposes two on-balance proxies for liquidity risk: (i) the unrealized security loss ratio and (ii) the loan loss allowance ratio. Banks choose to build up liquidity in anticipation of future expected losses from holding assets. On the policy frontier, besides credit and securities lending programs targeted at the interbank market, the author proposes interbank lending subsidization.

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Chapter One: Introduction

What does banks do? The answer to this varies country by country because of different legal systems. Smith (1776[1937], p305) defined the critical economic function of the banking industry as an intermediary that can maximise profits:

"The judicious operation of banking, by substituting paper in the room of a great part of this gold and liver, enables the country to convert a great part of this dead stock into active and productive stock; into stock which produces something to the country."

Banking is a major outcome from the development of modern society. Banks, by their nature, are important not only for individuals' finances, but also for national stabilization (Heffernan, 1996). However, events occasionally strain the banking system: such as physical disruption on 11th September 2001 as well as financial crisis of 2007/08.

The recent subprime mortgage crisis, which started from 2007, had a similar cause as that of the Scandinavian crisis 1980s: the boom and burst of the housing bubble; however, it has also raised puzzles as it was believed that the subprime market was too small to trigger the propagation of losses in the entire U.S. financial market, while, it was characterized as one of the worst credit crises since the Great Depression (Mishkin, 2008). The subprime mortgage crisis started from the housing markets, and then spread to the subprime mortgage market that was merely a small sector in the global financial market. It further affected the financial institutions. Take HSBC - the largest bank at that time - for an example, it wrote down 10.5 billion dollar holding in subprime-related mortgage-backed securities according to the BBC (2008). The failures of some crucial financial institutions, such as Lehman Brothers, pushed the crisis to its peak and thus brought the global financial market to collapse. Consequently, as reported by the IMF, U.S. banks accounted for approximately 60% of total losses, and 40% for UK and European banks (Reuters, 2009).

Even though the lessons are learnt from the past financial crises, financial crises still take

place. Reflecting the high costs of banking crises and their increased frequency, the banking industry stability is one of particular interest and the debate emerging from it is still on-going. However, scare previous literature have considered the possibility that banks could make actions to protect themselves during the financial crisis and therefore affect the propagation of losses through the financial linkages, such as interbank market. Therefore, this has been a main motivation for conducting a comprehensive investigation into bank behaviour in this thesis; and thus to identify an impending crisis. First, we analyse structural changes of bank accounting ratios in response to crises at aggregate bank-level. Moreover, the impact of bank size and interbank lending on banks' risk-taking are examined. Finally, we study how banks managed the interbank lending crunch that occurred during the financial crisis of 2007-2008 by adjusting their holding of liquidity assets, as well as how these efforts to the storm affected funding ability.

1.1 Bank Activities and Financial Crisis 2007/08

According to modern banking theory, a bank plays an intermediary role in the economy by reallocating capital, and providing liquidity services as well as risk management (Freixas and Rochet, 2008, p2).

First, a bank provides an intermediary role by taking deposits and granting loans (Heffernan, 2005). It plays a core role in reallocating capital because of the economies of scale: Banks can access more privileged information on borrowers; therefore the information economies of scale would enable banks to lending at lower cost compare to other financial institutions (Heffernan, 2005). On the other hand, although firms may finance in a more sustainable way by issuing bonds, external liquidity from banks would be also preferred: it gives a good signal to the market (Stiglitz and Weiss, 1988). However, banks may also face the challenge of risk-taking due to their nature.

Banks can monitor the risk level of borrowers and charge a loan rate with a risk premium due to the economies of scope. Banks also need to pay a deposit rate to depositors. Here, we define the interest margins as the difference between the loan rate and deposit rate

(Heffernan, 2005). What will happen if the volatility of interest rate could make costs of short-term funding higher than interest incomes from long-term loans? In this case, a higher interest margins will be required to cover additional costs including operation costs, intermediation fees and risk premiums (Ho and Saunders, 1981). And, in order to maximise returns at lower costs, banks may increase non-traditional activities - such as investment banking, venture capital, security brokerage, insurance underwriting and asset securitization - to offset the losses of traditional bank actives, which bring more diversification as well as high risk (Valverde and Fernandez, 2007). In the past three decades, the banking industry has showed a trend to the diversification of financial services and consolidation of financial institutions, especially prior to the financial crisis in 2007/08.

The Gramm-Leach-Bliley Act was proposed in 1999 in the United States, which allowed banks to engage more freely in providing more non-traditional activities (Mishkin, 2002). Modern economists believe that a large number of new lines of non-traditional financial services cause higher risk-taking, thus further tiger bank failure and financial instability (Stiroh, 2006; Saunders and Walter, 1994; Welfens, 2008). In contrast, some other academic studies to look at the question (e.g., Fahlenbrach *et al.*, 2011; Cole and White, 2012) concluded that the causes and nature of banks' financial weaknesses during the recent subprime mortgage financial crisis were similar to those observed at banks that failed or performed poorly during previous banking recessions. Banks that engaged in risky non-traditional activities also tended to take risk in their traditional lines of business, suggesting that deregulation was neither a necessary nor a sufficient condition for bank failure during the crisis.

Move to U.S. banks' balance sheet data. Figure 1 presents net interest income for commercial banks in United States from 1992 to 2014. Figure 2 shows the non-interest income to total income for U.S. banks from 1998 to 2013. Figure 3 displays net income for commercial banks in United States from 1984 to 2014. Overall, all three figures increased significantly before the end of year 2006. Net income for commercial banks then experienced a sharp decline in bank returns in 2007 due to the financial crisis and it reached the bottom in 2010. There was a dive in non-interest income at the beginning of year 2007,

which is consistent with the situation of financial markets. However, the decline of net interest income was mild and happened around 2010 (post crisis period). Thus, from those on-balance data, there's no strong evidence showing all U.S. banks moved completely away from traditional activate to non-traditional services to achieve higher income. The reason for this might be the serious regulation that restricted the establishment of branches (Hagen, 2005; Mishkin, 2002; Saunders and Walter, 1994; Welfens, 2008). In the United States, although a large number of financial institutions had existed since the 1980s, the number decreased due to a national consolidation through which banks could increase their size in order to benefit from the economies of scale (Mishkin, 2002). It also maybe some banks considered the switching costs from traditional bank activities to new activates, therefore they still focus on traditional services but make an effort to improve the efficiency of financial operations (Cole and White, 2012; Stiroh, 2006). Thus, in these cases, banks have more incentive to become large through consolidation in order to benefit from economies of scale (Canals, 2006; Dinger and Hagen, 2005). This leads to a discussion of the impact of bank sizes on bank risk level.

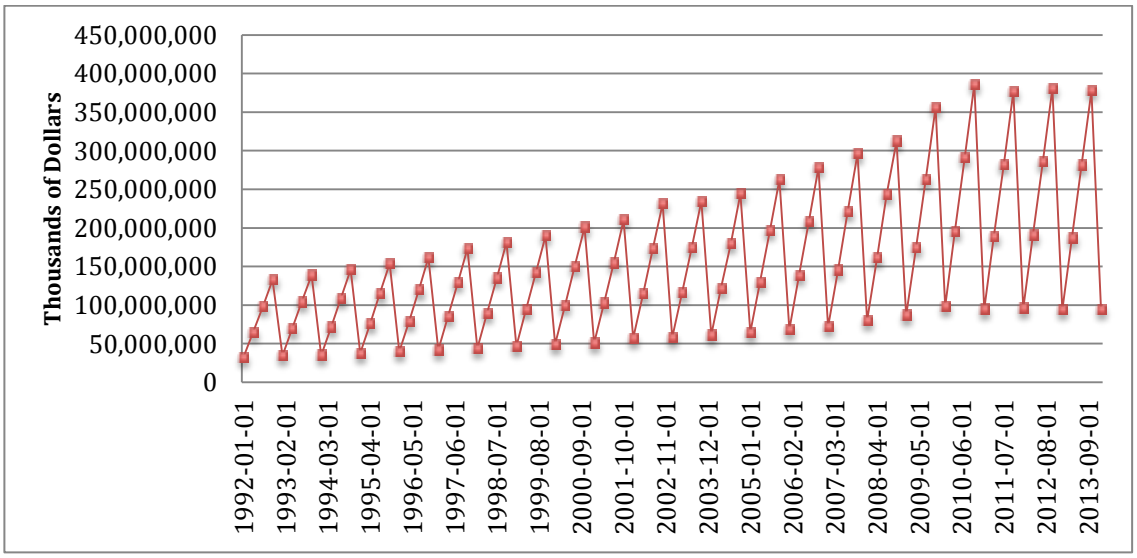

Figure 1: Net Interest Income for Commercial Banks in United States from 1992 to 2014

Source: OECD, The Federal Reserve Bank of St. Louis

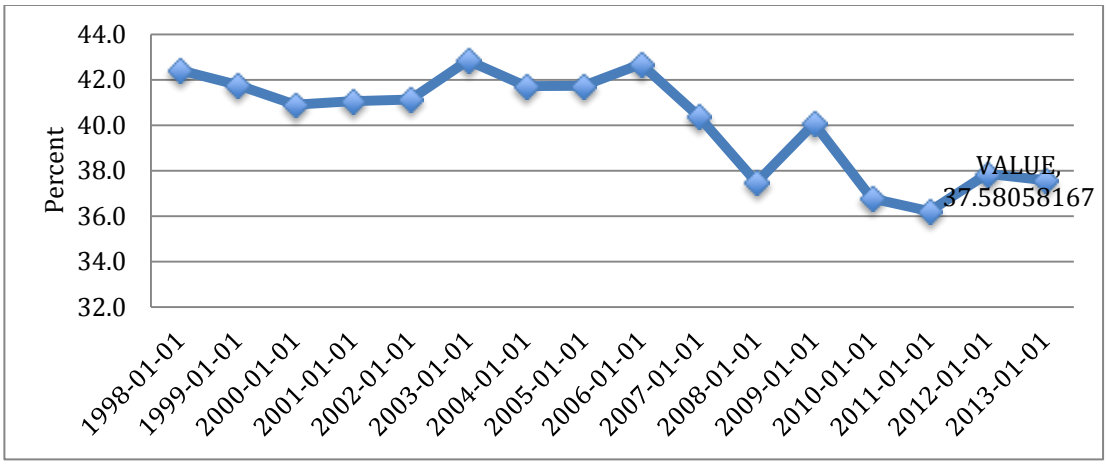

Figure 2: Non-Interest Income to Total Income for US banks from 1998 to 2013

Source: OECD, The Federal Reserve Bank of St. Louis

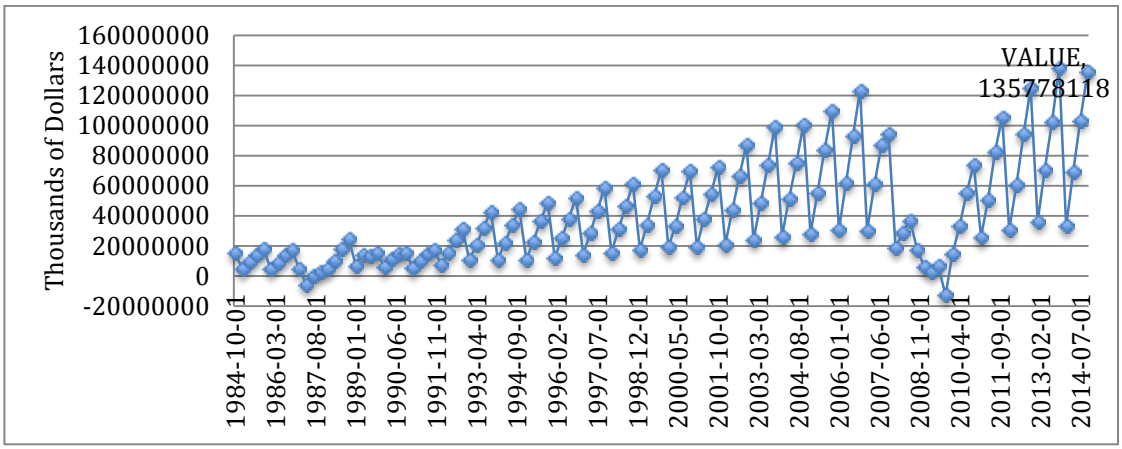

Figure 3: Net Income for Commercial Banks in United States

Source: OECD, The Federal Reserve Bank of St. Louis

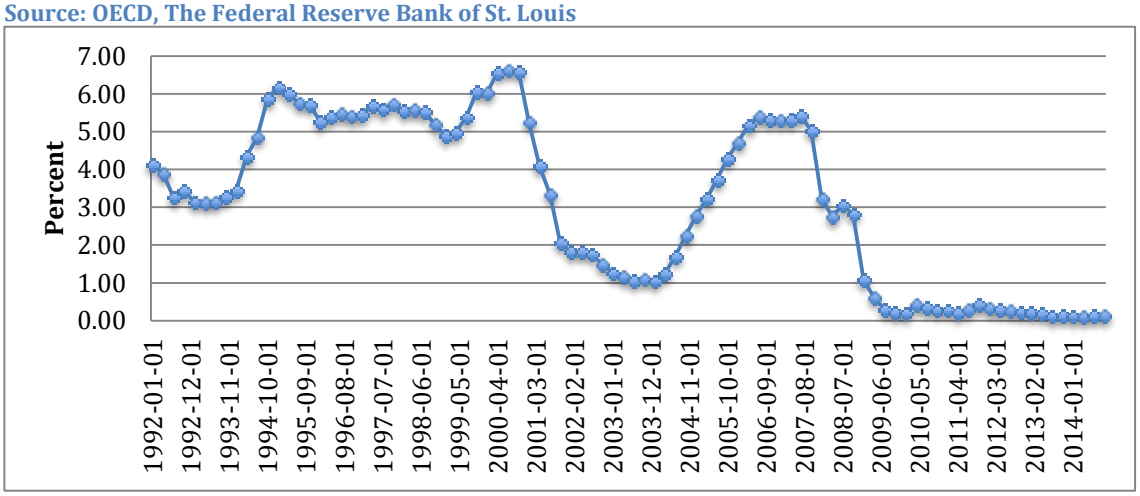

Figure 4: 3-Month Interbank Rates for the United States from 1992 to 2014

Source: OECD, The Federal Reserve Bank of St. Louis

Another core service provided by banks is a liquidity service (Heffernan, 2005; Matsuoka, 2012). Banks bridge savers and borrowers with their different liquidity preferences. For example, a bank lends funds to a firm which is commonly financed by deposits; while, the maturity of those deposits might be shorter compared to loans. In this case, the liquidity preferences of borrowers and savers are simultaneously satisfied through bank services. Moreover, interbank market works as the most immediate liquidity source within banks (Castiglionesi, Feriozzi, Lóránth, and Pelizzon, 2014); and the overnight interest rate can be a core indicator of market risk (Allen, Carletti, and Gale, 2009; Iori *et al.*, 2008).

In a downturn, insufficient bank liquidity could lead to inadequate allocation of capital, which increases a higher interbank rate as well as a higher market risk level (Iori *et al.*, 2008; Matsuoka, 2012). Figure 4 documents 3-Month Interbank Rates in the United States from 1992 to 2014. It plunged twice over the time: one happened in 2001 ('The early 2000s recession', which affected the United States in 2002 and 2003) and another one was around 2007 (Subprime Crisis 2007-2008). The later one as an example here: a decline of the interbank rate can be observed in late 2006 (even during the financial crisis period from 2007 to 2008) in order to support the refinance of problematic banks through the interbank market; while it slightly increases around middle of 2009 after the period of the 'panic of 2008', following the scenario in the financial market that banks demanded a higher interest rate due to a high level of uncertainty about the future availability of liquidity and fearing insolvency of their counterparts. It did decrease by the end of year 2007 due to the US government interventions. However, funding markets experienced significant distress again during the fall of 2008 after Lehman Brothers and AIG failed, and Fannie Mae and Freddie Mac were placed under conservatorship. As Gorton (2009) argues, the financial crisis resembled a banking panic that took the form of a run of financial institutions on other financial firms. The panic centered on the repurchase agreement market, which suffered a run when lenders withdrew their funds by declining to roll over their loan agreements, and by raising their repo haircuts. This created an indiscriminate distrust of counterparties to any financial transactions. Concerned about the size and location of the exposure to subprime-related assets, banks stopped lending to other banks, and decided to hoard liquid buffers.

Bank regulation also plays key role in development of the banking industry. According to the Basel Capital Accord proposed in 1988 and 2004, banks were required to increase the amount of capital holding against potential risk-taking. To be "well capitalized" under the Basel definition, a bank holding company must have a Tier 1 ratio of at least 6%, a Tier 1 Leverage Ratio of at least 5%, a CAR ratio (combined tier 1 and tier 2 capital) of at least 10%, and an Equity Capital to Total Asset Ratio of at least 4% to 6%, and not be subject to a written agreement to maintain a specific capital level. In the United States, according to FDIC guidelines for an "Adequately Capitalized institution", a bank is expected to meet a minimum requirement of qualifying Tier 1 Leverage Ratio of 4.0%, total risk-based ratio of 8.0%, of which at least 4.0% should be in the form of Tier 1 core capital. From the figure 5 below, Equity Capital to Total Asset Ratio fluctuated all the time and it was much higher than that of their required minimum level during the past 19 years. Despite certain mild fluctuations, it experienced a gradual and lasting rise before year 2007, which was approximately 10.0%; and then from then on, they decrease constantly, hitting 9.6% in late 2009. It failed in signaling the recent financial crisis.

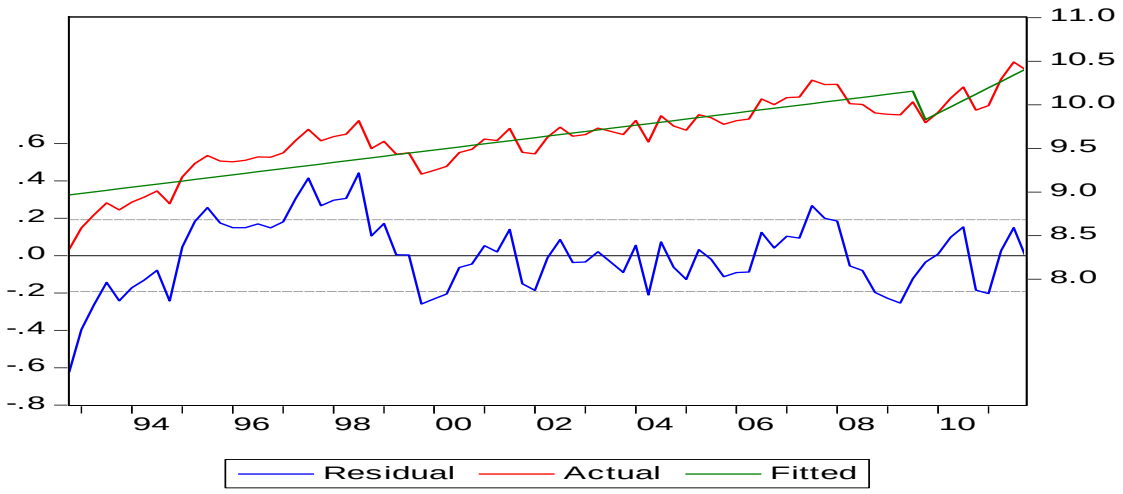

Figure 5: The Equity Capital to Assets ratio in the U.S., from 1992Q4 to 2011Q4

1.2 Research Motivation

The main motivation for this study stems from the recent subprime mortgage crisis in 2007-08, which was characterized as one of the worst credit crises since the Great Depression (Mishkin, 2008). The crisis of 2007-2008 echoes earlier big international financial crises with many similarities to those of the past which were all triggered by events in the U.S. financial system; including the crises of 1857, 1893, 1907 and 1929-1933. However, it also has some important modern twists. The panic in 2007 was not like the previous panics, in that it was not a mass run on banks by individual depositors, but instead of a run by firms and institutional investors on financial firms. Reflecting the high costs of banking crises and their increased frequency, banking sector stability has increased attention in policy discussions in past decade.

One of key questions emerging from those discussions is how to best identify an impending crisis, so that appropriate measures can be taken well in advance. Various studies have proposed early warning indicators of impending turmoil in banking systems (e.g., Alessi and Detken, 2011; Demirgüç-Kunt and Detragiache, 1998, 1999, 2005; European Central Bank, 2005; Frankel and Saravelos, 2012; Hardy and Pazarbaşioğlu, 1998; Hutchinson and McDill, 1999; Hutchinson, 2002; Kaminsky and Reinhart, 1999; Laeven and Valencia, 2012; Reinhart and Rogoff, 2009; Schularick and Taylor, 2011; Simaan, 2017; Taylor, 2013). However, full agreement on how to measure systemic banking problems and which explanatory variables to include has not yet been reached. Therefore, given the common threads that tie together apparently disparate crises, it can be useful to take a step back from the practical imperatives of maximizing goodness of fit and instead consider the conceptual underpinnings of early warning models. It is interesting to see whether a set of aggregate bank accounting ratios is sufficient to explain the emergence of a banking crisis? If so, additionally, we investigate whether these ratios convey important information on the timing of financial crises. This is the first motivation of this thesis. More specifically, we examine a broad set of balance sheet indicators for early warning purposes, and assess their relative likelihood of success.

In addition, the contagion risk in this financial event has been emphasised, since the failure of a bank may result in a banking panic, especially in the context of the interbank markets (Fourel *et al.*, 2013; Karas and Schoors, 2013; Krause and Giansante, 2012). The current research arising from this area is manifold; but, the banking systems in those network models as developed so far are free of any actual dynamics. By consequence, scarce previous literature have considered the possibility that the banks could make preemptive actions to protect themselves from a common market shock and therefore affect the propagation of losses through the banking system. For example, how interbank loans are granted, extended, and /or withdrawn in response to a financial crisis with the high level of uncertainty and increased counterparty risk during the financial crisis. Therefore, my second purpose of our study is to investigate how the actual behaviors of banks contribute to or mitigate the onset of a banking crisis. We investigate real banks' preemptive actions by looking significant structural shifts of banking ratios in response to the crisis at aggregate bank-level; even if the interactions themselves are unknown, we are aim to understand how banks react during the recent financial crisis.

What's more, interbank markets are a critical element of modern financial system (Iori *et al.*, 2008). Within the United States, interbank market is usually one of the most liquid aside from short-term U.S. government borrowing market. More particularly, as one of the most important but vulnerable systems in the whole economy, over the last 20 or so years, there has been a significant growth of interest in the question whether the U.S. interbank markets amplifies shocks to the whole banking sector or individual banks.

Through the interbank market, banks can coinsure against idiosyncratic liquidity risk by reallocating funds from those with an excess to others with a deficit (Allen, Carletti, and Gale, 2009; Angelini, Nobili and Picillo, 2011; Castiglionesi, Feriozzi, Lóránth, and Pelizzon, 2014; Gorton and Metrick 2009). However, it was predicted according to some recent economic theoretical models that the interbank lending market would freeze at the beginning of summer of 2007 just following the bankruptcy of Lehman Brothers as it did during the Asian banking crisis of the late 1990s. This may impose adverse implications on the whole financial system as it could be contagious and spills over from one to the others.

Therefore, Central bank as a lender of last resort (LLR) must conduct large-scale interventions to prevent a large scale of economic deterioration under this circumstance (Bagehot, 1873). However, the observed evidence in the Fed funds market in the immediate aftermath the collapse of Lehman Brothers did not support the hypotheses above. In addition, the run on Northern Rock very likely reflected not the failure of the Bank's lender of last resort policy but inadequacies in the UK's provision of deposit insurance, the ill thought out separation of financial supervision and regulation from the central bank and political pressure (Milne and Wood, 2008). On the other hand, a moral hazard problem is generated from LLR intervention: it encourages al banks to make an effort to be large by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail); while, the expansion of bank activities, especially non-traditional activities, may increase risk. Given that Central bank as a lender of last resort (LLR) might fail in conducting large-scale interventions to prevent a large scale of economic deterioration under this circumstance, we are interested at answering following two questions: How the actual behaviours of banks in interbank market contribute to or mitigate the onset of a banking crisis? Does an increase in interbank lending lead to higher risk-taking of banks, particularly considering the bank size effect?

In addition, in the absence of a well-functioning interbank market, idiosyncratic liquidity risks may be hard to coinsure against (Castiglionesi *et al.*, 2014), leading to credit rationing, liquidity hoarding for self-insurance, and higher funding costs. As a result, a large number of financial institutions found it increasingly difficult to access interbank funding and manage their liquidity risk: the number of lenders in the Federal funds market fell from approximately 300 in the summer of 2008 to 225 after Lehman Brothers' default, and the Fed funds rate experienced a one-day jump by more than 60 basis points on September 15, 2008, the date on which Lehman Brothers filed for bankruptcy (Afonso, Kovner, and Schoar, 2011). However, previous studies on the liquidity hoarding and funding ability in the interbank market offer mixed results (Acharya and Skeie, 2011; Castiglionesi *et al.*, 2014; Cornett *et al.*; 2011; McAndrews, Sarkar, and Wang, 2008; Taylor and Williams, 2009), motivating us to conduct a further study in this area; which would allow further proposal of more reliable policy implications.

1.3 Outline of the Thesis

This thesis combines three empirical studies on U.S. bank accounting ratios, interbank lending and liquidity hoarding. The empirical studies are based on U.S., including the run-up to the recent financial crisis 2007-2008, the episode of the crisis, and post stage of the crisis. In this research, the micro-level datasets used in this research are obtained from the FDIC call reports [1]provided by FDIC. The sample includes 16520 banks [2]and the time span has been restricted from fourth quarter of 1992 to the last quarter of 2011. The remainder of the thesis is organized as follows:

Chapter 2 firstly provides a brief overview of the financial crises and systemic risks; and then the current state of the literature on interbank market as well as the main empirical studies on the interbank lending are outlined. In what follows, we present recent literature on liquidity hoarding.

Chapter 3 starts by presenting research designs. Drawing upon a subset of aggregate U.S. bank accounting ratios from 1992Q4 to 2011Q4, in this study, Parametric and nonpararametric techniques are introduced to investigate the structural shifts of a set of bank ratios in response to the recent crisis. In what follows, we investigate whether those ratios convey important information on banks' preemptive actions. We also discuss the consequence of 'too big to fail' (TBTF) and show differences in the applicability of banking accounting ratios for the identification of banking problem between large and small banks.

The interbank market plays a role in risk-sharing between banks with credit linkages, however, contagion from one bank to the next could be propagated via the interbank

[1] In the United States, for every national bank, state member bank and insured nonmember bank, quarterly basis consolidated reports of condition and income are required by the FFIEC (Federal Financial Institutions Examination Council).

[2] 16520 is the total number of banks existed during the period of 01-09-1992 to 31-12 -2011. In total 16520 banks, some of them have been a failure, or been merged by other banks. To deal with mergers and acquisitions, in chapter 4 and 5, I drop bank observations with asset growth greater than 10 percent and winsorize variable at the 1st and 99th percentiles (13973 banks included).

markets, in Chapter 4, we examine how interbank lending affect the propagation of losses through financial linkages. Given that Central bank as a lender of last resort (LLR) might fail in conducting large-scale interventions, we also discuss the impact of interbank lending on bank risk-taking, particularly considering the bank size effect. Our empirical work in this chapter is based on the theoretical model introduced by Dinger and Hagen (2005) and our empirical results in previous chapter; here, we also consider the effect of policy of TBTF suggested by Freixas *et al.* (2000) in the context of U.S. interbank markets.

In Chapter 5, we examine the impact of the disruption of the interbank market on banks' liquidity creation and funding ability by splitting our whole sample into two subgroups: Net Lenders and Net Borrowers. We include the heterogeneity across different categories of liquid assets. We also propose two new on-balance proxies for banks' liquidity risk: the unrealized security loss ratio and the loan loss allowance ratio. Compared with previously suggested proxies for banks' liquidity risk-such as the proportion of unused loan commitments to their lending capacity-exposure to future losses in their balance assets represents more accurate measures of liquidity risk associated with the run in repo markets during the financial crisis. We use regression frameworks similar to that in Cornett *et al.* (2011).

In Chapter 6, we highlight a summary of the answers to the research questions, and indicate the main conclusions based on the empirical results. Our research contributes to the recent literature are discussed.

Chapter Two: Literature Review

2.1 Historical Crises

2.1.1 Three Historical Crises Before 1930s

First devastating slumps - starting with the America's first panic, in 1792, following with first a global crisis, in 1857, and ending with the world's biggest crisis, in 1929 - highlight two big trends in financial evolution.

In 1790, Alexander Hamilton, the first treasury secretary of the United States, wanted a 'state - of - the art' financial set up, like that of Britain; which meant American new bonds would be traded in open markets and the first central bank of the United States (BUS) would be publicly owned. It was an exciting investment opportunity. However, the expansion of credit by the new bank prompted massive speculation in bank shares and government debts by an Englishman William Duer and others. Rumours of Duer's troubles, combined with the tightening of credit by the central bank, led U.S. banking market into sharp descent.

Hamilton took American first bank bail out by using public fund to buy government bonds and pup up their prices, helping protected the banks and speculators who had bought at inflated prices (Sylla, 2007). All banks with collaterals were ensured sufficient borrowing at a penalty of 7%. From 1792 crisis, public firstly learnt that the products such as central banks, stock exchanges, and deposit insurances are cobbled together at the bottom of financial cliffs without a careful design.

By the middle of 1900s, the whole world was getting used to financial crises. Britain experienced on a one crash every decade rule: the crisis of 1837 and 1847 followed by panic in 1825-26. However, the railroad crisis of 1857 went differently: it was the first global crisis.Entranced by financial and technology innovation, British investors piled into rail companies whose earnings did not match up to their valuations. In late spring 1857, railroad stocks began to drop due to high leverage and overexposed. American financial

system had failed in October 1857. A shock in America Midwest tore across the country and spread from New York to Liverpool and Glasgow, and then London. Financial collapses jumped from London to Paris, Hamburg, Copenhagen and Vienna. It was more severe and more extensive than any crisis that had before (Garber, 2001; Kindleberger, 1986).

A Wall Street crash happened around year 1929 to 1933, which is the worst slump America had ever faced before (Calomiris and Gorton, 1991). Financial markets were booming in 1920s and stocks of firms exploiting new technologies, such as aluminium, were expected to continue to increase in value. However, at the same time, consumer prices fell and most of established businesses were weaker. The speculative boom of the roaring 20s came to end when the central bank raised interest rates in year 1928 to slow markets, and bank failures came in waves. Nearly 11,000 banks had failed between year 1929 and 1933 in USA. And eventually a fraud in London triggered a crash. De-risk the system was done by injecting massive public supplied capital. The Federal Deposit Insurance Commission (FDIC) was found on 1st January 1934 to manage bank runs once and for all. It took more than 25 years for Dow to reclaim its historical peak in 1929. Although the exact causal sources are often hard to identify, and risks can be difficult to foresee beforehand, looking back other financial panics are rarely random events. The large scale bank distress in the 1930s was traced back this way to shocks in the real sector. Banking panics more likely occur near the peak of the business cycle, with recessions on the horizon, because of concerns that loans do not get repaid (Gorton 1988; Gorton and Metrick, 2012). Depositors, noticing the risks, demand cash from the banks. As banks cannot (immediately) satisfy all requests, a panic may occur.

2.1.2 1931 German Crisis

The 1931 German crisis was a critical turning point in the great depression. Schnabel (2004) defined it as a twin crises- the simultaneous occurrence of a banking and a currency crisis.

It was primarily domestic in origin; and that the cause of failure was more political than economic (Ferguson and Temin, 2015). It was a currency crisis rather than a banking crisis in the first place. The vulnerable German banking system was struck by excess inflows and outflows of foreign capital (Adalet, 2003). Deposits were dominated by foreign currencies, and then investors lost confidence in Germany's ability to repay the foreign debt triggered by domestic political actions and international economy constrain. Germany defaulted on most of its foreign debt in 1932, following with highly restricted capital flows of which full convertibility was reach again until long after World War II (Schnabel, 2004). Banks suffered from reserve losses due to a run on the German currency and they turned to the Reichsbank (the central banks of Germany, from 1876 to 1945) for liquidity.

German banks, especially those highly interconnected large banks would adversely effect on the other financial intuitions and even the whole economy when they face potential failure. Therefore, the 'too big to fail' theory asserts that those banks must be supported by German government. However, the Reichsbank failed to act as the 'lender of last resort'. The banking and the currency crisis became increasingly intertwined as the crises went on at this stage. This twin crises imposed sever adverse effects on German economy: unemployment was over 4 million in 1932 (Schnabel, 2004). The 1931 Germany crisis had emerged as pivotal events in the propagations of the Great depression.

Banking crises are quite common, but perhaps the least understood type of crises. Financial institutions are inherently fragile entities, giving rise to many possible coordination problems (Dewatripoint and Tirole, 1994). Because of their roles in maturity transformation and liquidity creation, financial institutions operate with highly leveraged balance sheets. Hence, financial intermediations can be precarious undertakings. Fragility makes coordination, or lack thereof, a major challenge in financial markets. Coordination problems arise when investors and/or institutions take actions - like withdrawing liquidity or capital - merely out of fear that others also take similar actions. Given this fragility, a crisis can easily take place, where large amounts of liquidity or capital are withdrawn because of a self-fulfilling belief: it happens because investors fear it will happen (Diamond and Dybvig, 1983). Small shocks, whether real or financial, can translate into turmoil in

markets and even a financial crisis; and it have long been recognized, and markets, institutions, and policy makers have developed a number of defensive mechanisms. Although regulations can help, when poorly designed or implemented, they can increase the likelihood of a banking crisis- distortionary effects (Barth, Caprio and Levine, 2008). Moral hazard due to a state guarantee (e.g., explicit or implicit deposit insurance) may, for example, lead banks to assume too much leverage. Institutions that know they are too big to fail or unwind, can take excessive risks, thereby creating systemic vulnerabilities (Baldacci and Mulas-Granados, 2013; Laeven, 2011). For example, Ranciere and Tornell (2011) modelled how financial innovations can allow institutions to maximize a systemic bailout guarantee, and reported evidence supporting this mechanism in the context of the U.S. financial crisis 2007/08.

2.1.3 Savings and Loan Crisis

The Savings and Loan crisis happened in America of its 1980s and 1990s, which is not systemic banking crisis. Savings and Loans associations (S&Ls) are known as 'building societies' in U.K. Like most of commercial banks, S&Ls take deposits issue loans as well as making most of other financial activities. The deregulations of S&Ls in 1980s gave them more capabilities. Although it was hard to identify the control fraud, about thirds of Savings and Loans associations were technically insolvent in 1980s (Hellwig, 2009).

Felsenfeld (1990) demonstrated that the main cause of this crisis was the interest impairments happened among those Savings and Loans associations: the real cost paid for to access to their deposits is much higher than the profit they earned. They had held a large amount of mortgages, which issued to households in 1960s with same maturities if around 40 years at fixed rates of interest, typically around 6%. At the same time, the interest rate S&Ls had to pay their depositors had raised to above 10% due to the high inflation in late 1970s. In order to cover this discrepancy in their annual balance sheets, those S&Ls acted more imprudent in real estate lending, which made them are more vulnerable to defaults and bankruptcies (Reinhart and Rogoff, 2009).

The number of Savings and Loans associations jumped from 3,234 to 1,645. And it ended up with a large budget deficit of US in the early 1990s due to the bailout plan for those insolvent Savings and Loans associations. It was accumulated to about 124 billion dollars of a net loss to taxpayers by the end of 1999 eventually (Curry and Shibut, 2009). These crises imposed serious adverse impacts on America financial system, however it is not systemic. An individual failure ended within the financial intuition itself, but did not spread to others banks; also the crisis did not tear across other sectors, making them more vulnerable. One possible explanation of this is banks were better regulated and governed than S&Ls were.

2.1.4 Scandinavian Banking Crisis

The Norway, Swedish and Finland banking markets crashed in the late 1980s and the early 1990s after a spate of deregulation caused a rapid rise in credit upswings which subsequently triggered a bubble burst in real estate prices.

They were initiated by bank deregulation: a sustained increase in asset prices that unwarranted by their fundamentals results from overly rapid credit expansions (Englund, 1999). Finally, at some point, the bubble burst. The failure in real estate market spread to the banking markets via the credit linkages between banks and firms. And thus, Scandinavian economies experienced even larger widespread bankruptcies and a severe reversal of country- specific credit cycles after a shift towards a tightening policy of monetary in Sweden and Finland. Huge deleveraging followed the lending boom of the 1980s in Scandinavia. Eventually, the financial sectors were struck by a banking crisis interacted with a currency crisis.

The first economy to turn down was Norway. More severe macro downturns followed, especially in Finland, which was more than twice what was occurred in Sweden and Norway. For Sweden, this crisis cost all taxpayers around 2% GDP directly (Englund, 1999), while the government budget deficit reached 10% of GDP by 1994 (Persson, 1996). The governments ultimately had no choice but to intervene dramatically to save the

banking systems: significant injections of capital into the financial systems, the abandonment of currency pegs, and recapitalizations of banks.

2.1.5 Introduction of the Crisis of 2007-2008

The question of what happened in the financial crisis started in 2007, though the most basic and fundamental of all, seems very difficult for most people to answer. In this section, we will attempt to address this question by beginning with an overview.

The recent crisis started in the U.S. with the collapse of the subprime mortgage market in early 2007. Lax regulatory oversight, a relaxation of normal standards of prudent lending and a period of abnormally low interest rates, and etc.: all of these had contributed to the housing boom (Bordo and Haubrich, 2012; Delis, 2012). Households were stimulated to purchase house on mortgages in the boom of housing bubble, and they became speculative by obtaining subprime mortgages as they were confident that houses would continue to appreciate. At the same time, investment banks and hedge funds issued large amount of debt and invested the proceeds in mortgage-backed securities(MBSs), hoping the house prices to rise in order to keep high profiability on balance sheets (Welfens, 2008). However, the housing bubble started to burst, borrowers found it more difficult to refinance their periodic payments for mortgages (Beck, De Jonghe, and Schepens, 2013). Defaults on a remarkable proportion of subprime mortgages caused spill-over effects over the world via the securitized mortgage derivatives into which they were bundled, to the financial statements of investment banks, hedge funds and conduits[3]that worked as intermediators between mortgages and other collateralized commercial paper. The uncertainty of the value of the mortgages backed produced uncertainty soundness of the loans. All of this resulted in the freeze of the interbank market around August 2007 and thus substantial liquidity injections subsequently by the Federal Reserve and other central banks (Welfens, 2008). It also spilled over into the real economy through a virulent credit crunch which has been the most likely cause of a significant recession.

[3] Conduits are bank-owned entities but off their balance sheets.

The most of the central banks, like the Fed, have responded in a classical way via flooding the financial markets with liquidity to improve bank system solvency, and bailed out some templates like the Reconstruction Finance Corporation in the 1930s, Sweden in 1992 and Japan in the late 1990s (Welfens, 2008). Since then the Fed both extended and expanded its discount window facilities and cut the funds rate by 300 basis points. However, it worsened in March 2008 following the rescue of the Investment bank-Bear Stearns-by JP Morgan Chase pushed through by the Federal Reserve. A number of new discount window facilities with broadened collaterals which investment banks could access were created after the March crisis. A Federal Reserve Treasury bailout and partial nationalization of the insolvent GSEs, Fannie and Freddie Mac were justified in July on the grounds that they worked significant functions in the mortgage industry (Delis, 2012). In September 2008, it took a turn for the worse when the Treasury and Fed allowed the investment bank, Lehman Brothers, to fail which broke up the traditional beliefs that "all insolvent institutions would be saved in an attempt to prevent moral hazard. It was argued that Lehman exposure to counterparty risk less extensive but in worse shape than Bear Stearns. Although it was initially rejected by the Congress a week ago, the bill of the Troubled Asset Relief Plan (TARP) worth up to $700 billion, sponsored by the US Treasury was finally passed in the midst of continued financial turmoil by the encourage of senate. This was devoted to purchase of heavily discounted mortgage backed and other securities to remove them from the banks' financial positions and restore bank lending (Heffernan, 2005; Delis, 2012). The following day the authorities nationalized the insurance giant, AIG, to avoid the systemic consequences for collateralized-default swaps [4]if it were allowed to fail.

The fallout from the Lehman bankruptcy then spilled the liquidity crisis over into the global financial markets as interbank lending effectively seized up, on the fear that no banks were safe. In early October 2008, the crisis spread to Europe and to the emerging countries as the global interbank market ceased functioning. The UK and EU governments responded in kind by pumping equity into their banks, guaranteeing all interbank deposits and providing massive liquidity. Then on 13th October 2008, the US Treasury injected another $250

[4] They are insurance contracts on securities.

billion into the banks, to provide insurance of senior interbank debt and unlimited deposit insurance coverage for non-interest bearing deposits. Time has shown that most of these plans are similar to earlier, mainly successful, rescue templates like the Reconstruction Finance Corporation in the US in the 1930s, the Swedish in the 1992 and Japanese rescues in the 1990s mentioned earlier, and may solve the solvency crisis.

The crisis of 2007-2008 echoes earlier big international financial crises with many similarities to those of the past which were all triggered by events in the U.S. financial system; including the crises of 1857, 1893, 1907 and 1929-1933. There is more historical evidence to be viewed (Heffernan, 2005). Figure11 describes a picture over the past century: the upper panel from 1953 to December 2009 indicates the monthly spreads[5]- a measure of credit risk as well as information asymmetric (Mishkin, 1991). Figure 7 displays a longer period view of the Baa[6] corporate bond rate and the ten-year TCM rate from 1921 to September 2008. Also, National Bureau of Economic Research (NBER) recession dates (proxies by vertical lines in the figures) and major financial market events such as stock market crashes, financial crises, and some major financial market relevant political events are marked in both figures. The lower panels of both Figures represent policy interest rates - the Federal funds rate for early 20th century and the discount rate since 1921 respectively. From the upper panel of figure 6, the peaks are often lined up with the upper turning points in the NBER reference cycles. Moreover, in many cases, especially the 1930s banking crisis, most market stock crashes happened close to those peaks. The tightening of policy before the bust and loosening in reaction to the oncoming recession afterwards can be observed as well. It can been learnt in the recent crisis: in September 2008, the spread hits the level comparable to that reached in the last recession 2001-02 and above that of the credit crunch of 1990-91. It was just below the spreads in the early 1980s recession after the Volcker shock and President Carter's credit restraint program. All of these events were associated with significant recessions.

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[5] It is the spread between the Baa corporate bond rate and the ten-year Treasury constant maturity (TCM) bond rate.

[6] Credit rating is a financial indicator to potential investors of bonds, which are assigned by credit rating agencies such as Moody's, S&P and Fitch rating. Moody's assigns bond credit rating of Add, Aa, A, Baa, Ba, B, Caa, Ca, C with WR and NR as withdrawn and not rated.

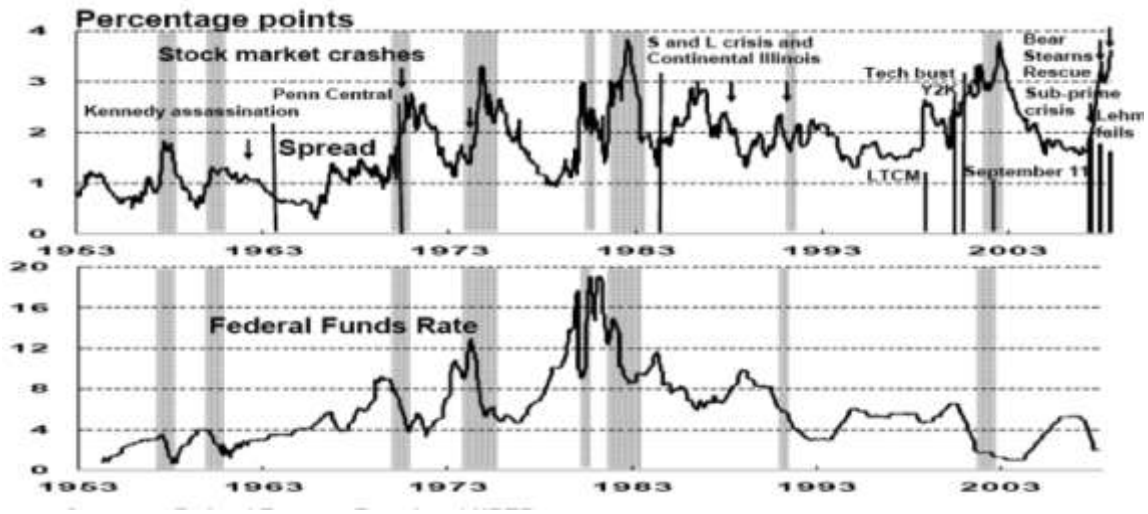

Figure 6: Federal funds rate and the spread between the Baa corporate bond rate and 10-year TCM bond rate (Bordo, 2008)

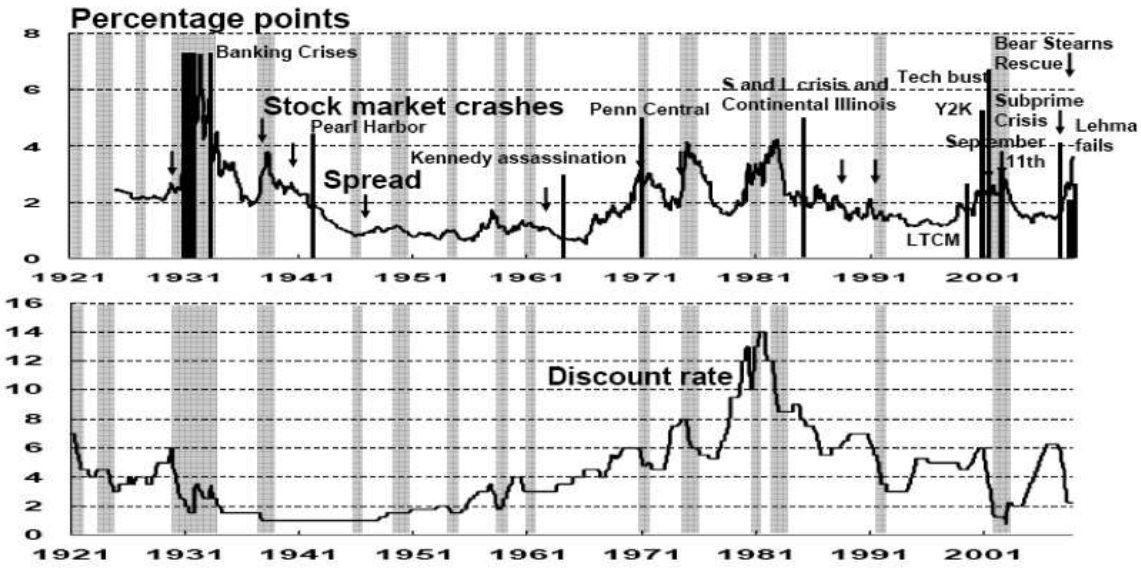

Figure 7: Discount rate and a monthly spread between the Baa corporate bond rate and the long-term composite rate[7] (Bordo, 2008)

Much has been written about the causes of the recent crisis (e.g., Calomiris, 2009; Claessens *et al*., 2012; Feldstein, 2009; Gorton, 2009; Teslik, 2009). While observers differ on the exact weights given to various factors, the list of factors common to previous crises is generally similar. Four characteristics often mentioned in common are: (i) asset price increases that turned out to be unsustainable; (ii) credit booms that led to excessive debt

[7] It is unweight average of bid yields on all outstanding fixed-coupon bonds neither due nor callable in less than 10 years.

burdens; (3) build-up of marginal loans and systemic risk; and (iv) the failure of regulation and supervision to keep up with financial innovation and get ahead of the crisis when it erupted. Those countries that had experienced the greatest increases in equity and house prices during the boom found themselves most vulnerable during the crisis. For example, Reinhart and Rogoff (2008) demonstrate that the appreciation of equity and house prices in the U.S. before the crisis was even more dramatic than appreciations experienced before the post-war debt crises.

However, it also has some important modern twists. The panic in 2007 was not like the previous panics, like the crisis of 1907, or that of 1837, 1857, 1873 and so on, in that it was not a mass run on banks by individual depositors, but instead of a run by firms and institutional investors on financial firms. Because it was not observed by anyone, including regulators, politicians, and the media and so on, other than those trading or otherwise involved in the capital markets because the repo market [8] does not involve ordinary Americans, but firms and institutional investors. This has made the events particularly hard to understand.

There have been a number of previous crises where banks as the credit intermediaries in financial market played a crucial role such as Spain in 1997, Norway in 1987, Finland in 1991, Sweden in 1991 and Japan in 1992, Australia in 1989, Canada in 1983, Denmark in 1987, France in 1994, Germany in 1977, Greece in 1991, Iceland in 1985, Italy in 1990, New Zealand in 1987, United Kingdom in 1974,1991,1995, United States in 1984, and Asian banking crisis from 1998 to 1999. Credit intermediation, in the traditional banking system, occurs between savers and borrowers in a single entity. Savers entrust their savings to banks in the form of deposits, which banks use to fund the extension of loans to borrowers. On one hand, relative to direct lending (that is, savers lending directly to borrowers), credit intermediation provides savers with information and risk economies of scale by reducing the costs involved in screening and monitoring borrowers and by facilitating investments in a more diverse loan portfolio. On the other hand, when the savers lose confidence in a bank, they withdraw their deposit from the bank and if everyone does

[8]The repo market is the place where the liabilities of interest are sale and repurchase agreements.

that, there will be a run on that bank and finally lead to the breakdown of the whole banking system (De Gregorio, 2013; Pozsar *et al.*, 2012).

The risky side of the credit intermediation for banks is one of the reasons to explain the fragility of the financial market. Since the activities and profitability of banks are regulated, on one hand, there will always be other institutions replacing the role of banks as the credit intermediaries to some extent, considering the credit demand of the financial market. On the other hand, regulations, for instance about the "Credit Risk Transfer" in Basel II allowed lower capital requirements for banks if they could transfer their credit risk to the third party such as non-bank financial institutions (FIs). In this way, non-bank FIs actually do provide credit intermediation as well as risk transfer.

However, non-bank FIs do not absorb deposits to be the guarantee of their capital as banks do and conduct higher risk activities to create infinite credit and transfer unlimited risk due to the lack of proper regulations. In addition, financial liberation and globalisation have connected the distinct institutions, nations and markets in an unprecedentedly close relationship. Therefore once a single or a few non-bank FIs with potential high risks fail due to an extreme event, banks will be immediately involved by the interconnections, and thus banks and non-banks altogether would pose panic to the whole financial market. For example, during the fall of 2008, some mutual funds "broke the buck" when their net asset value fell below par. This triggered sharp outflows from individual investors and many other mutual funds (Wermers, 2012). This "run", in turn, led the government to provide a guarantee against further declines. These guarantees constituted a continued source of fiscal risk as the government might be forced to step in to prevent a run again. Other investment vehicles specializing in specific asset classes in emerging markets also experienced sharp outflows as there was a general "flight to safety". There were more demand for advanced countries' government bonds and T-bills. More generally, the Subprime mortgage crisis 2007/08 has been interpreted by many as a widespread liquidity run (Gorton, 2009; Pozsar *et al.*, 2012).

2.2 Systemic Risk: Recent Theoretical and Empirical Literature

The global crisis 2007/09 has shown how a shock that originates in one country or asset class can quickly propagate to other markets and across borders: the nature of the balance sheet linkages between financial institutions and markets will affect the size of spill overs and their direction of propagation (Abiad *et al*., 2013). With fast globalization, however, financial linkages and channels of propagation are more complex. Much of the data needed for identifying and tracking international linkages, even at a rudimentary level, is not yet, and the institutional infrastructure for global systemic risk management is inadequate or simply non-existent. Therefore, systemic risks command much attention as the preoccupation of the banking industry. The objective of this part is to review different forms and originals of systemic risks.

2.2.1 Systemic Events and Systemic Risk

In order to reach a definition of systemic risk in financial system, we firstly clarify a definition of a systemic event. Then, the various notions of system risk will be introduced as follows. According to Bandt and Hartmann (2000), they define a systemic event both in the narrow sense and in the broad sense. In a narrow sense, a systemic event is defined as an event, where a bad shock affecting a certain or some random financial institution(s) or market(s) leads a chain reaction to affect others or whole markets. Another one follows an event, where a macro-economic shock simultaneously causes a shared negative reaction among the large scales of the financial institutions and markets. In both cases, contagion plays a core role in spreading a systemic event and turning it into a financial crisis, which can be reacted as a bank run, a decline in credit, a dramatic drop in financial asset prices, and so on. There are various nations of systemic risk. First of all, based on the two types of systemic events proposed by Bandt and Hartmann in 2000, systemic risk is defined as the threat engendered by one or several systemic events that can trigger repercussions, and then can become a financial crisis.

Another approach views crises as random events that are unrelated to types of economic development. This entails self-fulfilling beliefs (Diamond and Dybvig, 1983).

Here, expectations play a crucial role in determining whether a systemic event might occur. A co-ordination issue is raised by the existence of expectations that may develop, for example, because of a signal that from the very outset might be independent of those economic variables that can actually influence financial fragility. The signal connects to the situation in which the financial institutions actually find themselves might also be an imperfect one. In any event, co-ordination around this signal brings the financial system to an equilibrium that may be rational at an individual level but which is socially harmful. The problem of co-ordination thus raises the possibility of multiple equilibriums, or at least of a whole array of states that can characterize a variety of financial situations. Financial fragility is described by this possibility of multiple equilibriums. Nevertheless, co-ordination around crisis equilibrium is a fortuitous occurrence. A run on the banking system will take place if people do indeed panic, but it won't if they don't (as long as the banks are able to satisfy "normal" withdrawal needs).

With the respects to the macroeconomic side, Aglietta and Moutot (1993) defined systemic risk as the risk that may shift an economy from a "normal" equilibrium to an "abnormal" condition characterized by severe damage. Similarly, Minsky (1982) considers that financial crises are related to the economic cycle, in which case the events that initiate them are endogenous. Here crises are part of a dynamic that leads to the materialization of economic instability. In the financial system, it also can be defined as the likelihood that customary types of disturbances, which may cause disproportionately, negative after-effects if they happen in fragile financial systems [9](Davis, 1995). He also points out that financial fragility depends on the endogenous interaction between credit and asset values during the course of the economic cycle. This process does not revolve around the notion of multiple equilibriums. It is possible to have financial dynamics that unavoidably lead to crisis equilibrium. According to his study, particularly, financial fragility is the interdependency of those behaviors that can engender instability (i.e., it is a dynamic that causes a crisis).

[9] Financial fragility is the arena in which shocks become systemic events. It leads to externalities in the transmission of shocks, externalities that can provoke non-linearity (i.e. a cumulative strengthening of and discontinuity in) the ensuing shifts (Hellwig, 2009).

All in all, diverging perceptions of the systemic events that trigger such processes lead to formal differences in the crises' representation. However, the hypothesis of fragility is essential in all approaches.

2.2.2 The Financial Fragility Hypothesis and Systemic risk

Based on the definitions of systemic risk, the initial thinking for a framework of systemic risk related theories is to develop at least one hypothesis as to "why certain financial relationships are structured in such a fragile manner". A large number of systemic risk models are distinguished by the using of the different hypothesis of fragility. Their main contribution to describing the way in which a harmful shock is propagated can be denied; however, to understand the nature of shocks that striking fragile systems is also important, in order to distinguish main approaches to the origins of financial crises (Gale, 2000). Now, let us go back the hypothesis of financial fragility; two main factors drive financial fragility: liquidity and the asymmetry of information.

Liquidity is mainly related to models with multiple equilibriums as the liquidity of a financial intermediary or of a market that originates in a problem of co-ordination. As a starting point for a number of extrapolations, the basic model used by Diamond and Dybvig defines a crisis as a run on bank deposits; which is originated from a microeconomic conception of banking, as any agent who agrees to transform its liabilities into currency unconditionally and at a fixed-price; whilst convert its liabilities into illiquid assets. The unconditional nature of this promise makes the bank to apply a process of 'first come, first served'. Financial panic stems from self- referential beliefs by individual depositors that other depositors will prematurely attempt to make a withdrawal simultaneously. However, the liquidity-related co-ordination exclusively in terms of the deposit agreement[10], neglects the role of the financial markets. It only explains a run on a single bank, not contagion throughout the financial system.

[10] Here, the deposit agreements are used by economic agents to protect themselves from the uncertain nature of the demand for liquidity.

Contagion from one bank to the next is propagated via the interbank markets (Rochet and Tirole, 1996; Allen and Gale, 2001); which has been manifested in the settlements systems (Freixas and Parigi, 1998). The interbank market reapportions excess liquidity towards other banks that may have shortages only in case of no overall excess demand for liquidity, as interbank deposits cannot increase the aggregate liquidity. The lender of last resort will be the only solution if the interbank market fully freezes. If this lender is apathetic, those banks who would be the first to experience difficulties with a large numbers of withdraw depositors, thus propagating fragility and spreading panic through the interbank market, especially where there is a chain of bilateral relationships in this market where the gross outstanding positions (rather than the net ones) are exposed to liquidity risk. In addition, the net amount based settlement systems can cause the chain reactions with blinding speed if those payments are not secured. Based on this, net multilateral positions need to be settled via the Central bank's clearing system to ensure that the final payments are indeed being made. As the price of being benefit from this collective service, those direct member banks in these secured systems must follow certain prudential constraints and agree to share in the losses in case one of them fails. In a continuous gross amount settlement system, systemic risk cannot be triggered by a chain reaction of failures payments. But, a freeze on settlements can spread via the financial linkages if one bank's inability to pay at a certain juncture puts other banks into the same situation at a later time. It may be possible to freeze settlements to preclude crisis equilibrium; therefore the central bank has to provide liquidity in the form of collateralised inter-day loans.

Although central banks can overcome liquidity-related co-ordination problems in the interbank settlement systems, the same does not apply to markets, at least not within a sphere of current financial organization; because markets have become (or have once again become) large-scale providers of liquidity (Davis, 1994). Yet a co-ordination problem results in market liquidity closely reliant on the expectations of future prices (Masson, 1999). Market liquidity is the key as banks sell their assets to meet uncertain liability-side withdrawals. However, Genotte and Leland (1990) argued that expected future prices would no longer be co-ordinated on the basis of the given security's fundamental value when there is doubt about market's liquidity. The fear of lower prices results in unilateral

selling and thus the drops of prices. It follows withdrawal from the market or else abstaining from buying by financial institutions. A panic equilibrium will be the result in extreme price volatility.

Although the issue of credit is not included in the aforementioned framework of financial fragility, it does play a crucial role in the second factor - the asymmetry of information - with its two corollaries, contrarian strategies and moral hazard (Mishkin, 1991). In particularly, the Asian crisis documented the change from an abundance of credit to an extreme rationing thereby forming a sort of discontinuity (Marshall, 1998). Treating financial fragility as a function of the economic cycle, there is the interaction between credit and the financial markets. During financial crises, a plethora of commentaries has been made on the significance of this interaction by those historians; such as financial deregulation and the shaping of a single capital market in Europe (Kindleberger, 1996).

Under this process, the asymmetry of the contract of indebtedness is the micro-economic foundation. The limited liability of debtors on the loans they have received constitutes to an asymmetrical configurations of profits and losses. The asymmetry of information is a consequence of the legal form under the assumptions of indebtedness. When investors leverage up to buy securities, they are transmitting partial downside risk to the lenders, whilst keeping all of the upside potential for themselves. During the credit expansion phase, this triggers financial fragility because the asset price produced is systematically higher than their fundamental value (Allen and Gale, 2001). Given that the credit expectation decides assets' future price and itself is something uncertain, the rise in the size of the bubble matches the rise in uncertainty. In the aforementioned configurations, a bubble can translate the existence of unrealistic profit expectations, and thus a slow credit growth rate may be enough to burst the bubble. Here it is a financial crisis. Inasmuch as the systemic event - the collapse in asset prices comes up with the problem of the possibility that they can be liquidated in order to reimburse debts.

Systemic risks would be considered only in a decentralized financial environment in which financial institutions create credit risks in their mutual transaction. And there are various

ways for banking regulator to prevent systemic risk. Traditionally, governments implicitly rescue insured distressed banks via discount loans, nationalization, and so forth. However, it may lead to substantial cross-subsidies from healthy financial institutions to frail ones through the government - mediated mechanism, it also bring out moral hazard problem. An alternative method of reducing the exposure to systemic failure would consist in a strict collateral requirement in derivative market. In this case, to what extent that the government would be affected by a bank failure in a centralized system depends on the constraints it puts on banks. Last, centralizing banks' liquidity management eliminates systemic risk. The central bank bears the credit risk if the banks defaults and the defaults cannot propagate to the other banks through interbank linkages. It guarantees the finality of payments in settlement systems.

2.3 U.S. Interbank Lending During the Crisis

2.3.1 Introduction of the Interbank market

Interbank market is a critical element in modern financial system. It helps banks meet large volumes funding liquidity requirements, and allows banks with a temporary surplus of cash to invest it reliably for period maturities from overnight to one year.

This market differs itself from other financial sectors due to its distinct policies for finding liquidity, its close unique relationship between financial institutional participants and its unique over - the - counter (OCT) structure. Also, interbank market is acting and central hubs for complex financial networks, connecting all financial institutions in banking sector (Iori *et al.*, 2008).

Inside the United States, interbank market is usually one of the most liquid aside from short-term U.S. government borrowing market: outstanding transactions to other banks averaged close to $440 billion in 2009. Interbank transactions mainly include overnight and term interbank loan in the Fed funds market or its equivalents, intraday debits on payment systems, and contingent claims in OCT market.

The interbank market is one of particular interest because the overnight rates (shortest term) are determined in this market; hence it has a significant influential power on the longer maturities rate. Overnight segment of interbank market is where banks look to mitigate any risk that driven from short-term liquidity short, and thus to ensure that trading day us closed with a balanced position. Here, the behaviour of the overnight interest rates emerges from the results of the rules and practices governing the refinancing operations run by central banks. The interest on interbank loans also is a critical guide for other type of loans and for the pricing stocks and bonds. For example, under Eurosystem, the way financial organizations behave in the interbank market is directly driven by the governances from the operational framework that created and enforced by the European Central Bank (ECB) for implementation of their monetary policies (Temizsoy *et al.*, 2015). For specifically, ECB uses four ways of operations to implement the policy: the main (MROs), structural operations, and longer-term (LTROs) refinancing operations as well as fine-tuning (FTOs) (Temizsoy *et al.*, 2015). In this way, the Eurosystem controls liquidity and manages interest rate in their money market with the help of

the open market operations (OMOs). This operational framework requires all financial institutions to hold minimum reserve during a specific reserve maintenance period (RMP) in order to allow the Eurosytem operational framework to stabilize money market interest rate and create structural liquidity storages. And the minimum reserve requirements are calculated on the basis of banks' individual balance sheet.

Interbank lending makes a great contribution to the efficiency of financial markets generally. There are two way for those interbank transactions to resolve short-term imbalances of supply of demand. In any normal day, some banks receive more deposits than expected, while others receive more-less than expected. Similarly, some banks experience an unexpected demand for loans such as from homeowners or investors in equities; while other banks face the opposite situation. If banks could not reliably lend and borrow on any particular day to offset those unanticipated ebbs and flows, a large volume of cash would be need to hold to insure itself against the possibility of unexpected payment inflows or outflow. However, having extra-large amount of cash holdings is a big waste as those recourses could be invested profitably elsewhere. The interbank market helps banks to solve this problem in satisfying temporary, localized excess demand for funding liquidity that is needed for the smooth function of other financial organizations.

Even for many banks that are mostly funded by deposits, interbank loans may be a critical marginal source of additional funds. Usually, the rate of interbank loans is lower than for other trading partners as banks are seen as low-risk confidence borrowers; investors require a smaller risk premium and even without collateral. However, events occasionally strain the interbank lending: such as physical disruption on 11th September 2001 as well as financial crisis of 2007-09. Uncertainty about banks' own needs combined with concerns about potential shortfalls prompted banks to be more unwilling to lend for more than a few days, and even then only at every high interest rates. The higher rate and reduced availability of interbank lending would create a vicious circle of over caution, extraordinary increase in demand for liquid, reduced willingness to lend and higher cost. For the neither collateralized nor insured against interbank loans, one financial institution's failure may trigger a chain of subsequent failures and eventually force the central bank to intervene to stop the contagion process in the bud. Interbank lending also could reduce the transparency of the data of banks' balance and off-

balance sheet and complicate the measurement of actual banking liquidity and solvency ratios for prudential purposes.

2.3.2 U.S. Interbank Lending During the Crisis

More particularly, as one of the most important but vulnerable systems in the whole economy, over the last 20 or so years, there has been a significant growth of interest in the question whether the U.S. interbank markets amplifies shocks to the whole banking sector or individual banks.

Although the interbank markets malfunction occasionally, they still have significant influence on the modern economy through monetary policy (Matsuoka, 2012). In the U.S., the Fed funds rate, also known as overnight interbank rate, is worked as main channel in monetary policy. In addition, interbank market works as the most immediate liquidity source within banks; therefore it can be a core indicator of the functioning of the banking market. Insufficient bank liquidity leading to inadequate allocation of capital could happen if any problems happen in this market.

It was predicted according to some recent economic theoretical models that the interbank lending market would freeze at the beginning of summer of 2007 just following the bankruptcy of Lehman Brothers as it did during the Asian banking crisis of the late 1990s. This may impose adverse implications in the whole financial system as it could be contagious and spills over from one to the others. Therefore, Central bank must conduct large-scale interventions to prevent a large scale of economic deterioration under this circumstance (Bagehot, 1873).

However, the observed evidence in the Fed funds market in the immediate aftermath the collapse of Lehman Brothers, did not support the hypotheses above. Figure 8 below shows daily amounts of transactions and daily interest rate in the Fed funds market. Four key dates are highlighted in figure 8: BNP Paribas limits withdrawals on 9th August 2007; JP Morgan announces Bear Stearns acquisition on 16th March 2008; Lehman Brothers goes bankrupt on 15th September 2008; and First effective day of interest on reserve balances on 9th October 2008. Although the rates spiked and loan terms became more sensitive to bank risk, not only

the amount of transactions[11] but also the cost of funds remained stable overall[12]. It seems likely that the aggregate market did not expand to meet extraordinary demands for funds. This was also examined by Afouso *et al.* (2010) and the conclusion remains: the market did not freeze.

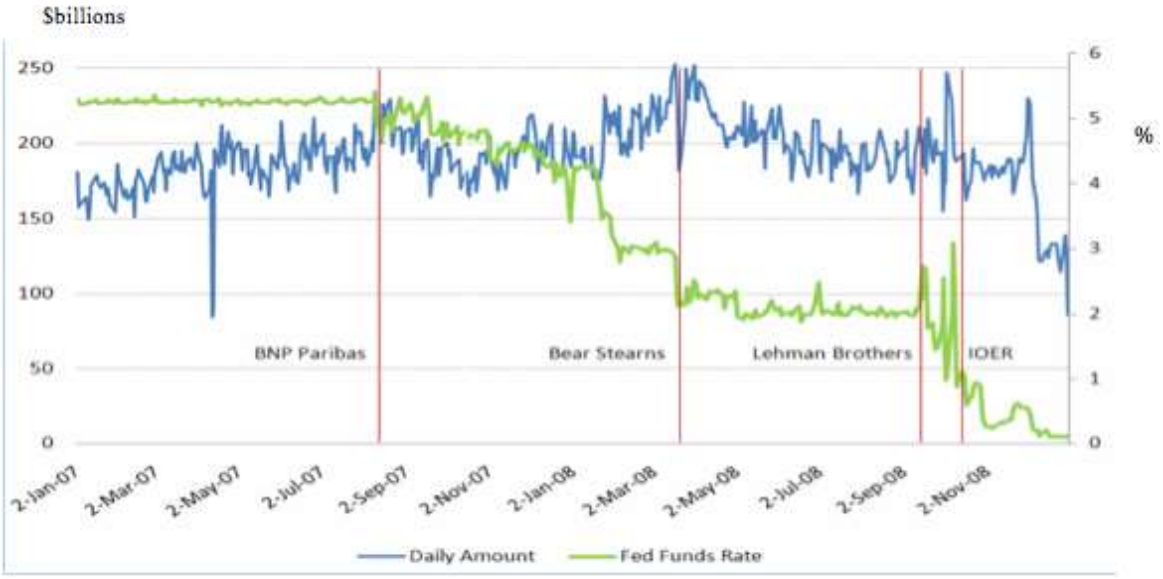

Figure 8: Daily amount of transactions ($billions) and Fed funds rate in Federal funds market (Afonso *et al.*, 2011)

While, it cannot be denied that the Fed market did not grow to meet the expected high demand as other sources of funding dried up; for example, credit terms tightened especially for large banks with worse performance in the two days following the failure of Lehman. In contrast, it did not happen to small banks. However, immediately before the Federal Reserve's $85 billion loan to AIG was announced on 16th September 2008[13], the spreads between the demands and supply of funds for large banks returned to pre-crisis levels or below, although borrowing amounts remained lower. It suggests that the market has changed their beliefs of 'too big to fail' (TBTF).

Besides, more mixed impacts of the recent crisis through interbank market have been documented in Table1 below:

[11] The daily amount of transactions only began to fall after the interest on reserves (IOR) period begins.

[12] After Lehman Brothers' bankruptcy, the weighted average rate then jumped with substantially more widening of the distribution.

[13] The spreads dropped and again, weeks later, after the initial Capital Purchase Program announcement on 14th October.

Country	Studied by	Year	Results
UK	Acharya & Merrouche	2013	Precautionary hoarding by settlement banks
	Wetherilt *et al.*	2009	Fewer interbank lending relationships during the crisis
	Halsall *et al.*	2008	Shifts in timing of interbank loans during the sub-prime turmoil
Germany	Memmel & Stein	2008	Low risk of interbank contagion
Italy	Angelini, Nobili & Picillo	2011	Interbank rates become more sensitive to borrower characteristics
US	Gorton & Metrick	2009	"Run on repo" with increased haircuts in the $10 trillion repo market especially for lower quality assets

Table 1: Mixed impact of the recent crisis through interbank market

What is more important is, are there any lessons to be learnt from the recent crisis? The answer is positive: those financial institutions (FIs) should be properly regulated. First FIs should be stopped from exposing to distress, not only in detecting management fraud in order to maintain the health of balance sheets, but also in setting up a stricter requirement of capital buffer. In addition, more attentions should be paid on the liquidity risk that raised from the maturity mismatch between short term financial instruments and long-term ones. In August 2007, the central banks reacted quickly in the Bagehot manner to deal with the freezing of the interbank markets in August 2007. The ECB flooded the European money market with respect to liquidity as did the Fed, which lowered the discount rate by 50 basis points. It seems likely that the first part of Bagehot's lesson to lend freely was heeded but not quite on the second part of lending at a penalty rate. The run on Northern Rock very likely reflected not the failure of the Bank's lender of last resort policy but inadequacies in the UK's provision of deposit insurance, the ill thought out separation of financial supervision and regulation from the central bank and political pressure (Milne and Wood, 2008). Moreover, it has been pointed out that one of deepest problem facing the financial system is solvency which stems from the difficulty of pricing securities backed by a pool of assets. As a result, in the credit market, it is the inability to determine which firms are solvent and which are not as the portfolios they hold are filled

with securities of uncertain value, derivatives that are so complex the art of pricing them has not been mastered.

2.3.3 Models of Systemic Risk in Interbank Lending

Recall section 2.2., we've learnt that in financial system, systemic risk could lead to systemic failure at a large enough scale through different channels. According to literature, there are three main sources for systemic failure. First, given that financial institutions hold in similar types of investments, a large enough failure by one bank would lead to a decrease in the prices of their assets and affect the solvency of other FIs which hold the same investments (Allen and Gale, 2000; Edison, Luangaram and Miller, 1998; Radelet and Sachs, 1998). The second aspect of systemic risk arises from a bank run: depositors and investors attempt to withdraw funds at the same periods of time leading to a collapse of the financial system (Calomiris and Kahn, 1996; Diamond and Dybvig, 1985; Donaldson, 1992; de Bandt, 1999). Third, the inter-locking exposures among banks, create the potential for one bank's failure to have 'knock on' effects on the financial health of the banks rather than forming a basis for mutual insurance (Allen and Gale, 2000). Here, we focus on the third one.

The following part further to review the existing theoretical and empirical literature about systemic risk: Examples include Kaufuman and Scott (2003), Chan-Lau et al. (2009), Bandt and Hartmann (2000), and etc.; and thus identify areas in which areas in which future research efforts are needed.

First of all, the significant effects of reduced liquidity upon the speed of banking failures are recorded in some theoretical models. The concept in such models is that banks suffer losses in the value of assets because of 'fire sales' stemming from their liquidations by failing banks. This affects the assets of non-failing banks, causing loses which can exceed their capital base, and in turn render them vulnerable to collapse (Allen and Gale, 2001; Diamond and Rajan, 2005). Another thread of models focus on how interbank loans can be used to reduce systemic risk. It works so by encouraging banks to monitor each other's reactions as their exposure to interbank loans renders them susceptible to other bank failures (Rochet and Tirole, 1996). Another study by Freixas *et al.* (2000) demonstrates how interbank lending can be used as a tool to lessen the impact of depositors' withdrawals. An empirical study was made to underpin

such models by Cocco *et al.* (2009). Moreover, an investigation conducted by Eichberger and Summer (2005) shows rising capital adequacy can actually serve to increase systemic risks in equilibrium. These models have 'equilibrium model' in common; and they are based on the assumption of acknowledged interactions between a particular bank and other banks so that they are not modelled explicitly therefore the effects of interbank loans cannot be studied directly, especially in the networks properties and structures.

In contrast to those equilibrium models, more recently and popularly, explicit models treat financial interactions between banks as networks and simulation techniques are commonly used to indicate the spread of possible bank failure. The application of network models range widely. For example, Vivier-Lirimont (2004) employed network model to assess the optimal network structure of interbank loans from the banks point of view. While it might only work in explaining the existence of specific network structures, rather than in the understanding of systemic risks; also, a strand of models still, focus on the implications of 'liquidity effects', are similar to the equilibrium models mentioned above: the only difference is that they explicitly use the network structure of financial connections to work out the spread of banking failures due to liquidity effects (Cifuentes *et al.*, 2005). Haldane (2009) gives a general overview of the limitations of such modelling methods.

Unlike all of the above mentioned models describing the behavior of banks themselves in a rather rudimentary fashion, models presented in Eboli (2007), Gai and Kapadia (2007), Nier *et al.* (2007), Battiston *et al.*(2012), and May and Arinaminpathy (2010) explicitly consider the banks' balance sheets, and then how a bank failure spreads through the system via interbank lending. In these models, assumptions about the properties of banks, their network structure and how failures propagate themselves are made. For example, it is commonly assumed that all banks follows an Erdös-Renyi randomized network, so that the banks are same in size and capital base therefore all interbank loans are identical: empirical facts about the real banking system and the heterogeneity of banks are not taken into account. Besides, because of the limitations of these assumptions, a comprehensive overview of the determinants of financial crises cannot be achieved, relying as they do on average field estimates based on a small number of common parameters. A common conclusion of such models is that increased bank connectivity can enlarge the spread of failure, yet in the case of very high connectivity this can

be reduced again. A more obvious result is that a higher capital base reduces the scale of banking crisis. In addition to the literature above, Sui (2009) investigated the relevance of network structure in the spread of banking failure; and also took into account the significance of the originator of the crisis in a rather stylized approach. Lastly, the distribution of losses in such a model is described by Canedo and Jaramillo (2009a).

Furthermore, a large scale of empirical papers have attempted to provide more sights on the vulnerability of a particular banking system to systemic risks, usually by focusing on individual countries and either using the real structure of interbank lending (with data observed from central banks) or at least estimate such a structure. The papers addressing this aspect include Sheldon and Maurer (1998), Elsinger *et al.*(2001), Blavarg and Nimander (2002), Wells (2002), Graf *et al.*(2004), Upper and Worms (2004), Lyre and Peydro-Alcalde (2005), Mistrulli (2005), Elsinger *et al.*(2006), Gropp et al (2006), Iori *et al.*(2006), Lelyveld and Liedorp (2006), Degryse and Nguyen (2007), Estrada and Morales (2008) , Canedo and Jaramillo (2009b), and Toivanen (2009). Empirical literature of interbank loan networks reveals a power law tail in their connections (Boss *et al.*, 2004a). Analysis of the US Fed wire system shows a degree distribution that follows power law with a power law exponent (λ) 1.76 among the 9000 banks (Soramäki *et al.*, 2007; Becher *et al.*, 2008). Austrian interbank system that consists of more than 900 banks again is analyzed by Boss *et al.* (2004b) and Cajueiro and Tabak (2008) and finds a λ of 1.85 for the out degree for the period from 2000-2003. In the Brazilian banking system, a tail range of between 2.23-3.37 is indicated in a study between June 2007 and November 2008 of more than 600 banks (Edson and Cont, 2010). The investigations of smaller banking systems in Italy and the UK, conducted by Becher *et al.* (2008) and Iori *et al.* (2008), find there a high level of tiering, that is to say a small number of banks control most of others. The Swiss interbank network is a relatively small system (around 100 banks). In this case, there was a rather distorted system of the distribution of links: just 2 large banks control the interbank loan market, which suggests an extremely small power law exponent (Müller, 2006). Craig and Von Peter (2014) analyzed the larger German banking system in detail by a core-periphery model. They found the German network has a high-tiered structure: just 2% of the banks dominate the core. The result was very consistent from 1999 to 2007 by using bilateral exposures. As mentioned above, there is a board range indicated in the different size of banks and also their interconnections, which doubts the assumptions of random networks and banks

of equal size. Upper (2007) contains comprehensive overviews of empirical methods and disparity results provided in many of these papers mentioned early. With the various properties of banking systems in each country, it is of course the case that there is a wide range of systemic risks due to interbank lending. There is a requirement for a comprehensive tool to examine systemic risks in need of taking into account all this variation. Krause and Giansante (2012) further enhanced an explicit model of a more realistic banking system with heterogeneous banks of different sizes, balance sheet structures, and the sizes of interbank loan as well as network topologies.

Apart from focusing on systemic risks triggered by interbank loans, there has also been modelling of particular areas related to estimating systemic risks: Eisenberg and Noe (2001), and May *et al.* (2008) looked at the payment networks; Markose *et al.* (2008) investigated counter party exposures in credit default swaps and Battiston *et al.* (2007) examined trade credits between companies. However, the banking systems developed in recent literature are all free of any actual dynamics in the network itself. It would be worth to investigate how the actual behavior of banks contributes to or mitigates the onset of a financial crisis. For example, the liquidity hoarding - a mechanism whereby shocks can be propagated is by banks taking fright and being reluctant to lend - is thought by some to the main problem at present literature. Therefore, the literature on liquidity hoarding will be presented in the next section.

2.3.4 Liquidity Hoarding in the Interbank Market

This section briefly reviews literatures associated liquidity hoarding with the financial turmoil of 2007-2009. Bank liquidity hoarding is not a new phenomenon. For example, in the aftermath of the Great Depression, and particularly during the late 1930s, U.S. commercial banks accumulated substantial amounts of voluntary excess reserves. As Ramos (1996) points out, during and immediately after a severe liquidity crisis, banks hoard excess cash to self-insure against further drains of cash and to send markets a strong message that their solvency is not at risk and that bank runs are not justifiable. The situation during the banking crisis of the 1930s clearly resembles the bank behaviour during the most recent financial crisis. As suggested at that time, banks sought to build up liquidity buffers to reduce their risk exposure on the asset side of their balance sheets at times when capital and debt was very expensive.

The financial crisis started in August 2007 when interbank markets froze and the market for asset-backed commercial paper (ABCP) collapsed: from $1.2 trillion in August to about $850 billion by year-end. The dry-up of liquidity continued in 2008 as investors became concerned about the credit quality and the liquidation value of collateral backing ABCP transactions (Covitz, Liang and Suarez, 2013). Similarly, outstanding volumes in the unsecured commercial paper market for financial firms plunged by about $350 billion after the failure of Lehman Brothers and the bailout of AIG in October 2008.

In the face of fear and uncertainty in financial markets, large institutional investors withdrew their funds from the collective pool of cash by declining to roll over their loan agreements. In normal times, this can be done without causing significant effects on interest rates. However, with deepening concerns about the credit quality of counterparties and the fact that the magnitude of the exposure to subprime-related assets was unknown, investors withdrew their funds en masse. This withdrawal created a huge shortage of collateral, which forced institutions to sell securities to meet the increased demand for liquidity. As the repo and interbank markets shrunk, the increased sale of securities drove their prices further down. Such deterioration in the value of securities (most of which were being used as collateral in repo transactions) was a natural source of liquidity risk leading to the precautionary hoarding of liquid assets.

In an effort to ease conditions in interbank and credit markets, the Federal Reserve provided a significant amount of liquidity to the banking sector via several new facilities. These new facilities include the Money Market Investor Funding Facility (MMIFF), the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), the Fed's Term Auction Facility (TAF), the Commercial Paper Funding Facility (CPFF), the Primary Dealer Credit Facility (PDCF), the Term Securities Lending Facility (TSLF), and the temporary liquidity swap arrangements between the Federal Reserve and foreign central banks.

For example, TAF, introduced in December 2007, was a new approach taken by the Fed to address concerns of stigma attached to the discount window (Armantier, Ghysels, Sarkar, and Shrader, 2014). TAF delivered term funds through auctions to banks that were in need. It expanded immediately following Lehman Brothers' default. Previous studies on the effectiveness of TAF in mitigating liquidity problems in the interbank market offer mixed results (McAndrews, Sarkar, and Wang, 2008; Taylor and Williams, 2009).

As the functioning of financial markets improved, many of the liquidity programs expired or were closed in 2009. The composition of the Federal Reserve's balance sheet continued to shift in the second half of 2009 and early 2010, when the liquidity supports to markets took the form of purchases of Treasuries and mortgage-backed securities. The considerable decline in the credit extended through the various liquidity programs was more than offset by the increase in securities holdings.

Combined with an approximately $220 billion capital injection through the Capital Purchase Program (TARP), a total of about $820 billion was provided to the banking industry during 2008 and 2009. Interestingly, most of the funds received by banks resulted in an increase in excess reserves of $765 billion over 2008 and $318 billion in 2009. This information suggests that banks decided to keep the injected funds in the form of reserves at the central bank.

The build-up of excess reserves held at the central bank during the implementation of the liquidity programs provides the first piece of evidence of liquidity hoarding in the U.S.. Moreover, this evidence is consistent with the argument that injecting more excess reserves into the banking sector does not necessarily lead to more bank lending. As Martin, McAndrews, and Skeie (2011) argue, in the context of interest paid on bank reserves and no binding reserve requirements, excess reserves may end up contracting lending. This is the case when interest rates are very low (almost zero) so that the marginal return on loans is smaller than the opportunity cost of making a loan. The adverse effect on lending is more apparent when banks face increased balance sheet costs associated with agency costs or regulatory requirements for capital or leverage ratios. Using a related argument, Hancock and Passmore (2011) contend that when the cost of capital is high and banks are capital constrained, additional excess reserves impose a tax on the banking sector because they tie up capital for a low profit or unprofitable use. As mentioned above, a large accumulation of excess reserves at the central bank after monetary expansions is also found using data for settlement banks in the U.K. and the unsecured euro interbank market.

Several theoretical papers have examined the motivation for banks to hoard liquid assets. For example, banks may decide to hoard liquidity for precautionary reasons if they believe they will

be unable to obtain interbank loans when they are affected by temporary liquidity shortages (Allen and Gale, 2004). Precautionary liquidity hoarding has also been modelled as the response of banks to the fear of forced asset liquidation, as in the frameworks of Diamond and Rajan (2009), Gale and Yorulmazer (2011). By the study of Diamond and Rajan (2009), banks hoard liquidity in anticipation of future liquidation of assets which, in the context of severe disruptions in funding markets, provide a high expected return from holding cash. In the model of Gale and Yorulmazer, banks hoard liquidity to protect themselves against future liquidity shocks (precautionary motive) or to take advantage of potential sales (strategic motive). Acharya and Skeie (2011) develop a model in which banks hoard liquidity in anticipation of insolvency of their counterparties in interbank markets (rollover risk).

Another strand of the literature derives liquidity hoarding as a result of Knightian uncertainty when due to increased uncertainty banks make decisions based on worst-case scenarios (Caballero and Krishnamurthy, 2008)—and contagion in financial networks. For example, Caballero and Simsek (2009) propose a framework in which banks operate in complex network structures. In those market structures, the information that banks normally collect to assess the financial conditions of their trading partners becomes insufficient. To learn more about their counterparty risks, they have to collect information on the health of the trading partners of the trading partners of the trading partners, and so on. During times of financial distress, this process becomes extremely costly. Moreover, the confusion and uncertainty that follows a liquidity shock can trigger massive flight-to-quality episodes, and force illiquid banks to withdraw from loan commitments and illiquid positions. As the flight-to-quality unfolds, the financial crisis spreads.

In a similar vein, Zawadowski (2011) uses the idea of financial contagion in network structures to show that uncertainty in short-term funding markets among interconnected institutions can lead to excessive liquidity hoarding. The author shows that, after a liquidity shock, uncertainty about not being able to roll over interbank loans leads to inefficient liquidation of assets, which causes no default in equilibrium but a significant drop in lending. The novelty in his analysis is that uncertainty is capable of spreading and magnifying the impact of liquidity shocks through an interbank network. This network works as an interwoven structure in which each bank

finances several other banks, so that uncertainty about funding in one bank spreads to more and more banks in the consecutive layers of intermediation.

Recent empirical evidence on liquidity hoarding is provided by Acharya and Merrouche (2013), Heider, Hoerova, and Holthausen (2008), De Haan and Van den End (2011), and Wolman and Ennis (2011). Using data for large settlement banks in the U.K., Acharya and Merrouche (2013) show that banks significantly increased their liquidity buffers after August 2007. This increase in liquid assets occurred when the interbank markets started to dry up and bank borrowing costs ballooned. Heider, Hoerova and Holthausen (2008) also provide evidence of liquidity hoarding in the euro interbank market. Unlike the very small spreads and infinitesimal amounts of excess reserves in normal times, they show that the unsecured euro interbank market exhibited significantly higher spreads leading to a dramatic increase in banks' excess reserves. Using a panel Vector Autoregression (p-VAR) approach, De Haan and Van den End (2011) find that in response to funding liquidity shocks, Dutch banks reduce wholesale lending, hoard liquidity in the form of liquid bonds and central bank reserves, and conduct fire sales of equity securities. Finally, Wolman and Ennis (2011) using data on U.S. commercial banks find that banks holding large excess reserves at the Federal Reserve since the fall of 2008 also increased their holdings of other liquid assets such as short-term securities. Furthermore, their findings indicate that banks holding high levels of liquidity have enough capital to expand their lending without facing binding capital requirements.

Chapter Three: The Structural Shifts of Banking Ratios and Financial Crisis 2007/8

3.1 Introduction

Reflecting the high costs of banking crises and their increased frequency, banking sector stability has increased attention in policy discussions in past decade. Bank runs have occurred in many countries throughout history. In the U.S., bank runs were common during the banking panics of the 1800s and in the early 1900s during the Great Depression. The crisis of 2007-2008, while it was characterized as one of the worst credit crises since the Great Depression, echoes earlier big international financial crises with many similarities to those of the past which were all triggered by events in the U.S. financial system; including the crises of 1857, 1893, 1907 and 1929-1933. However, it also has some important modern twists. The panic in 2007 was not like the previous panics, in that it was not a mass run on banks by individual depositors, but instead of a run by firms and institutional investors on financial firms. It has also raised puzzles as it was believed that the subprime market was too small to trigger the propagation of losses in the entire U.S. financial market (Mishkin, 2008).

While there are many benefits in knowing whether and if so when a crisis may occur, it has been a challenge to predict crisis. Recall our work in literature review, various studies have proposed early warning indicators of impending turmoil in banking systems (e.g., Alessi and Detken, 2011; Demirgüç-Kunt and Detragiache, 1998, 1999, 2005; European Central Bank, 2005; Frankel and Saravelos, 2012; Hardy and Pazarbaşioğlu, 1998; Hutchinson and McDill, 1999; Hutchinson; 2002; Kaminsky and Reinhart, 1999; Laeven and Valencia, 2012; Reinhart and Rogoff, 2008, 2009; Schularick and Taylor, 2011; Taylor, 2013). However, full agreement on how to measure systemic banking problems and which explanatory variables to include has not yet been reached. Given the common threads that tie together apparently disparate crises, it can be useful to take a step back from the practical imperatives of maximizing goodness of fit and instead consider the conceptual underpinnings of early warning models.

In addition to this, although a large body of literature has proposed various ways for identify an impending crisis by studying systemic risks as well as contagion models via different channels, scare previous literature have considered the possibility that banks could make actions to

protect themselves during the financial crisis and therefore affect the propagation of losses through the financial linkages. In order to combine the dynamics into existing contagion model with valid explanatory variables, studying the real banks' preemptive actions in the crisis thereof is also essential.

Drawing upon a subset of aggregate U.S. bank accounting ratios from FDIC call reports, in this chapter, we present an econometric analysis of the applicability of those ratios for studying banks' preemptive behaviours by using. The sample period has been restricted from the fourth quarter of 1992 to the last quarter of 2011; and 16520 banks are included. More specifically, we firstly examine a broad set of balance sheet indicators for early warning purposes, and assess their relative likelihood of success. It aims to provide an organizing framework for selected indicators of vulnerability to crises, especially those that are associated with banks more generally. In what follows, we will also investigate real banks' preemptive actions by looking their significant structural shifts in response to the crisis at average bank level; even if the interactions themselves are unknown, with the aim to understand how banks react during the recent financial crisis. The characteristics of banks' balance sheets during the crisis may help explaining the behaviors of the banks during the crisis will be investigated: more specifically, how interbank loans are granted, extended, and withdrawn in response to a banking crises developing.

3.2 Literature Review

There is much to be gained from better detecting the likelihood of a crisis: it can help put in place measures aimed at preventing a crisis from occurring in the first place or limiting the damage if it does happen. A thorough analysis of the consequences of and best responses to crises has become an integral part of current policy debates as the lingering effects of the latest crisis are still being felt around the world. Yet, in spite of much effort, no single set of indicators has proven to explain the various types of crises or consistently so over time. And while it is easier to document vulnerabilities, such as increasing asset prices and high leverage, it remains difficult to predict with some accuracy the timing of crises. This section presents a short review of the evolution of the empirical literature on prediction of crises.

There is a large literature on early warning indicators for crises, described well in Chamon and Christopher (2012). The emerging economy crises of the 1990s gave impetus to the work, which has been further developed in the aftermath of the recent global financial crisis that engulfed the advanced economies as well as emerging economies. The literature to date could be described as being eclectic and pragmatic. It has been eclectic in that the exercise involves appeal to a wide variety of inputs, covering external, financial, real, and fiscal variables, as well as institutional and political factors and various measures of contagion. In their overview of the literature as of 1998, Kaminsky, Lizondo and Reinhart (1998) catalogue 105 variables that had been used up to that date.

The literature has also been pragmatic in that the exercise has focused on improving measures of goodness of fit, rather than focusing on the underlying theoretical themes that could provide bridges between different crisis episodes. The pragmatic focus has also meant that traditional regression techniques, such as the probit model as used in Berg and Patillo (1999), has given way increasingly to non-parametric techniques that minimize the signal to noise ratio as in Kaminsky, Lizondo and Reinhart (1998). The reason is that non-parametric techniques fare better when there are a large number of explanatory variables. And Breuer (2004) class them into four generations based on their often used.

Early warning models have evolved over time, with the first generation of models focusing on macroeconomic imbalances starts from Great Depression in the U. S. (Miskhin, 1978). Given a macroeconomic shock, it firstly adversely affects banks' borrowers and subsequently impacts upon the depositories themselves; thereby trigger bank runs that ultimately lead to the failure of financial institutions. Calomiris and Mason (1997) deposit withdrawals by using data from the 1932 Chicago bank panic: insolvency caused by contagion effects was found.

Second-generation models draw upon depositor behavior and they treat banking crises as "sunspot" events: sudden changes in depositors' expectations can trigger a crisis. Diamond and Dybvig (1983) corroborated the randomness of bank runs. And they pointed out banking crises are unrelated to the business cycle. However, Gorton (1988) rejects this hypothesis in long run. He finds a systematic association between bank runs and recessions; which would cause depositors to change their perception of risk. In short sum, in the next generation of models, still largely geared towards external crises, balance sheet variables became more pronounced. Relevant indicators found include substantial short-term debt coming due (Berg *et al.* 2004).

Third-generation models use predetermined (lagged) macro variables as leading indicators and they underscore the role of a boom and bust business cycle. Hardy and Pazarbaşioğlu (1998), Demirgüç-Kunt and Detragiache (1999), and the European Central Bank (2005), confirms these findings. However, Gavin and Hausman (1996) reject. Contrary to the second-generation models, bank assets are taken into account in the analysis. During periods of economic upswing, banks engage in excessive lending against collateral such as real estate and equities that appreciate in value, thus facilitating a lending boom. A sudden bust results in collapsing asset prices and financial institutions scale back their lending. And thus borrower default rates increase. However, the institutional environment is ignored. Evidence for the impact of the institutional setting on the probability of observing systemic events in banking systems is, however, mixed.

Contrary to the third-generation models, fourth-generation models aim to identify the impact of the institutional environment. An early warning system for banking crises that takes account of the institutional environment can be found in Demirgüç-Kunt and Detragiache (1998); and then these models are extended by Hutchinson and McDill (1999), Eichengreen and Arteta (2000),

and Hutchinson (2002). These models emphasize the role of the bureaucracy, protection of shareholder and creditor rights, rule of law and contract enforcement, sophistication of supervisory and regulatory frameworks, incentive schemes created by deposit insurance and the socioeconomic environment. Beck, Demirgüç-Kunt, and Levine (2005) additionally consider concentration in the banking industry for their analysis of banking crises; whereas Barth, Caprio, and Levine (2008) use a World Bank database for bank regulation and supervision. While the generous design of deposit insurance schemes tends to destabilize banking systems, especially in where the political setting is insufficiently developed (Demirgüç- Kunt and Detragiache, 2005). Barth, Caprio, and Levine (2008) fall short in providing statistically significant evidence for the hypothesis that a strong regulatory environment bolsters financial soundness. Das, Quintyn, and Chenard (2005) finds that countries with a higher quality of financial sector policies perform better in responding to macroeconomic pressures on the overall level of stress in the financial system. Gropp *et al.* (2004) find market based indicators, such as the distance to default can be early warning indicators for banking problems on the micro level, whereas DeNicolo and others (2005) use the distance to default to assess the exposure to systemic risks. However, its sole reliance on the availability of market prices considerably limits its applicability to banking systems where such information cannot be obtained. Someone may argue that macroprudential indicators are good at capturing macroeconomic imbalances, while banking system indicator need to be used to identify bank problem. Demirgüç-Kunt (1989) provides a detailed account of the early literature in the field. Pazarbasioglu *et al.* (1997) firstly using bank-specific factors with macroeconomic indicators to measure individual bank soundness, and then aggregating the bank-by-bank estimates into an index of banking system soundness. Sahajwala and van den Bergh (2000) survey the early warning systems in place at supervisory agencies and bank regulators in various G10 countries, whereas King and others (2005) offer a synopsis of recent advancements in the literature. The time to failure of individual institutions was investigated by Lane and others (1986) and Whalen (1991). Some macroprudential indicators that can simultaneously embrace sources of banking vulnerabilities are introduced by Fox et al. (2005) to capture unsustainable departures of asset prices. An overview of statistically significant variables in selected third and fourth generation models is listed in Appendix 7. It emphasizes the importance of institutional variables in signaling failure of banks due to insufficiently control for the macroeconomic environment.

More specifically, one of the major purposes of those researches is to construct early warning models that identify risky banks prior to failure and signal bank supervisors to take corrective actions. Most of these studies have used data from the wave of bank and thrift failures during the late-1980s and early 1990s (e.g., Cole and Gunther, 1995; DeYoung, 2003; Oshinsky and Olin, 2005; Schaeck, 2008; Thomson, 1991; Whalen, 1991; Wheelock and Wilson, 2000). These studies have identified a set of bank failure predictors: low asset quality (nonperforming loans), high concentrations of business or commercial real estate loans, illiquidity, cost inefficiency and/or poor management, rapid asset growth, reliance on non-core deposit funding and, not surprisingly, low profitability and low equity capital. Appendix 8 gives an overview of the financial soundness indicators (FSIs) identified in the Compilation Guide on Financial Soundness Indicators (IMF, 2004). And the precise definitions of the "core" and "encouraged" FSIs were introduced in the Compilation Guide on Financial Soundness Indicators (IMF, 2004). Despite substantial progress in the recent past, there is still no universal database of "core" and "encouraged" FSIs to facilitate financial crisis. A set of appropriate tools are need to assess strengths and weaknesses of financial systems led to efforts to define sets of so-called "core" and "encouraged" (FSIs), designed to monitor the health and soundness of financial institutions and markets, and of their corporate and household counterparts (Sundararajan *et al.*, 2002). A small but growing set of studies have begun to apply these techniques to more recent data on bank failures during the financial crisis (e.g., Altunbas, *et al.* 2012; Berger, *et al.* 2016; Cole and White, 2012; Rossi, 2010). One of the central findings is that not much has changed. rapid growth in credit and asset prices is found to be the most reliably related to increases in financial stress and vulnerabilities, but still imperfect predictor. As Claessens *et al*. (2012) show, not all booms are associated with crises: only about a third of boom cases end up in financial crises. Others do not lead to busts but are followed by extended periods of below-trend economic growth. And many booms result in permanent financial deepening and benefit long-term economic growth. While not all booms end up in a crisis, the probability of a crisis increases with a boom. Furthermore, the larger the size of a boom episode, the more likely it results in a crisis.

A separate set of studies measures the impact of noninterest income on bank stability and risk. The earlier studies (e.g., Gallo et al. 1996; Jiangli and Pritsker 2008; Kwast 1989; Litan 1985; Uzun and Webb 2007; Wall 1987) tend to find that expansion into nonbanking activities such

as securities underwriting, securities brokerage, and asset securitization helps banks diversify away risk, at least partially. But more recent studies tend to find increased risk (Simaan, 2017). Allen and Jagtiani (2000) find that expanding into nonbanking securities and insurance activities increases both systematic risk and interest rate risk at bank holding companies. DeYoung and Roland (2001) show that noninterest income contributes positively to bank earnings volatility. Stiroh (2004, 2006) finds no substantial evidence of diversification benefits from pairing noninterest income with interest income. DeJonghe (2010) shows that noninterest income-intensive banks have higher tail betas and as such are more sensitive than traditional banks to extreme market and macro-economic swings; consistent with this, Clark et al. (2007) find that fee income from retail banking activities tends to be pro-cyclical. Elyasiani and Wang (2008) report that bank holding companies that generate large amounts of their incomes from fees are less transparent to investors. While Demirguc-Kunt and Huizinga (2010) find some evidence of diversification gains from low levels of noninterest income. DeYoung and Rice (2004) point out a number of fallacies regarding bank noninterest income, including the misconception that banks earn noninterest income chiefly by expanding into nonbanking activities or nontraditional banking activities.

In addition to those, global factors also play important roles in driving sovereign, currency, balance-of-payments, and sudden stops crises. In practical terms, recent early warning models typically use a wide array of quantitative leading indicators of vulnerabilities, with a heavy focus on international aspects. Indicators used capture vulnerabilities are centered in the external, public, financial, nonfinancial corporate or household sectors, and combine these with qualitative inputs (IMF, 2010, 2014). Since international financial markets can play multiple roles in transmitting and causing, or at least triggering, various types of crises, as happened recently, several international linkages measures are typically used. Notably banking system measures, such as exposures to international funding risks and the ratio of non-core to core liabilities, have been found to help signal vulnerabilities (Shin, 2013). Since international markets can also help with risk-sharing and can reduce volatility, and the empirical evidence is mixed, the overall relationship of international financial integration and crises is, however, much debated (Kose et al., 2010; Lane, 2012).

Overall, most of the econometric models for banking crises reviewed in this part belong to the early warning systems (EWS) literature, which focuses on crisis prediction. Although every distress or failure period is different, most are characterized by some patterns. The goal of the models is mostly to find these patterns and to enable accurate prediction of bankruptcy. However, prediction models have become more sophisticated over time and more complex and interdisciplinary. As a result, EWS models are becoming more difficult to interpret, which is going beyond their private usefulness in the view of Mayes and Stremmel (2012). What's more, their findings to date are far from conclusive, highlighting a need to further assess a commonly agreed set of core indicators for the build-up of banking system vulnerabilities. Therefore, there is considerable scope for improvement as the number of supervise failures in the global financial crisis suggests.

3.3 Empirical Strategy

My analysis aims to examine time-series variation of real banks' preemptive actions before, during and after the financial crisis. More specifically, we investigate a broad set of balance sheet indicators for early warning purposes; and assess their relative likelihood of success by looking their significant structural shifts in response to the crisis first at average bank level and then in three sub-samples. To analyze the structural shifts and breaks, following tools and models are employed.

3.3.1 Sample and Ratios selection

Shin (2013) has outline three main broad sets of indicators for early warning purposes:

- Indicators based on market prices, such as CDS spreads, implied volatility and other price-based measures of default or distress
- Gap measures of the credit to GDP ratio
- The Behaviour of banking sector asset and liability aggregates

To anticipate my conclusions, the first approach (based on market prices) seems most appropriate for obtaining indicators of concurrent market conditions but unlikely to be useful as early warning indicators with enough time for meaningful remedial action. Empirical results also indicate that those based market prices, such as spreads on credit default swaps, do not give sufficient warning of a crisis (Shin, 2013; Claessens, *et al.*, 2013). The credit to GDP gap measure is a distinct improvement from the first as an early warning indicator, with a good pedigree from the work of BIS economists and has been explored extensively as part of the Basel III bank capital rules. Yet, there are doubts about its usefulness as a real time measure, or as a measure that yields a threshold that can be applied uniformly across countries. That leaves the third approach - one based on bank aggregates, including various components of balance sheet. Shin (2013) has also suggested that this third approach is the most promising, as it preserves the advantages of the credit to GDP gap measure but also stands a good chance of yielding indicators that can be used in real time.

In this research, the datasets used in this research are obtained from the FDIC call reports [14]. The sample includes 16520 banks [15]and the time span has been restricted from fourth quarter of 1992 to the last quarter of 2011. Data for some of the banks are only available for certain research time periods, which results from the re-structuring or failures of banks; and we give NIL under this circumstance.

Furthermore, the research questions were explored firstly based on collected actual balance sheets data and financial ratios by using CAMELS [16]approach. There are some micro-level models traditionally are widely considered in identifying individual failing banks by using CAMELS financial ratios and macroeconomic variables, such as stock prices. The CAMELS approach was developed by bank regulators in the United States as a means of measurement of the financial condition of a financial institution. The CAMELS analysis requires at least last three years and interim statements for the most recent 12-month period. The acronym CAMELS stands for:

- Capital Adequacy
- Asset Quality
- Management
- Earnings (Profitability)
- Liquidity & Funding
- Sensitivity to Market Risk (losses arising from changes in market prices)

In our research, a set of curial financial ratios in first five subsections according to CAMELS approach have been drawn from our micro-level datasets mentioned as early as the fourth quarter 2011 and back to 1992; which are expressed as the primarily financial characteristics of the banks. The full definitions of financial ratios employed in this report are listed in Appendix 1.

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[14] In the United States, for every national bank, state member bank and insured nonmember bank, quarterly basis consolidated reports of condition and income are required by the FFIEC (Federal Financial Institutions Examination Council).

[15] 16520 is the total number of banks existed during the period of 01-09-1992 to 31-12 -2011.

[16] In the U.S., since from the 1980s banks' failure till now, CAMELS has been widely used as a crucial supervisory tool to examine the overall conditions of individual (Dang, 2011). Commonly, CAMELS rating system is an acronym made up of Capital adequacy, Asset quality, Management, Earnings (or Profitability), Liquidity & Funding and Sensitivity to Market risk; also, it is the uniform financial institution rating system which was launched on 13 Nov. 1979 by FFIEC. A Scale of one to five (one stands for best, and five is worst) is set for each part in an onsite bank health examination; and a single measure-the "composite" rating is assigned.

What's next, parametric and nonpararametric techniques will be introduced to test whether a set of aggregate balance sheet indicators for early warning purposes is sufficient to explain the impending financial crisis, and assess their relative likelihood of success. It aims to provide an organizing framework for selecting indicators of vulnerability to crises, especially those that are associated with banks more generally. In what follows, we will also investigate real banks' preemptive actions by looking their significant structural shifts in response to the crisis both at average and an individual bank level. Also, we discuss the consequence of 'too big to fail' (TBTF) and show differences in the applicability of banking accounting ratios for the identification of banking problem between large and small banks.

3.3.2 Unit Root Tests

A strand of econometric tools is employed to examine the crucial financial ratios and then the dynamic changes of those financial characteristics of the banks in the next two parts. First, it is necessary to study the time series properties of the included variables. In order to generate a non-spurious regression, every variable included in the regression need to be stationary. If variables are found to be integrated one, regression in levels would lead to spurious results. And if a regression is spurious, the estimated parameter will be inconsistent and both t- and F-statistics will diverge (Phillips, 1988).

Since we are dealing with financial variables, it is very likely that the interbank rate and many of the explanatory economic fundamentals are non-stationary in simple level form. Therefore, before running the models specified in the next section, we proceed with some tests of non-stationary (unit root). The unit root tests we run are: the Augmented Dickey-Fuller (ADF) tests (Dickey and Fuller 1979), KPSS (Kwiatkowski, Phillips *et al.*, 1992), Ng-Perron test (Ng and Perron 2001) and Lee and Strazicich unit root test(Lee and Strazicich 2003). For fundamentals that are expected to grow over time, we specify the unit root tests with a constant and a time trend.

The general empirical estimation of the models for unit root tests gives the form:

$$\Delta s_{t+1} = \alpha_m + \beta_m X_{m,t} + \eta_{m,t+1} \tag{3-1}$$

Where $X_{m,t}$ denotes the vector of independent variables; β_m is a vector of parameters and $\eta_{m,t+1}$ is a random term.

If the series is non-stationary and the first difference of the series is stationary, the series contains a unit root. A basic and widely used unit root test is the Augmented Dickey-Fuller (ADF) tests ((Dickey and Fuller 1979). It takes a unit root as the null hypothesis. Whereas the KPSS test due to (Kwiatkowski Phillips *et al.*, 1992) provides an alternative for testing the null of a level- or trend-stationary process against the alternative of a unit root. Both these tests have been criticized for the poor size and low power(Caner and Kilian 2001). The Ng-Perron test by (Ng and Perron 2001) attempts to solve the size and power distortions of the ADF and KPSS test.

The ADF test mainly concentrates on whether time series are affected by transitory or permanent shocks. The Modified Akaiake Criterion is used to determine the optimal lag length. Unlike the ADF test, the KPSS has stationary as the null hypothesis and a unit root as the alternative hypothesis. Kwiatkowski *et al.* (1992) argue that it can be of interest to test both types of hypotheses when investigating the dynamic properties of a time series.

Both ADF and KPSS tests cannot distinguish very well between highly persistent stationary processes from non-stationary processes. Moreover, the power of these tests generally diminishes as exogenous regressors are added to the test regression. Ng and Perron (2001) have used modified AIC and BIC in choosing the optimal lag length. They demonstrate that the choice of lag length determines the best size and power properties of the unit root test. The traditional lag selection criteria such as AIC and BIC are not well suited with integrated data. By a series of simulation experiments, Ng and Perron recommend selecting the optimal lag length by minimizing the modified AIC.

Appendix2 displays the augmented Dickey-Fuller tests for the ratios tested. In 41out of 85 cases, we fail to reject the null of a unit root using 95% confidence intervals. The fourth column shows results of the KPSS tests. This confirms the result from the ADF test. In 38 out of 85 cases, we reject the null of stationarity using 95% confidence intervals. But at the 90% confidence interval, there are only 34 out of 85 series which exhibit unit root. For all ratios, the series that are found to be non-stationary in their levels are found to be stationary in their first difference.

Fifth column shows the Perron-Ng test results. It can be seen from the table that the test performed better in terms of size and power. For individual series, the unit root null cannot by reject for most of the individual series, i.e. 35 out of 85 ratios are still I (1). Failure to incorporate structural changes in testing the unit root of these series may be the possible reason for bias in finding non-stationary. However, there is an improvement in the result with homogeneous coefficients. The Perron-Ng tests show almost variable is stationary at 10% confidence level.

3.3.3 Structural shifts

According to a new database about the timing of systemic banking crises prepared by Laeven and Valencia (2012), the United states banks experienced two systemic banking crises started from 1988 and late 2007 respectively. More than 1,400 financial institutions and 1,300 banks failed in the earlier one; and over $180 billion were injected to clean them up. The collapse of U.S. sub-prime mortgage market pulled the trigger on another bank crisis in August 2007. Profits of U.S. banks declined remarkably from the fourth quarter of 2007 compared to previous year; and capital ratios increased following the requirements by the U.S. department of Treasury, after 03 September 2009: financial characteristics of the banks' balance sheets hardly qualifies as serious analysis during this ad hoc selection of time spans. In this case, under the assumption of stationary[17] of data, the structural variation in time series (balance sheet indicators for early warning purposes) will be tested in order to assess their relative likelihood of success.

To begin our discussion, the simplest dynamic model (Hansen, 2001) – the first-order autoregression[18]– has been employed:

$$\boldsymbol{y_t}=\boldsymbol{\alpha}+\boldsymbol{\rho y_{t-1}}+\boldsymbol{e_t} \qquad \boldsymbol{Ee_t^2}=\boldsymbol{\sigma^2} \qquad (3\text{-}2)$$

Where,

α, ρ, σ^2 are the parameters, and e_t is a serially uncorrelated shocks in a time series $\boldsymbol{y_t}$.

[17] It stands for the constancy of parameters, such as the mean, variance and trend over time.

[18] Before we applied all ratios in to the Hansen dynamic model, Augmented Dickey-Fuller (ADF) unit root tests were applied to the level series of financial ratios, then to the first differences and then to the error terms of the regressions of these series to test for stationarity or nonstationarity. There are 53 ratios out of 86 in total stationary in the first different (For more details see Appendix 2).

A structural break occurs when at least one of the parameters are not constant anymore at the breakdate over the time period; while it might need a period of time to take effect instead of immediately. In our study, for the rule of parsimony and simplicity, an immediate structural break has been assumed. Furthermore, a break may affect at least one of or all of parameters in the model, which may have different implications. The parameter ρ implies the changes in the serial correlation in y_t, and the intercept α reflects the mean of y_t which can be expressed as the equation $E(y_t) = \mu = \frac{\alpha}{1-\rho}$. For example, if $y_t$is the yield on earning asset, then changes in μ are probably the issue of primary interest as they are identical to changes in the trend; and σ^2 controls the volatility of this ratio.

The Chow test (1960) is typically classical test for testing structural breaks by using an F statistic; but it only works if the breakdate is known. For unknown timing structural test, a research has to pick an arbitrary candidate breakdate or to pick a breakpoint based on some known characteristics of the dataset. But, the Chow testing could be misleading for both cases: in the first case, the point may be uninformative; and in the second case, an untrue breakpoint might be identified as the candidate point is endogenous[19] when there is none. Here, the potential solution is Quandt (1960) if the breakdate is treated as unknown. In Quandt's paper (1960), he advised using the largest Chow statistic over all possible breakpoints; and its construction can been seen by plotting the sequence of Chow test valves as a function of candidate breakpoints (Hansen 2001). With the ideal developed by Quandt and Hansen, and combining the Eview 7 tools; Break point Maximum LR/wald F-STATISTIC are applied to identify the potential breakpoints for each financial ratio in Appendix 2. In this paper, we also use Quant-Andres unknown break point test (1960) and Chow test (1960) to verify the breakpoints obtained by Break point Maximum LR/wald F-STATISTIC (see all details in Appendix 3).

A well-known weakness of the conventional unit root tests is that they ignore the existence of structural breaks in the variables. Ever since the seminal article of (Perron 1989), researchers began to consider structural changes when testing for unit roots.

[19] It is correlated with the data.

Perron (1989) shown in the presence of structural breaks, the unit root test, which is against trend stationary alternatives are biased to the non-rejection of the null hypothesis. His proposal is characterized by a single exogenous known break in the trend function. This assumption has been criticized by many author such as Cristiano (1992), Zivot and Andrews (1992), and Lumsdaine and Papell (1997). They argued unit root tests detect a structural change endogenously. As a consequence, they conducted different methodologies to endogenously determine the break. This involves estimating a Perron (1989) type equation over all possible breaks.

Zivot and Andrews (1992) propose a modification of Perron's test in which they allow one unknown structural break to be determined endogenously from the data. Lumsdaine and Papell (1997) extend the Zivot and Andrews (1992) model by allow for two structural breaks under the alternative hypothesis of a unit root. One limitation on these ADF-type endogenous break unit root tests is that they derive the critical values by assuming no structural break under the unit root null. Given this assumption, researchers might conclude the time series is trend stationary when in fact they are non-stationary with breaks. Furthermore, they tend to incorrectly select the break point (Lee and Strazicich 2003). To address this issue, Lee and Strazicich (2003) propose a one break LM unit root test as an alternative to Zivot Andrew test and a two break minimum Lagrange Multiplier (LM) unit root test for the Lumsdaine-Papell test. The test starts with an assumption that the null hypothesis is a unit root with up to two breaks. It not only endogenously determines structural breaks, the alternative hypothesis also unambiguously implies the series is trend stationary(Glynn, Perera *et al.*, 2007). The ability to permit up to two breaks in the null and two breaks in the level or slope of the alternative make this approach particularly flexible and attractive. Therefore, this study selects the Lee and Strazicich unit root test.

The Lee and Strazicich (2003) procedures for the one- and two-break LM unit root test statistic is obtained from the following regression:

$$\Delta y_t = \delta' \Delta Z_t + \phi S_{t-1} + u_t \tag{3-3}$$

Where the vector of exogenous variables, $\mathrm{Z_t}$, takes the form $\left[1, \mathrm{t}, \mathrm{D_{jt}}, \mathrm{DT_{jt}}\right]$ $where$ $\mathrm{j} = 1,2$. we considered model A which is known as a 'crash model' and allow for time change in the intercept, $\mathrm{D_{jt}}$.model C allows for a shift in the intercept and change in the

trend slope under the alternative hypothesis.

$$D_{jt} = \begin{cases} 1 & t > T_{Bj} + 1 \\ 0 & elasewise \end{cases} \qquad DT_{jt} = \begin{cases} t - T_{Bj} & t > T_{Bj} + 1 \\ 0 & elsewise \end{cases} \tag{3-4}$$

Where T_{Bj} is the time period of the structural break; The LM test statistic is given by: τ = t-statistic for test the unit root null hypothesis that $\phi = 0$. The location of the structural break T_B is determined by selecting all possible break point s for the minimum t-statistic as follows:

$$LM_\lambda \tau = inf_\lambda \tau(\lambda) \tag{3-5}$$

The critical value for the one- and two-break minimum LM unit root test statistics are tabulated in Lee and Strazicich (2003). The limitation of the above test is that it does not account for potential structural breaks in the series. To address this issue, we first allow for one break in the LS unit root test, then for two breaks. See all summaries results in Appendix 4.

To focus on the ad hoc periods around the break points, the financial ratios data listed in Appendix 2 was further regressed on a set of quarterly dummies[20]based on the structure break we found early summarized in Appendix 3&4. If we find that we can identify a significant structural break[21] in a time series, in the next step we attempt to determine whether the sign of the trend is negative or positive and whether it is significant or not. Besides, it would be of interest to observe the level changes which are outlined by the structural breaks.

In order to determine how the trend has shifted over time, we proceed to model the data generating process in the manner conducted by Kellard and Wohar (2006)[22]. The financial ratio series are regressed against a constant (α), a time trend (t), a level dummy variable (D) and a slop dummy variable (Dt) corresponding to the results of the

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[20] Dummy variables are applied in the OLS, $D(t) = \begin{cases} 0, & t \leq 0 \\ 1, & t > 0 \end{cases}$

[21] In recent study in the time series literature, test for the significance of the trend and level changes can be carried out irrespective of whether the data contains a unit root or not. See Harvey *et al.* (2007). In the context of this study, unit roots may be useful as they give the empirical support as to whether data contains stochastic trends or not. With root test with a single structural break may be suggested.

[22] Kellard and Wohar (2006) conducted a study of the disaggregated commodity prices between year 1900 and1998; and they also attempted to fit a trend stationary model.

structural break test. Thus the estimation process is carried out using the following equations[23]:

$$y_t = \alpha + \beta_1 t + \beta_2 D + \beta_3 D * t + \varepsilon_t \quad (3\text{-}6)$$

Where,

D and Dt denote the level and slope dummy respectively.

In regression models, an appropriate method to estimate the parameters - including the breakpoint - is least squares (Hansen, 2001). Operationally, each sample is split at each possible breakpoint; the other parameter estimated by ordinary least squares, known as OLS (refer to Appendix 5 for further details). The changes of slope and or trends have been summarized in the Appendix 5&6.

[23] The single structural break is assumed in this study.

3.4 Results and Analyses of Empirical Work

A set of U. S. bank ratios[24] has been analysed to help identify and understand how the actual behavior of banks made in response to the financial crisis of 2007-2008 developing on the historical perspective: crucial financial ratios will be well described and discussed in five different subsections according to the CAMELS approaches with own modification. We assess their relative likelihood of success by looking their significant structural shifts in response to the crisis. Full definitions of financial ratios and their estimated parameters with structure breaks are listed in Appendix 1-6.

3.4.1 Key Ratios for Examining Capital Adequacy

First of all, capital adequacy is defined as the capital level expected to maintain balance with the risks exposures such as market risk, credit risk and operation risk, in order to absorb the potential losses and thus protect their debt holders. In 1930, FDIC defined a capital model in terms of capital-asset ratios because of the primary risk derived from default on loans. Karlyn argued, in 1984, and proposed the capital adequacy based on capital-deposit ratio as the depository risk arising from the bank run, with a large scale of deposit withdrawals is greatest risk. Currently, financial institution supervisors use the capital- asset ratio. In this subsection, capital adequacy is examined based upon the following three important measures: Equity Capital to Assets Ratio, Tier 1 Leverage Ratio and Total Risk-based Capital Ratio (more ratios for examining capital adequacy are listed in Appendix). Figure 9 below illustrates the key capital adequacy ratios from fourth quarter of 1992 to 2011 last quarter; and the estimated parameters by ordinary least squares are summarized in Appendix 5&6.

Equity Capital to Assets ratio is a core index for judging capital health, and the Tier 1 Leverage ratio is utilized by Federal and banks to determine if there is enough capital to cover potential losses on the asset side of balance sheet. Total Risk-based Capital ratio, namely CAR, is calculated as the total risk based capital as percent of risk-weighted assets. To be “well capitalized” under the Basel definition, a bank holding company must have a Tier 1 ratio of at least 6%, a Tier 1 Leverage Ratio of at least 5%, a CAR ratio (combined tier1 and tier2 capital) of at least 10%, and an Equity Capital to Total

[24] Here, we will mainly focus on early warning indicators we’ve selected based on FSIs and CAMELS.

Asset Ratio of at least 4% to 6%, and not be subject to a written agreement to maintain specific a capital level. In the United States, according to FDIC guidelines for an "Adequately Capitalized institution", a bank is expected to meet a minimum requirement of qualifying Tier 1 Leverage Ratio of 4.0%, total risk-based ratio of 8.0%, of which at least 4.0% should be in the form of Tier 1 core capital.

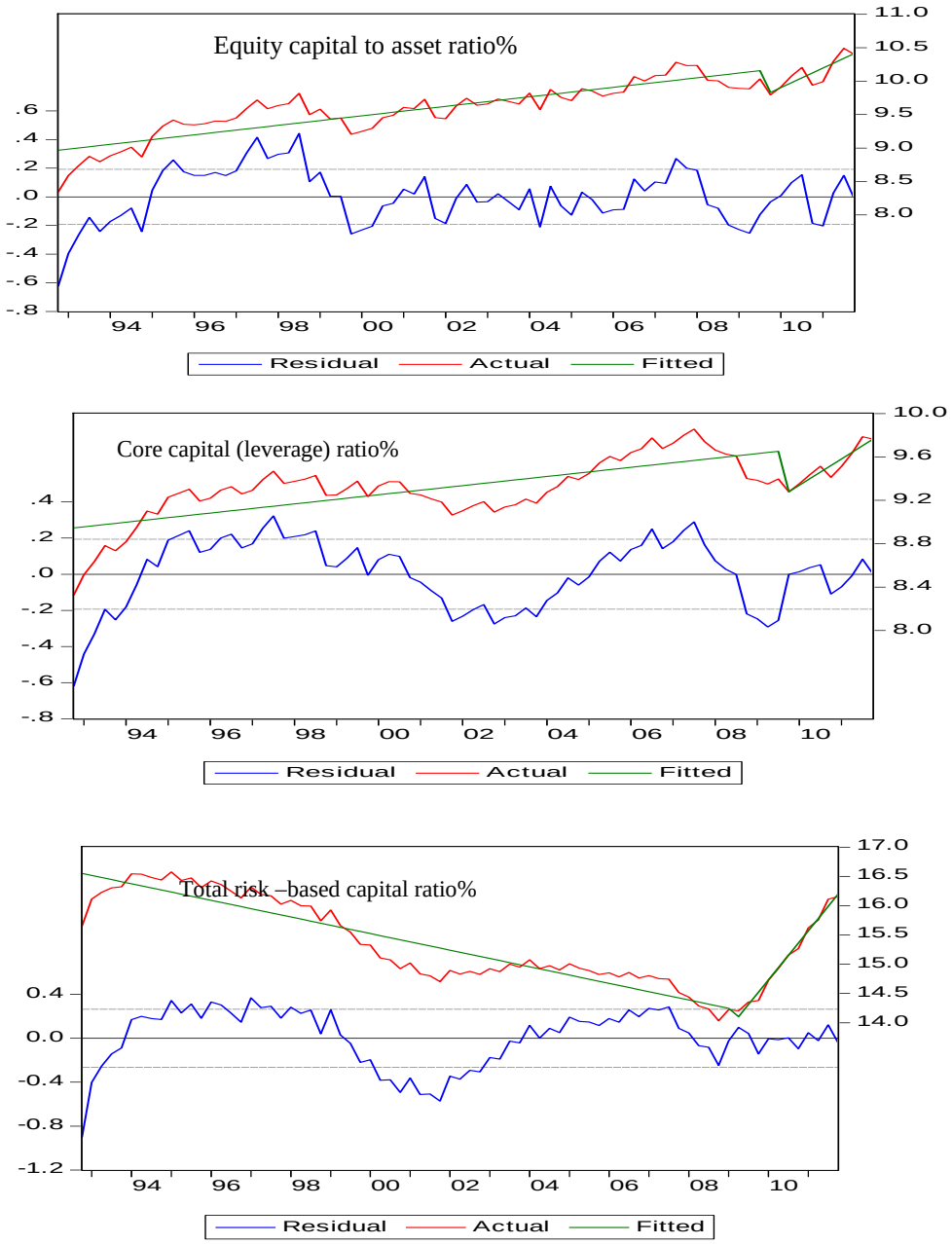
Here, we investigated banks' overall performance from 4th quarter of 1992 to 4th quarter of 2011 on capital firstly. From the figure 9 below, all three ratios fluctuated all the time and were much higher than that of their required minimum level during the past 19 years.

Despite certain mild fluctuations, the Equity Capital to Assets ratio experienced a gradual and lasting rise before year 2007, which were approximately 10.0% for both; and then from then on the decrease constantly, hitting the 9.6% and 9.3% respectively in 3rd quarter of in late 2009. The regressions with dummy variables were conducted to identify the main changes in capital level during the crisis. From the Appendix 5, the dummy variables in level and dummy variables in trend are over 5% critical value, indicating the coefficients of the dummies in trend and level are significant. Therefore, the Equity Capital to Assets ratio as well as leverage ratio, the slump or structure break can be verified in late 2009. After the break date, both ratios constantly increased again. In contrast, the trend of Total Risk-based Capital ratio turned moderately downwards from the end of 1992 to later 2008, bringing the figures down to roughly 14% in 2008 Q4; however, it was still much higher than the minimum capital level. It is worth mentioning that the figure climbed more quickly after 4th quarter of 2008, reaching 16.3% by the end of 2011.

What is remarkable is how tranquil the Capital Adequacy ratios are before the crisis. There is barely a ripple in the series in the period 2004 to 2006 when the vulnerability to the financial crisis was building up. Even though all three ratios did show an obvious structure break and slump during the financial crisis, around late 2008, early 2009, those ratios performed generally more than well according to the minimum capital requirement under the FDIC definition; which failed in playing a key role of being a first sign of financial crisis. There is clear empirical evidence from the global financial

crisis (GFC) and earlier that risk-weighted capital buffers were not good predictors in practice, which is verified in our case (Estrella, Park and Peristiani, 2000). Northern Rock for example was fully compliant with risk-weighted measures shortly before its failure (Mayes and Wood, 2009).

Figure 9: The estimated regressions of key capital adequacy ratios with the corresponding the breakpoints, the U.S., 1992Q4 to 2011Q4



3.4.2 Key Ratios for Examining Asset Quality

Grier (2007) argued that poor asset quality is the main reason of major bank failures. Therefore, the risk of loan losses derived from delinquent loans is the primary risk faced by the banks, because the loan is one of most important asset category; and thus the asset quality assessment in order to manage credit risk is necessary, though may be difficult. Based on the study conducted by Frost (2004), the Loan Loss Reserves[25] to Total Loans ratio as well as Coverage ratio were employed as the primary measurement for judging the quality of a loan portfolio. Appendix 1 lists the formulae as well as the minimum requirement of those two key ratios to be considered as "well capitalized" the U. S. banks. Figure 10 illustrated fitted regressions of loss allowance to loans ratio and coverage ratio during the period of 4th quarter of 1992 to 4th quarter of 2011 (more details are listed in Appendix 5).

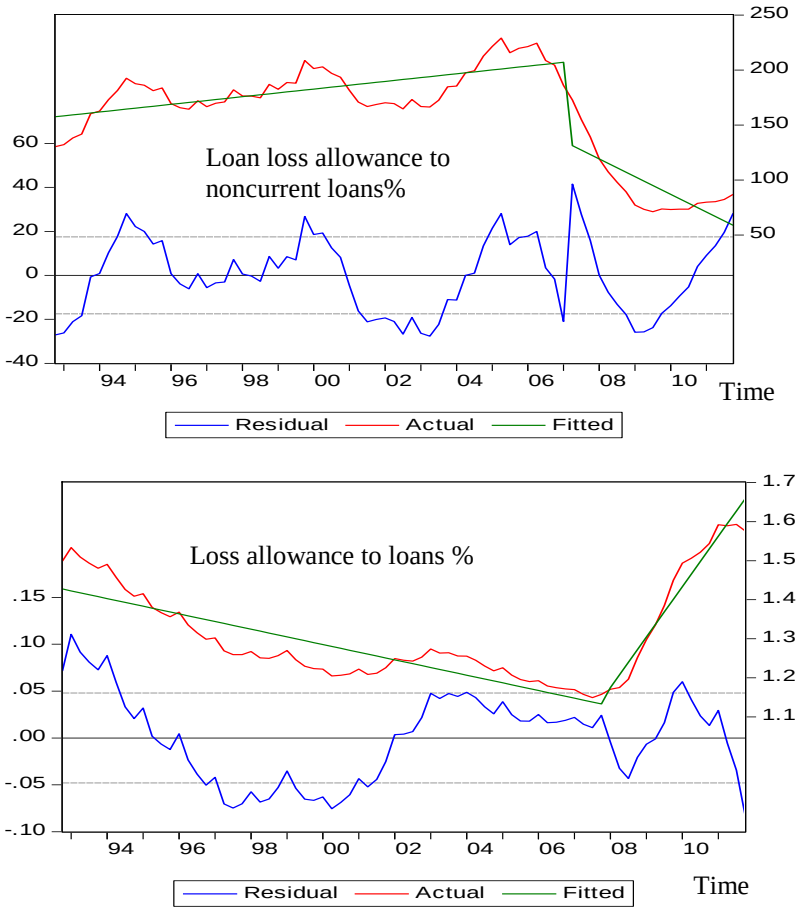


Figure 10: The estimated regressions of key ratios for examining asset quality with their corresponding the breakpoints, the U.S., 1992Q4 to 2011Q4

[25] It is also called Loss allowance to loans ratio.

From the upper figure 10, loss allowance to loans ratio shows an obvious "U" shape pattern, reaching a bottom at 1.15% (but still over the minimum level of 1%) by 2007. The structural break test verifies the significance of change in trend at 4th quarter of 2007 (see Appendix 3 for further details). Non-performing loans are considered carefully in coverage ratio as contained in three lowest categories of loans: substandard, doubtful and loss. Comparing to the minimum criteria of 1.5x set by FDIC, banks were in generally safe from 1993 to 2007; but it started to fail in meeting the requirement by the 4th quarter of 2007. The coverage ratio bottomed itself by the end of 2007 at less than 0.8x, which is far away from the peak record of 2.3x around year 2005. After the break point, the coverage ratio constantly decreased again; but the percentage of loan loss allowance to total loans was acting in completely different way. One possible explanation of those is that banks start to increase loss allowance and decrease the short-term lending in order to protect them from illiquidity. Loan loss reserves have a forward-looking component that reflects banks' efforts to increase their loan provisioning in anticipation of expected losses, and therefore, provide another motivation to hoard cash in anticipation of such losses. Loan Loss allowance to total loans ratio will be well examined as an on-balance proxy of liquidity risk in our chapter 5.

All in all, both ratios verified the structure break date of 2007Q4 during the financial crisis and the changes were consistent with the assumption. Similar to the previous research -for example, Keeton and Morris (1988), Fisher *et al.* (2000), and Dinger and Hagen (2009)- the coverage ratio worked well as it gave a good warning sign just before the financial crisis began. Loan Loss allowance to loans ratio gave the sign of banks' precaution actions, such as liquidity hoarding and lending cut. However, a more rigorous supervisory system or a higher minimum requirement level for loss allowance to loans ratio may be proposed.

More ratios are discussed below to describe the loan concentration profile (see figure 11) as well as the recovery situation in figure 12. All in all, lending fell across all types of loans during the crisis. In chart 11, the total noncurrent loans and leases, loans and leases 90 days or more past due plus loans in nonaccrual status, weighted less than 5% of total gross loans and leases in the past 20 years. It fluctuated all the time before end of 2006 while it has had a rapid increase since then, peaking once around 3.3% by the 2nd quarter of year 2009. The figures dropped again after 2009. These changes were again highly statistically significant (see Appendix 5). In more detail, the loans to individuals, such as household, family, and other personal expenditures, accounted

for 16% of total loans at end of 1992, while the weights dropped to 3% by a constant decrease. The continuing cut in individuals' loans can be observed in the last 20 years.

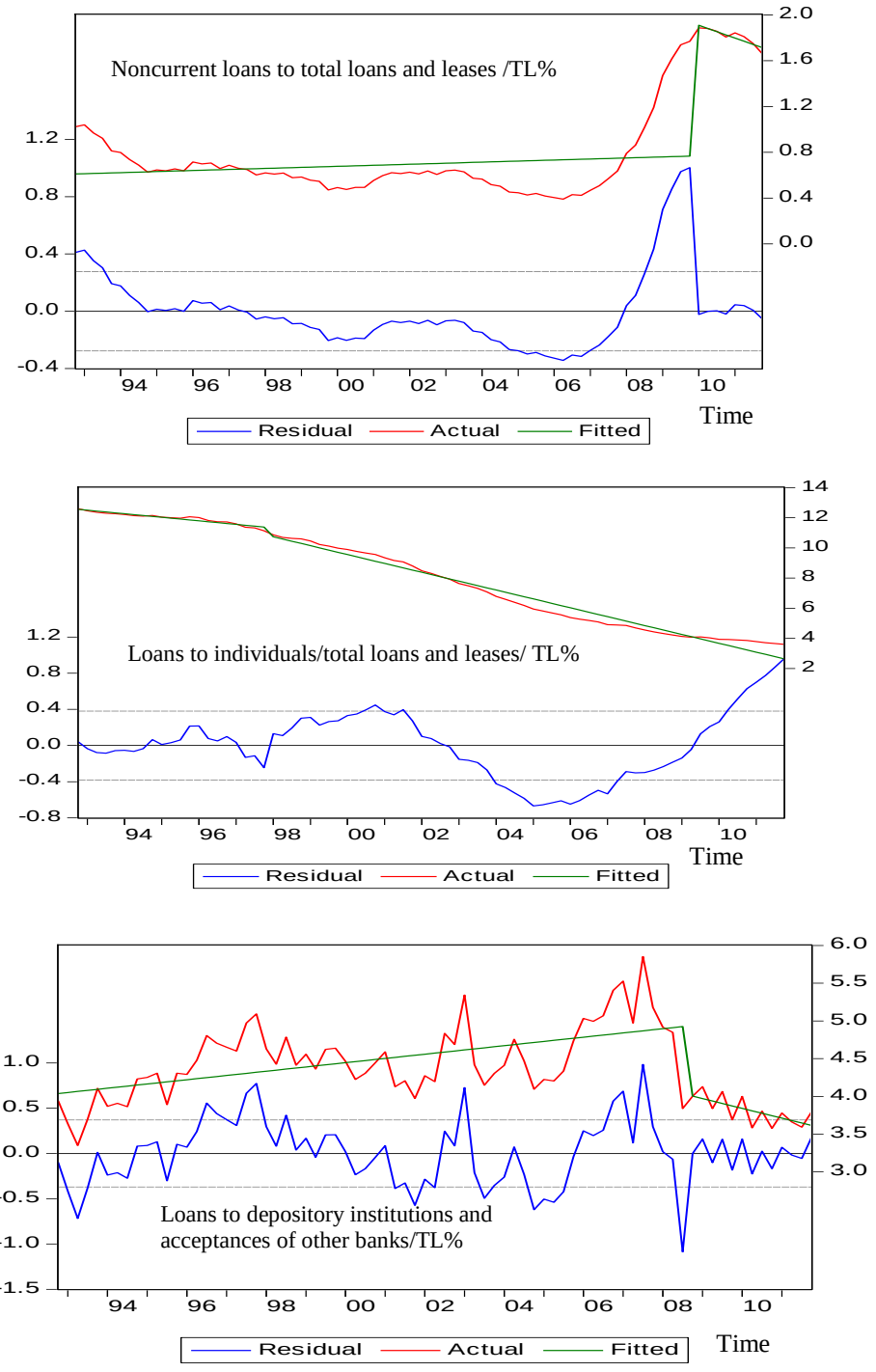


Figure 11: The estimated regressions of key ratios for testing loan concentration profile with their corresponding the breakpoints, the U.S., 1992Q4 to 2011Q4

From the loan recovery profile in figure 12, a seasonal fluctuation can be observed. After 2008Q2, the amount of net loans charged-off rocketed, peaking at 9 times of the previous average level 0.05%. The change in 2008Q2 during the recent crisis is highly statistically significant (see

Appendix 5). However, no similar strong sudden change was found in any subcomponents such as Net Loans Charged-off to Commercial and industrial, Net Loans charged-off to individuals and Net Loans Charged-off to Credit card loans (see Appendix for full definitions and tests). As the large amount of bad debts written off, there was a simultaneous run by borrowers who drew down their credit lines, leading to a reverse spike in commercial and industrial loans reported on banks' balance sheets. Here, the quality of assets held by banks may really be doubtful.

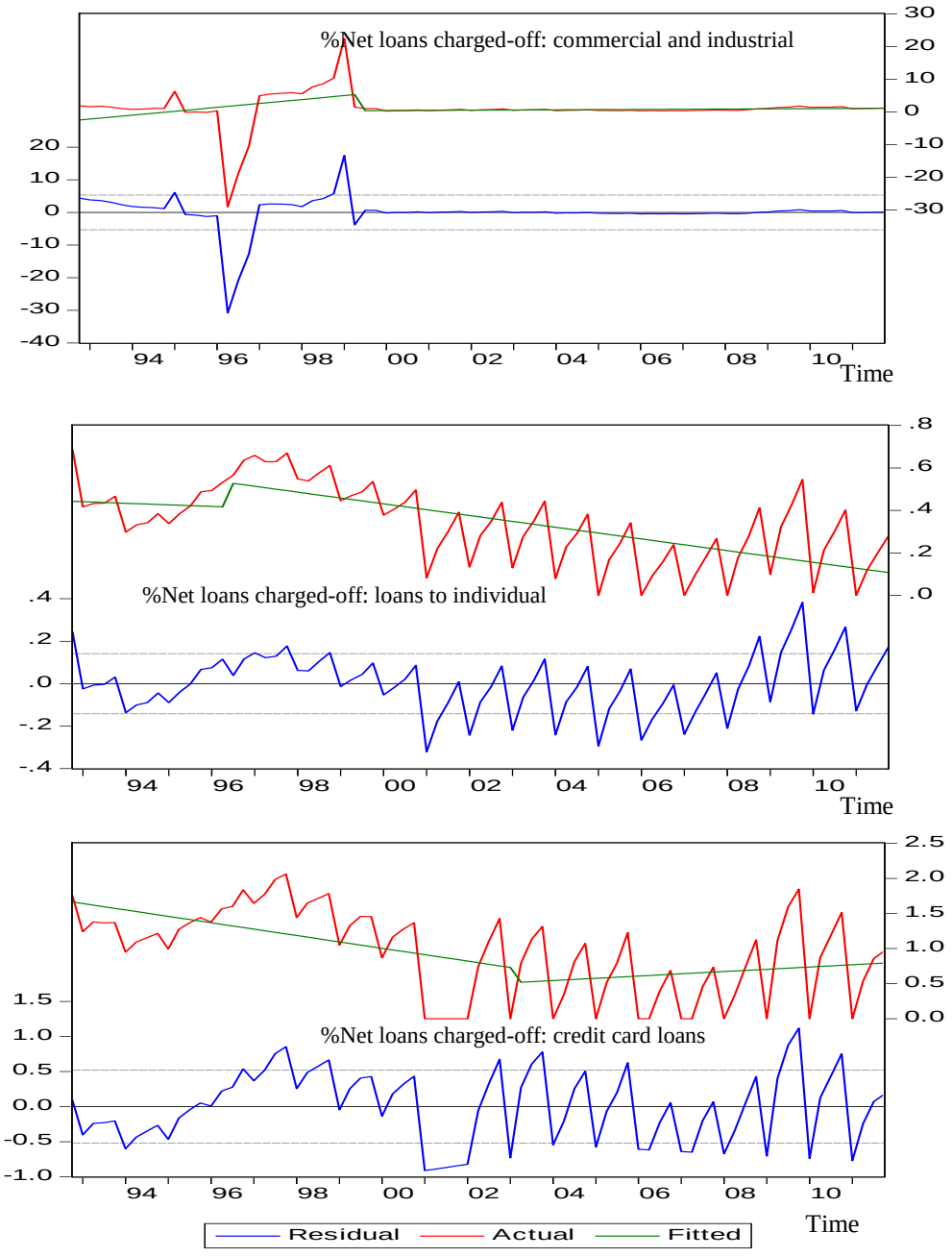


Figure 12: The estimated regressions of key ratios for loan recovery profile with their corresponding the breakpoints, the U.S., 1992Q4 to 2011Q4

3.4.3 Key Ratios for Examining Interbank Lending

Now let's go back to the interbank loan topic. One core business provided by banks is a liquidity service (Heffernan, 2005). Banks bridge savers and borrowers with their different liquidity preferences. For example, a bank lends funds to a firm which is commonly financed by deposits; while, the maturity of those deposits might be shorter compared to loans. In this case, the liquidity preferences of borrowers and savers are simultaneously satisfied through bank services. Moreover, interbank market works as the most immediate liquidity source within banks; and the overnight interest rate can be a core indicator of market risk. In a downturn, insufficient bank liquidity could lead to inadequate allocation of capital, which could increase a higher interbank rate as well as a higher market risk level. Figure 4 in chapter one documents 3-Month Interbank Rates for the United States from 1992 to 2014. It plunged twice over the time: one happened in 2001 ('The early 2000s recession', which affected the United States in 2002 and 2003) and another one was around 2007 (financial crisis 2007/08). The later one as an example here: a decline of the interbank rate can be observed in late 2006 (even during the financial crisis period from 2007 to 2008) in order to support the refinance of problematic banks through the interbank market; while it slightly increase around middle of 2009 after the period of the 'panic of 2008', following the scenario in the financial market that banks demanded a higher interest rate due to a high level of uncertainty about the future availability of liquidity and fearing insolvency of their counterparts. It did decrease again in mid-2010 due to the U.S. government interventions.

As mentioned early, after the failure of Lehman Brothers, there was a run by short-term bank creditors, particularly in the interbank market. Banks act in lending less even if they had better access to deposit, which were observed in constantly decreasing of ratio of loans to depository institutions and acceptances of other banks in the top panel of figure 13. The interbank loan breakdown by the nature of borrowers, of which over 60% in average are the loans lent to commercial banks in U.S., peaked at 70% during the year 2005 to early 2010; and less than 5% in loans to foreign branches of U.S. banks during whole time period. All the numbers verified the structure break date of 2009Q2 and structure break tests were again highly statistically significant (see Appendix 5). The evidence shows the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of financial crisis. This gives me an initial idea of combine interbank loans movements into our chapter 4 and 5. It is worth mentioning that the figure of loans to banks in foreign countries shot up by the end of year 2004 and then fluctuated all the time; which may indicate more global activities.

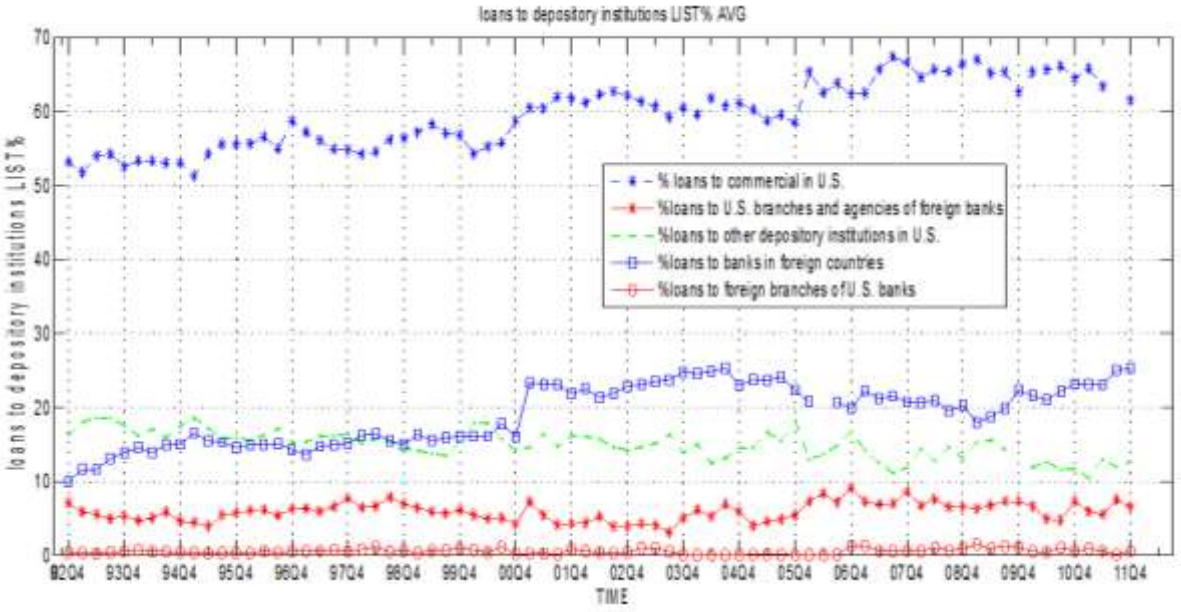


Figure 13: The estimated regressions of key ratios for interbank loan given profile with their corresponding the breakpoint, the U.S., 1992Q4 to 2011Q4

Again, from Figure 11 and Figure 13 above, the interbank market was large and active in the U.S.: outstanding loans, typically overnight lending, to other banks averaged close to $440 billion in early 2008; while, the financial crisis started from 2007, triggered an unprecedented, sustained strains in interbank lending. The crisis prompted a surge in demand for liquid assets in the entire U.S. financial system, in turn, rather than lend surplus liquid assets out, most banking preferred to hold, in case their own need might increase. With the increasing level of uncertainty and counterpart risks, banks became increasing unwilling to lend and thus the size of interbank loans in average plummeted by the end of 2008; the big fall happened after the failure of Lehman Brothers in September. The situation was constantly becoming worse when interbank loans created a vicious circle of increased caution, greater demand for liquidity, reduced willingness to lend and higher loan rates, the waves of financial crisis may be seen in the graph. The evidence demonstrates that funding fragility and the changes of interbank loans both in level and trend at third quarter of year 2008Q3 were highly statistically significant (Appendix5).

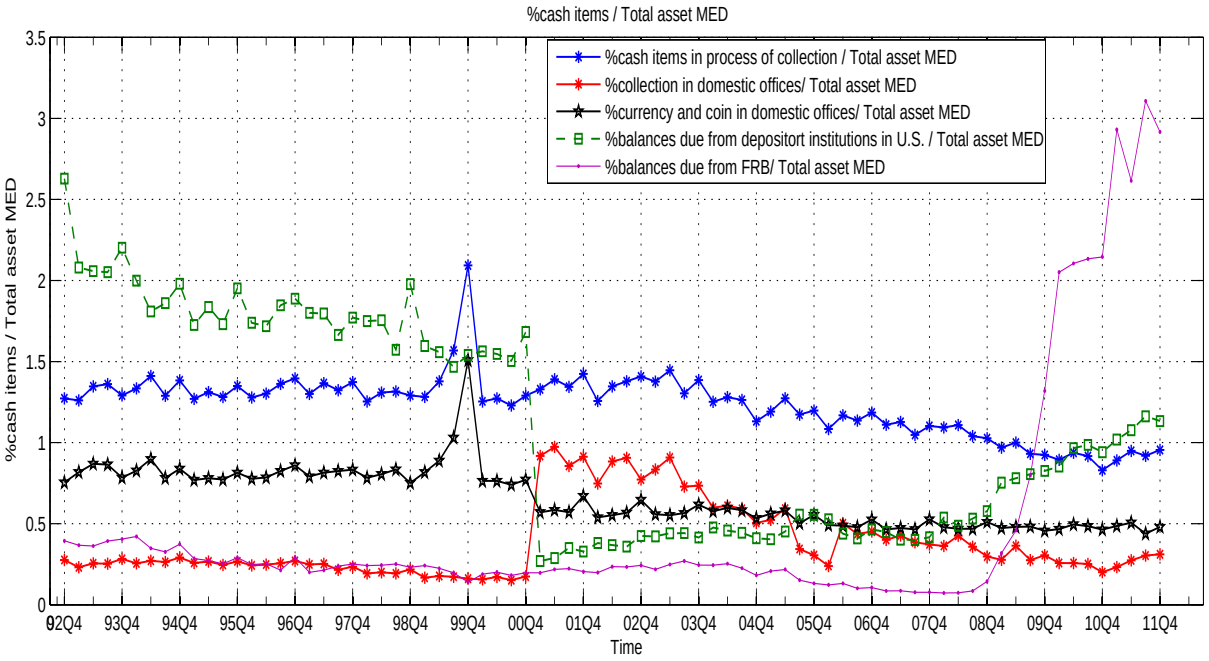
In contrast to the interbank loan given, the key ratios of cash and balances due from depository institutions showed a skyrocket around second quarter of 2009; and went up with moderate growth rate (see figure 14). After several rounds of contagion, some banks in U.S. are in default while others have enough capital to absorb the losses. These banks will consider themselves in

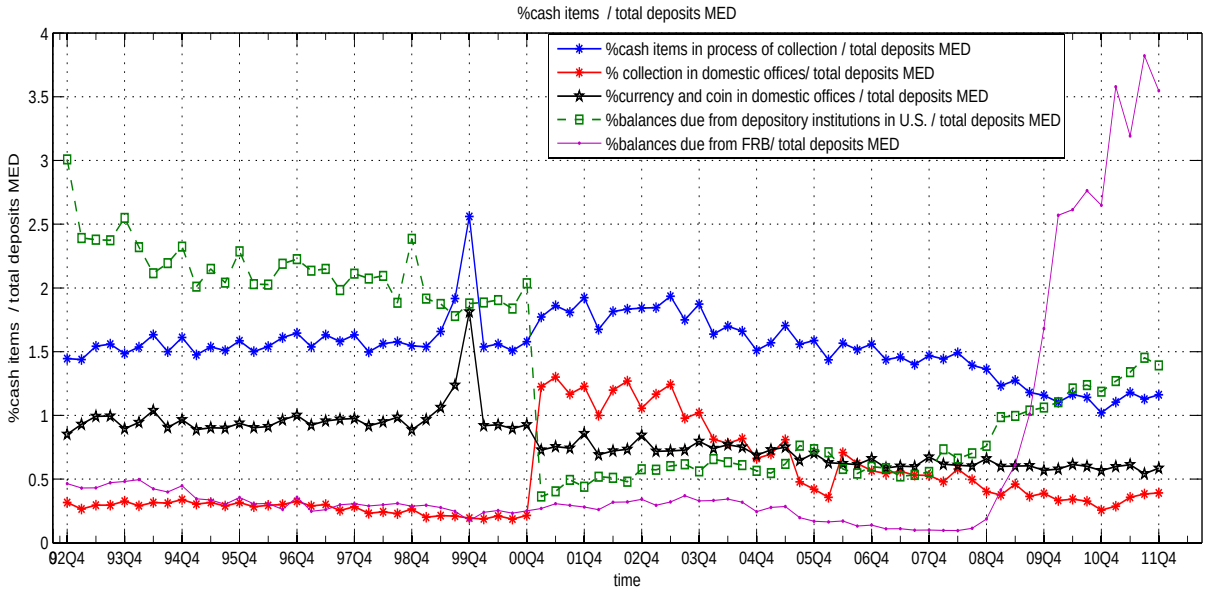
distress if their new level of capital does not satisfy supervisory requirements anymore, especially the failed in belief of "to big to fail" after Lehman Brothers went bankruptcy.

One possible reason of uprush observed in the Figure 14 (Page 71) is preemptive defensive actions from banks, such as liquidity hoarding. The changes happened around 2nd quarter of 2009 are also statistically significant. This is another important dynamic we will consider in our model. At the same time, banks may also experience a liquidity shortage from private investors in the money market, because they may face high quality collateral, high interest rates or simply reject the transaction. It can be observed according to the trend of the ratio of cash due from depository institutions to total deposit in Figure 14. If a bank fails to satisfy its short-term commitments, it defaults due to illiquidity. The Federal Reserve injected substantial liquidity and cut the funds rate by 300 basis points in interbank lending market in August 2007. But it worsened in March 2008. On 13th October, the U.S. treasury followed suit with a plan to inject $250 billion into the U.S. banks. Eventually, unprecedented actions by Federal to add liquidity and guarantee bank debts were able to counter the record strains in 2009, but did not prevent extensive damage to the whole financial system. The lower panel shown in Figure 14 (Page 71) indicate a larger scale of Federal funds had been injected into banks during the crisis; and a clear minimum can be found in 2009Q1 and another slump in second quarter of 2010. And the time has told these plans, which were similar to earlier, mainly successful, rescue solutions like the RFC in U.S. in the 1930s, may not solve the crisis.

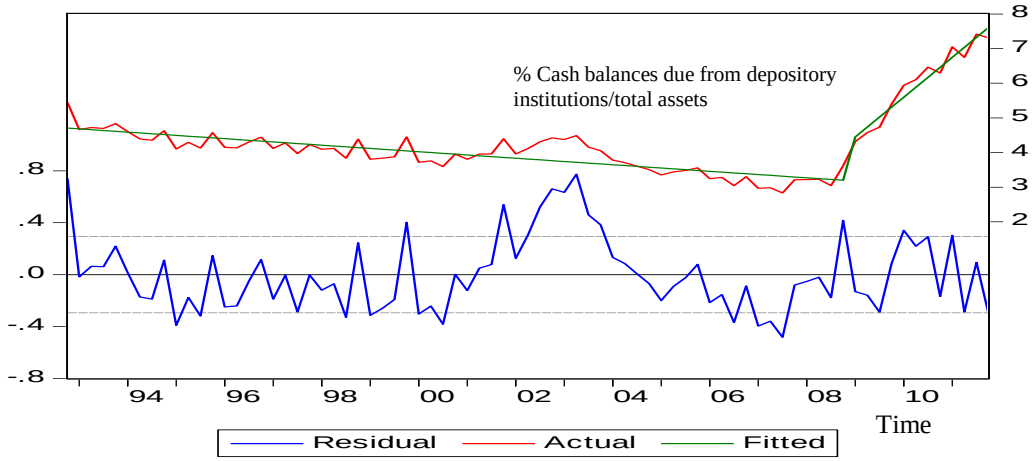
The recent banking crisis made painfully clear to alive banks that they cannot always count on being able to borrow at low cost when needed. Take the Lehman Brothers as an example: it seemed to be safe experienced creditor runs and significant cash outflows, which ultimately led to its defaults. Here, heavy reliance of financial institutions on wholesale funding was overlooked, whereas capital levels were closely monitored. The result is consistent with analysis in capital part. Again, the liquidity hoarding behavior of banks were observed, which may arise from failure of a specific asset and consequently fire sales, or a more general loss of confidence of confidence trust. Initial overpricing of assets by complex, untransparent assets credit rating agencies can make for severe liquidity shocks. However, one may argue new interbank loans might be granted as the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of financial crisis. The findings of this section will be considered in our studies in chapter 4 and 5.

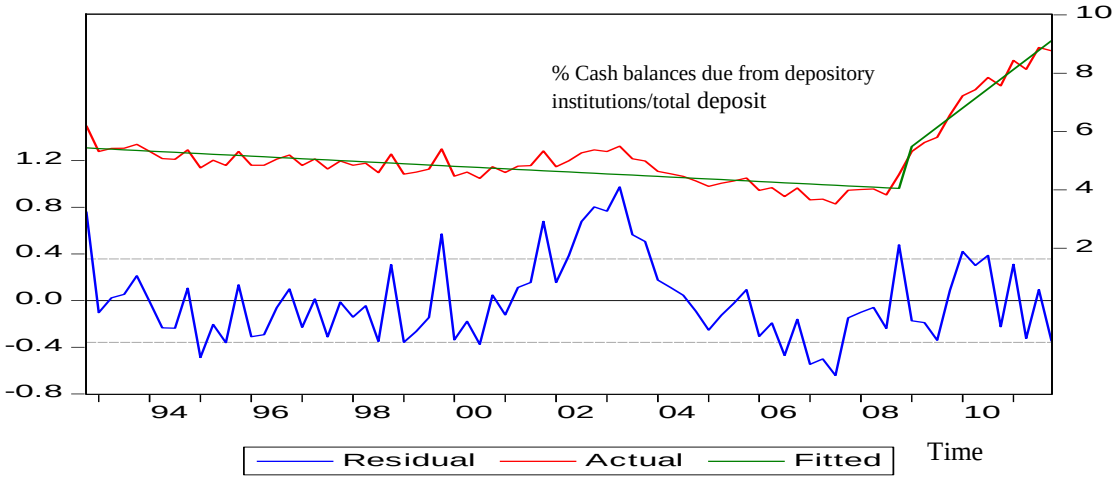
Figure 14: The estimated regressions of key ratios for interbank loan taken profile with their corresponding breakpoint, the U.S., 1992Q4 to 2011Q4[26]

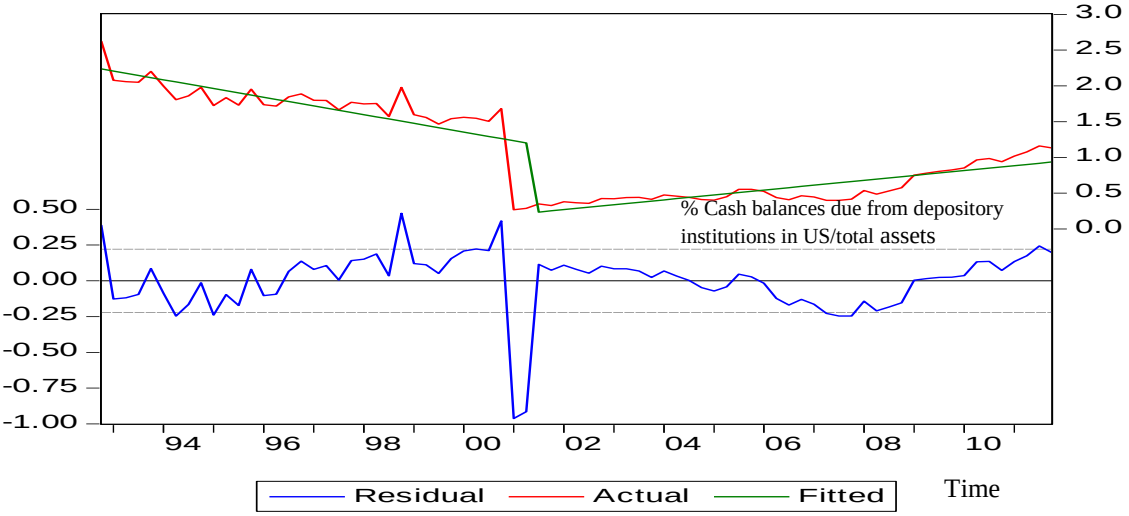




[26] Figure 14 continues in page 71, which presents the estimated regressions of key ratios of cash balances due from depository institution profile with their corresponding breakpoint


% Cash balances due from depository institutions/total assets
.8
.4
.0
-.4
-.8
8
7
6
5
4
3
2
94
96
98
00
02
04
06
08
10
Time
Residual
Actual
Fitted


% Cash balances due from depository institutions/total deposit
1.2
0.8
0.4
0.0
-0.4
-0.8
10
8
6
4
2
94
96
98
00
02
04
06
08
10
Time
Residual
Actual
Fitted


% Cash balances due from depository institutions in US/total assets
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
3.0
2.5
2.0
1.5
1.0
0.5
0.0
94
96
98
00
02
04
06
08
10
Time
Residual
Actual
Fitted

3.4.4 Key Ratios for Examining Liquidity

According to Uniform Financial Institutions Rating System (1997), a financial institution is required to maintain a certain level of liquidity to meet its potential financial obligations in a timely manner as well as liquidate assets with minimal loss. It is emphasized by Rudolf (2009) again: there may be a maturity or interest rate mismatch as banks make money by mobilizing short term deposits at lower interest rate while investing funds in long-term at higher rates.

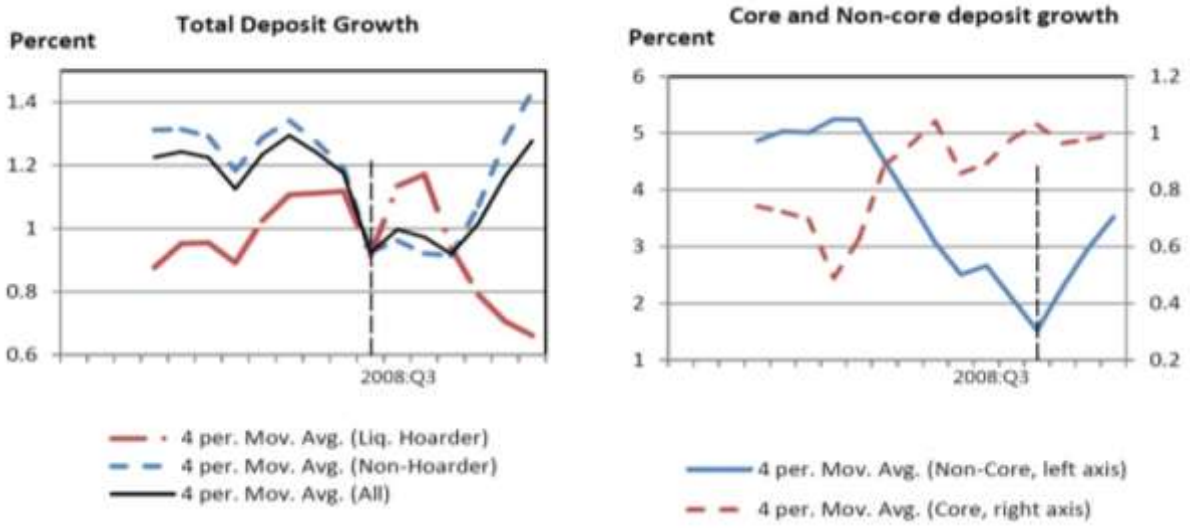


Figure 15: Deposit Growth (Quarterly growth rates, 4-period moving average)[27]

Figure 15 above depicts deposit flows of U.S. commercial banks between 2002 and 2011, and reveals a distinctive behavior of core and non-core deposits during the financial crisis. Previous work has raised concerns on the extent to which banks facing heightened liquidity risk are able to meet the increased borrowing demand from corporations shut out of commercial paper markets.

As argued by Diamond and Rajan (2001) and empirically documented by Gatev and Strahan (2006) and Gatev, Schuermann, and Strahan (2009), commercial banks can cope with higher loan demand in the form of drawdowns of unused corporate credit lines as long as they are perceived as less risky and receive deposit inflows from institutional investors pulling their funds from securities markets (e.g. the commercial paper market). Core deposits include transaction deposits, savings deposits, and small time deposits (less than $100,000). Non-core deposits include large time deposits ($100,000 or more) and foreign deposits.

[27] Please see full definitions of liquidity hoarder and non-hoarder in section 5.3. We class all banks into two groups: Liquidity hoarders and non-Liquidity hoarders. Liquidity hoarders in this study are defined as banks for which the average ratio of total liquid assets to total assets increased by more than 3.5-percentage-point from a period before the interbank lending crunch (1992:Q4 to 2008:Q2) to the crisis period (2008:Q3 to 2011:Q4).

The growth rate of core deposits increased during the crisis, whereas the growth of non-core deposits contracted by almost fifty percent. Such behavior suggests a flight-to-quality effect in deposit flows. The figure shows that deposit growth, mainly non-core deposits, decreased remarkably over the second half of 2007. The sharp contraction in non-core deposits began immediately after the interbank markets—especially, the ABCP market-dried up. Furthermore, this sharp contraction continued through the 3rd Quarter of 2008, despite the significant decline in short-term interest rates that followed the reduction of the target Federal funds rate about 2 percent by the spring of 2008. Deposit growth recovered months later, more notably by the end 2008. Intensifying turbulence in financial markets in particular after the failure of Lehman Brothers and AIG-caused significant outflows from money market mutual funds and contributed to the strong expansion of bank deposits. Favoured by the increase in the deposit insurance limit from $100,000 to $250,000 and the implementation of the Temporary Liquidity Guarantee Program (TLGP) in October 2008, transaction deposits grew considerably (about one-fifth) in 2008.

In this section, two key ratios are used for examining liquidity as a supplement of last part. They are Net Loans and Leases to Deposits Ratio and Net Loans and Leases to Core Deposits Ratio. More details with a certain criteria are listed in Table 2:

Ratios	**Formula**	**Criteria**
Net loans and leases to deposits ratio	Net loans and leases / Total Deposits	$\leq 75\%$
Net loans and leases to core deposits ratio	Net loans and leases / Core deposits	$\leq 80-90\%$

Table 2: Liquidity ratio analysis

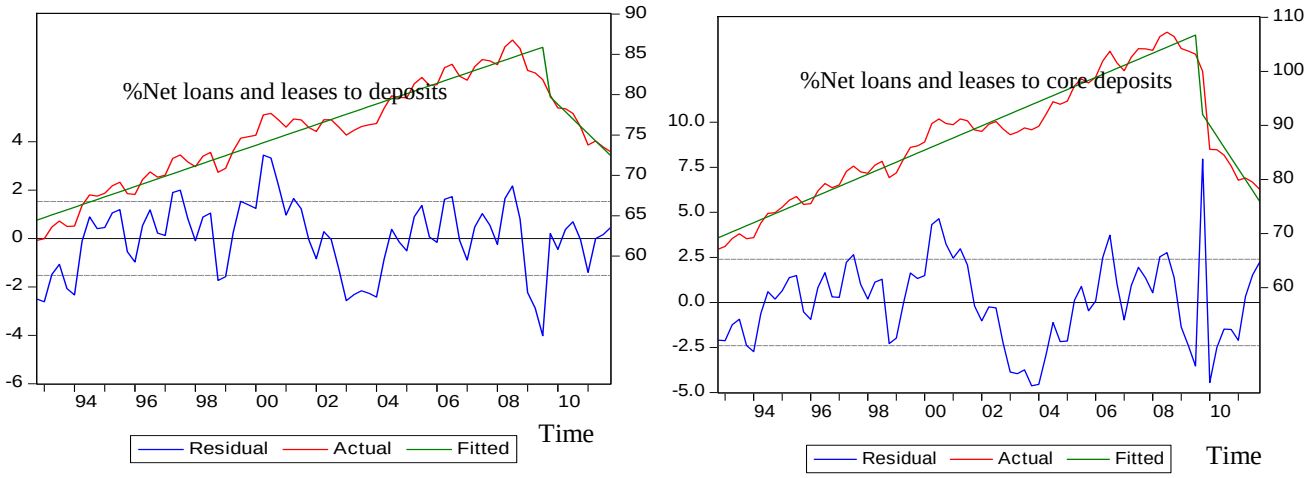


Figure 16b: The estimated regressions of two key ratios for examining liquidity with their corresponding breakpoint, the U.S., 1992Q4 to 2011Q4

In figure 16b, from 1992Q4 to 2009Q2, two ratios rose drastically, peaking at 87% and 107% in 2009Q2 respectively. The changes in both level and trend are statistically significant (see Appendix 5). Then the trends of both turned strongly downwards, bring the figures down to 73% and 77% respectively in the fourth quarter of 2011. It is noticeable that the robust lending growth during an inflationary and house booming environment before the financial crisis raised the concern on banks' liquidity. The net loans and leases to core deposits ratio was higher than the maximum level of 80% to 90% in most time after year 2003; which indicated that the bank didn't have capacity to write new loans, but, they just simply ignored the problems. The deposits mismatched to investments and banks ignored the facts that they may not be converted quickly to cover redemptions. The results of liquidity ratio analysis support the observed liquidity hoarding behavior of banks and less active moments in interbank loan market. The crisis prompted a surge in demand for liquid assets in the entire U.S. financial system, in turn, rather than lend surplus liquid assets out, most banking preferred to hold, in case their own need might increase. With the increasing level of uncertainty and counterpart risks, banks became increasing unwilling to lend and thus the size of interbank loans in average plummeted by the end of 2008; For example, the big fall happened after the failure of Lehman Brothers in September, particularly in the interbank market. The situation only got to be controlled by the end of 2009 after a large scale of government injection and banks' liquidity hoarding.

The results from the empirical investigations in previous section, which can be assumed to be valid in principle for most banking systems, provides us with some guidance on the banks' dynamic actions in the interbank loan market that we are able to use in our research design (Brunnermeier, 2009; Cornett, McNutt, Strahan, and Tehranian, 2011; Gorton and Metrick ,2012). In this section, we found that whereas capital levels were closely monitored, heavy reliance of financial institutions on whole-sale funding was overlooked: banks that seemed to be safe experienced bank runs, which ultimately led to their defaults. The sudden decrease in interbank market activity and increase in the banks' liquidity hoarding behavior were observed as well. However, one may argue new interbank loans might be granted, extended and withdrawal as the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of financial crisis.

3.4.5 Key Ratios for Examining Profitability

There are three ratios we present as a measurement of profitability: net interest margin, yield on earning assets and noninterest income to earning assets.

Overall, yield on earning assets and noninterest income for all banks increased significantly before 2006; however, both net interest margin decreases. Our result suggests that both net interest margin and yield on earning assets serves as indicator for the timing of a crisis. A break was found at 2008Q1 in post crisis period. And net interest margin is appropriate indicator for the detection of banking system vulnerabilities. It provides a signal for systemic banking problems. The net income for commercial banks did plunge in 2007, which is a significant response to the financial crisis.

Recall chapter one, Figure 2 shows the non-interest income to total income for United States banks from 1998 to 2013. Compare to net interest margin, it does not suggest any significant changes before 2006 but some increase between 2003 and 2006 (See Figure 18). It experienced a sharp decline in bank returns and non-interest income in early 2003 due to monetary policy. Figure 3 in chapter one displays net income for commercial banks in United States, which shows a significant increase despite a gradual increase in non-interest income before 2007 (see Figure 2).

Here, according to the definition of Heffernan (2005), we define the net interest margin as the difference between the loan rate and deposit rate; and it also cover additional costs including operation costs, intermediation fees and risk premiums. In Figure 17, it is clearly shown that overall interest margin declines through the period and it touches the bottom at 2008Q1.

A bank acts as an intermediary role by taking deposits and granting loans and it plays a core role in reallocating capital because of the economies of scale: Banks can access more privileged information on borrowers; therefore the information economies of scale would enable banks to lending at lower cost compare to other financial institutions.

The drops of net interest margin may due to the volatility of interest rate, as it could make costs of short-term funding higher than interest incomes from long-term loans. In this case, a higher interest margins will be required to cover additional costs including operation costs, intermediation fees and risk premiums, and thus a lower net interest margin. And, in order to maximise returns at lower costs, bank may increase non-traditional activities to offset the losses

traditional bank actives, which bring more diversification as well as high risk (Valverde and Fernandez, 2007).

In the past three decades, the banking industry has showed a trend in the diversification of financial services and consolidation of financial institutions, especially prior to the financial crisis in 2007/08. This trend can be found at Figure 19. Thus, it that there's an evidence showing U.S. banks moved away from traditional activate to non-traditional services to achieve higher non-interest income because of the greater competitions in traditional financial market. Non-interest income increases dramatically since 2002 and then the speed of increase slows around 2003Q3. The break is statistically significant under 5% significant level.

The reason for this might be the serious regulation that restricted the establishment of branches (Canals, 2006; Cole and White, 2012; Fahlenbrach et al., 2011; Mishkin, 2002). In the United States, although a large number of financial institutions had existed since the 1980s, the number decreased due to a national consolidation through which banks could increase their size in order to benefit from the economies of scale (Mishkin, 2002). It experienced a sharp decline in bank returns and non-interest income in early 2003 due to monetary policy. It also maybe some banks considered the switching costs from traditional bank activities to new activates, therefore they still focus on traditional services but make an effort to improve the efficiency of financial operations. Modern economists believed that a large number of new lines of non-traditional financial services cause higher risk-taking, thus further tiger bank failure and financial instability (Stiroh, 2006; Saunders and Walter, 1994; Welfens, 2008). Thus, in these cases, banks have more incentive to become large through consolidation in order to benefit from the economies of scale (Canals, 2006). In contrast, Fahlenbrach *et al.*, 2011and Cole and White, 2012 concluded that the causes and nature of banks' financial weaknesses during the recent financial crisis were similar to those observed at banks that failed or performed poorly during previous banking recessions. Banks that engaged in risky non-traditional activities also tended to take risk in their traditional lines of business, suggesting that deregulation was neither a necessary nor a sufficient condition for bank failure during the crisis.

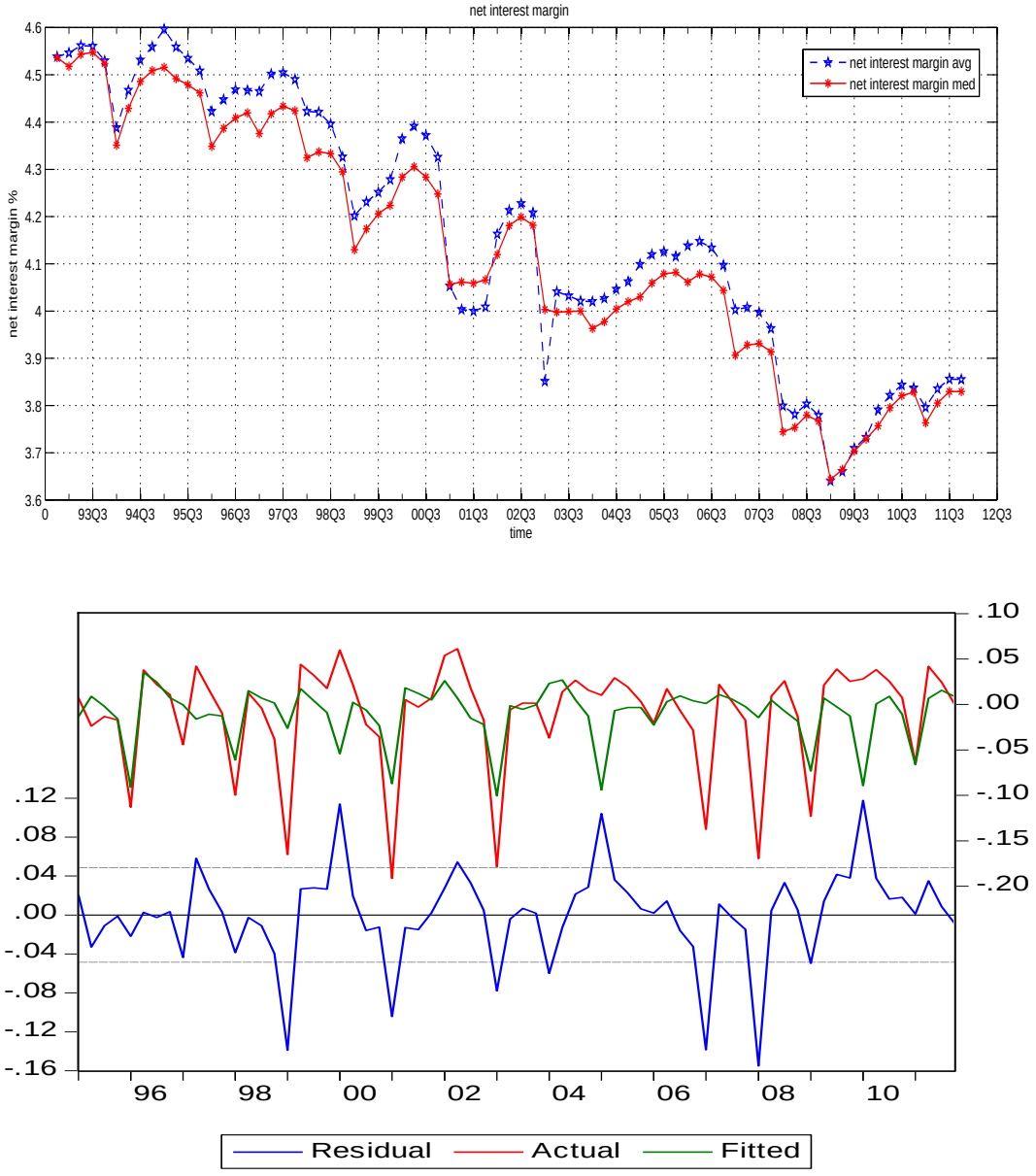


Figure 17: Net Interest Margin for all Banks in United States from 1992 to 2014

Note: Break found at 2008Q1

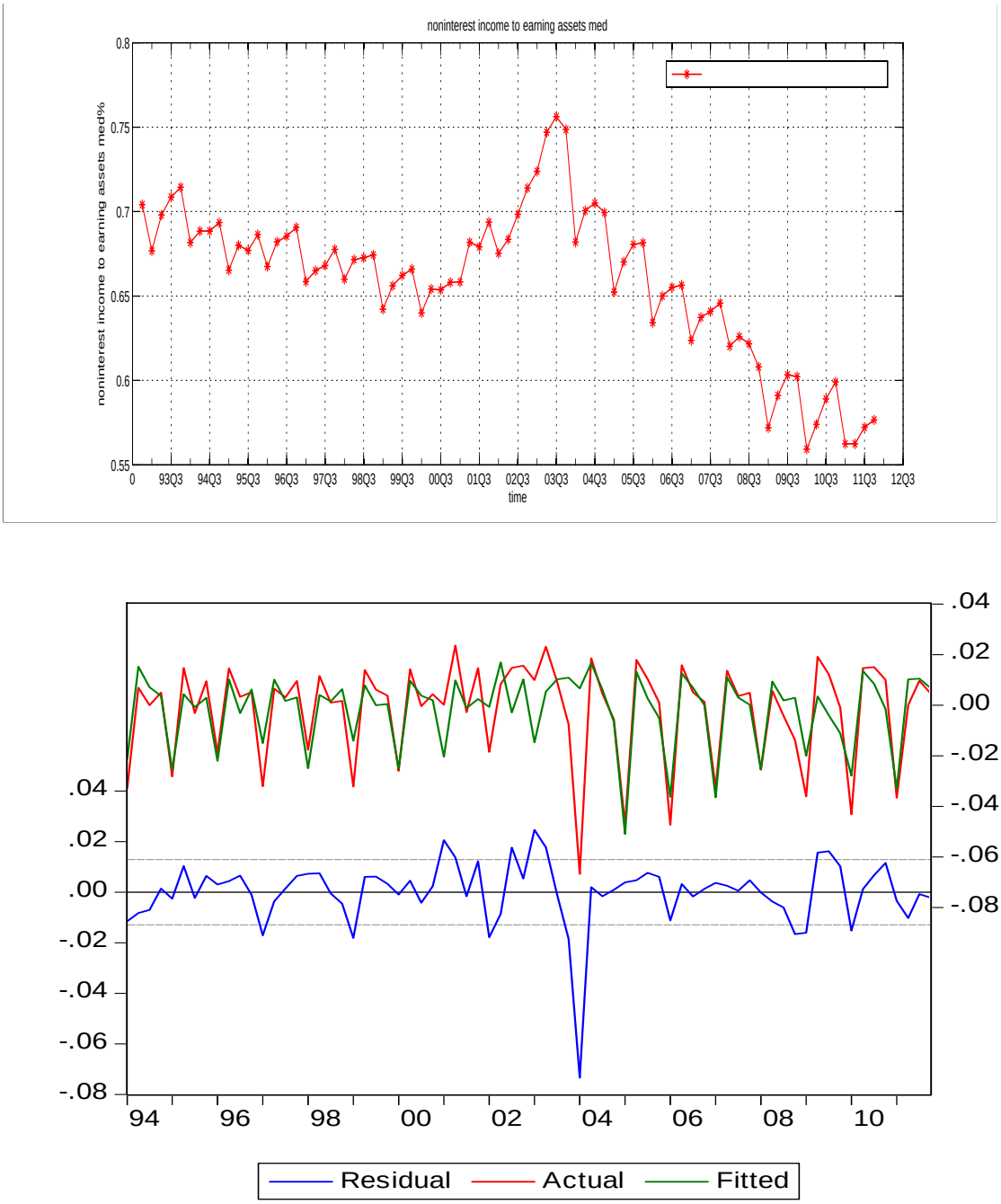


Figure 18: Non-Interest Income to Earning Assets for U.S. banks from 1992 to 2014

Note: Break found at 2003Q3

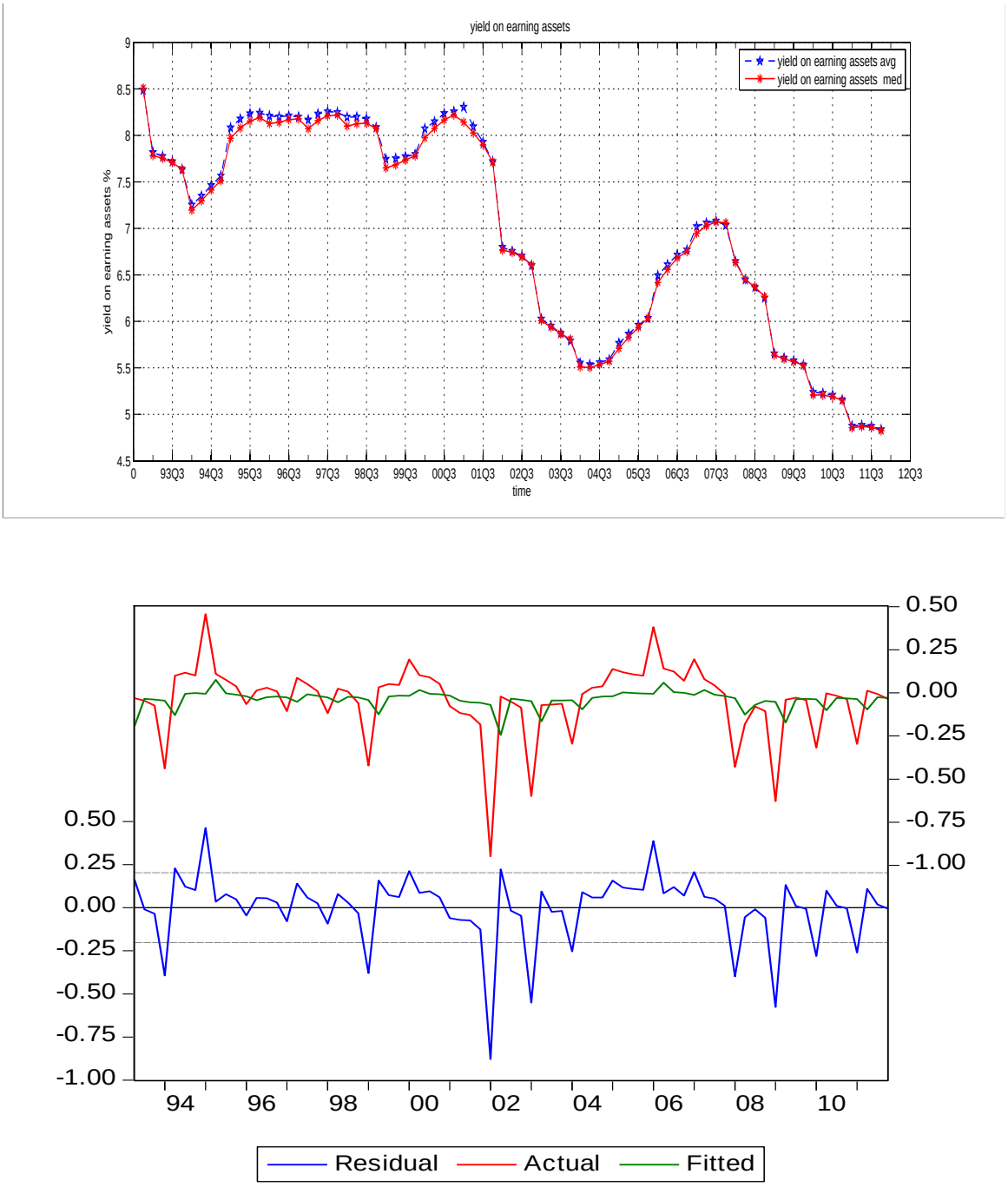


Figure 19: Yield on Earning Assets for U.S. banks from 1992 to 2014

Note: Break found at 2008Q1

3.5 The Bank Size Effect and Episode Analysis

Beltratti and Stulz (2009) argued that many large banks have seen most of their equity destroyed by the recent financial crisis in 2007/08. Was the poor performance of the banks the outcome of a financial Tsunami that hit them unexpectedly, or were large banks more predisposed to experience large losses? Many observers have argued that ineffective regulation contributed or even caused the collapse. If that is the case, we would expect difference in the regulation of financial institutions regarding to bank sizes to be helpful in maintain the stable of financial system. Other observers have criticized the governance of small banks and suggested that better governance would have led to better performance during crisis. It is need to be pointed out that banks were affected differentially simply because they had different balance sheet and thus different financial ratios. In this section, we discuss the consequence of 'too big to fail' (TBTF) and show differences in the applicability of banking accounting ratios for the identification of banking problem between large, median and small banks.

Section 3.5 address similar issues to those discussed in section 3.4, and same data and methods are employed. Therefore, only results and discussions will be presented in this section. Please refer to methodology in section 3.3 for further reference. In order to consider the effect of bank size in identifying significant structural shifts of selective early warning ratios in response to the crisis, we divide whole sample into three groups (big bank, median bank and small banks) by bank sizes. A bank is classified as a small firm if its bank asset size is below the 60^{th} percentile, as a medium-size banks if its total asset is between the 60^{th} and 30^{th} percentile, and as a large bank if its bank assets is above 10^{th} percentile. Three sets of proportions of bank sizes are considered to divide sample in our work: 25%-50%-25%; 10%-20%-70%; and 10%-30%-60%; and the 3^{rd} asymmetric way is most suitable way for current U.S. bank system. Please see Appendix 9 for full results.

3.5.1 The Bank Size Effect

All in all, we've found bank size does matter in context of applicability of banking accounting ratios serve as early warning signals. Our results suggest that certain indicators such as nonperforming loans ratio (NPLs), loan deposit ratio, loan provision ratio and interbank lending ratio are appropriate indicators for the detection of banking system vulnerabilities for both big and small banks. And nonperforming loans ratio (NPLs) additionally serves as an indicator for

the timing of a crisis. However, again capital ratios failed to provide signals for systemic banking problem.

While the changes in the financial system affected all banks, they had a particularly large impact on the largest banks. The business model of large banks became clearly distinct from that of small or medium-sized banks. The evolutions of regulatory capital ratio, nonperforming loans ratio (NPLs), loan deposit ratio, loan provision ratio and interbank lending ratio are carefully examined in each sub group. The business model of large banks became clearly distinct from that of small or medium-sized banks. First, large banks today engage disproportionately more in market-based activities (Figure 20 and 21). Second, large banks hold less capital than small banks, as measured either by a tier 1 capital ratio or a leverage ratio (Figure 22 and 23). Third, large banks have less stable funding than small banks, as measured by the ratio of deposits to total assets (Figure 24). Fourth, large banks engage more interbank activities, as measured by interbank loan (Figure 25). From Figure 26 below, while the financial crisis started from 2007, triggered an unprecedented, sustained strains in interbank lending; we found that the interbank market was large and active, for large banks, in the U.S. in early 2008. With the increasing level of uncertainty and counterpart risks, all banks became increasing unwilling to lend and thus the size of interbank loans in average plummeted by the end of 2008; the big fall happened after the failure of Lehman Brothers in September. The crisis prompted a surge in demand for liquid assets in the entire U.S. financial system, in turn, rather than lend surplus liquid assets out, most banks preferred to hold, in case their own need might increase. The situation was constantly becoming worse when interbank loans created a vicious circle of increased caution, greater demand for liquidity, reduced willingness to lend and higher loan rates, the waves of financial crisis can be seen in the graph. For small banks, the evidence demonstrates that funding fragility and the changes of interbank loans both in level and trend at third quarter of year 2008Q4 were highly statistically significant (Figure 27). Finally, large banks have poorer asset quality than small banks, as measured by NPLs to total gross loans ratio (Figure 28).

Figure 20: Large Banks Engage More in Nonlending Activities

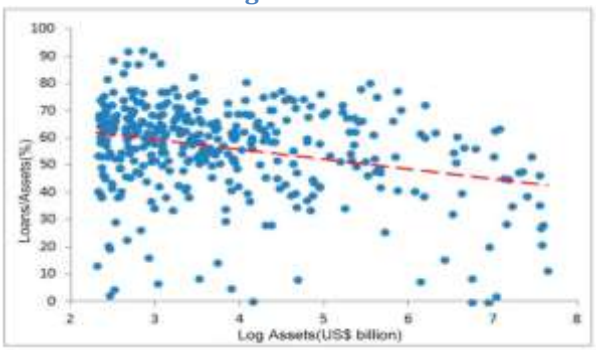


Figure 21: Large Banks Generate More Income from Noninterest Income

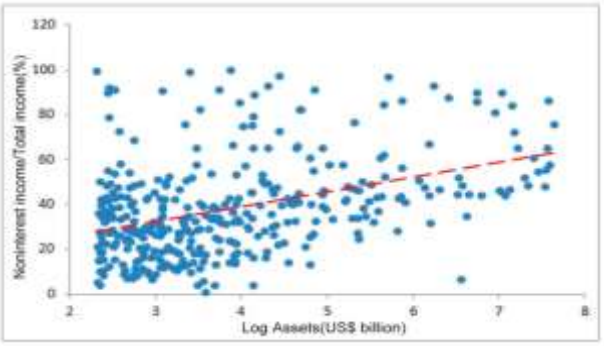


Figure 22: Large Banks Hold Less Tier 1Capital

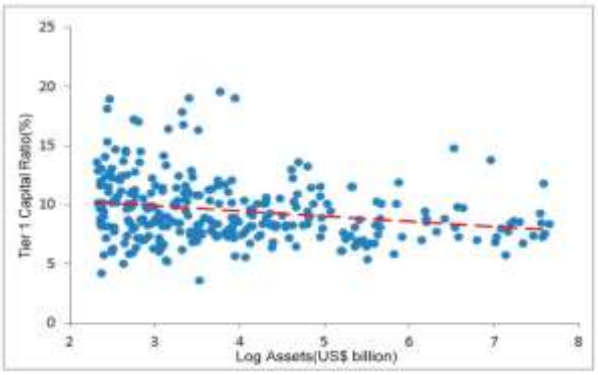


Figure 23: Large Banks Have Higher Leverage

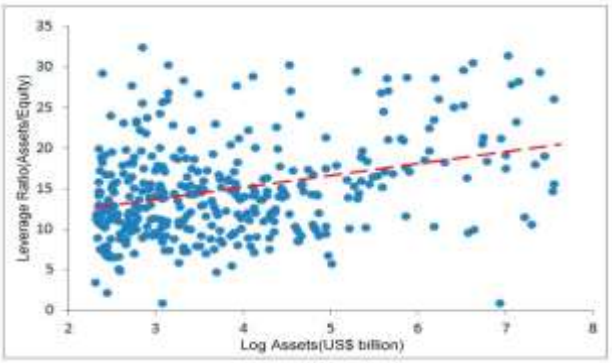


Figure 24: Large Banks Have Fewer Deposits

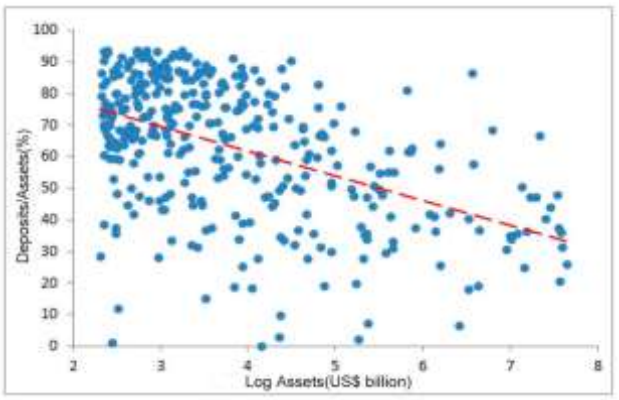
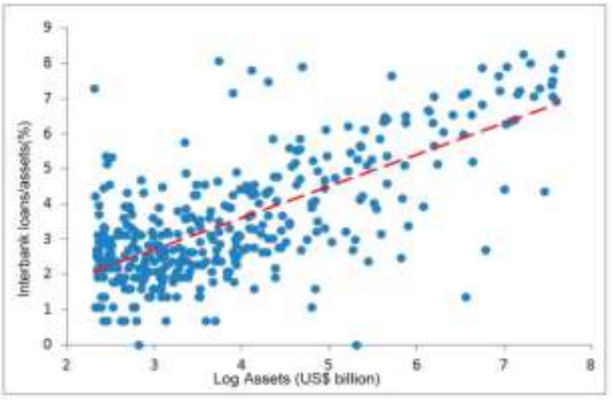
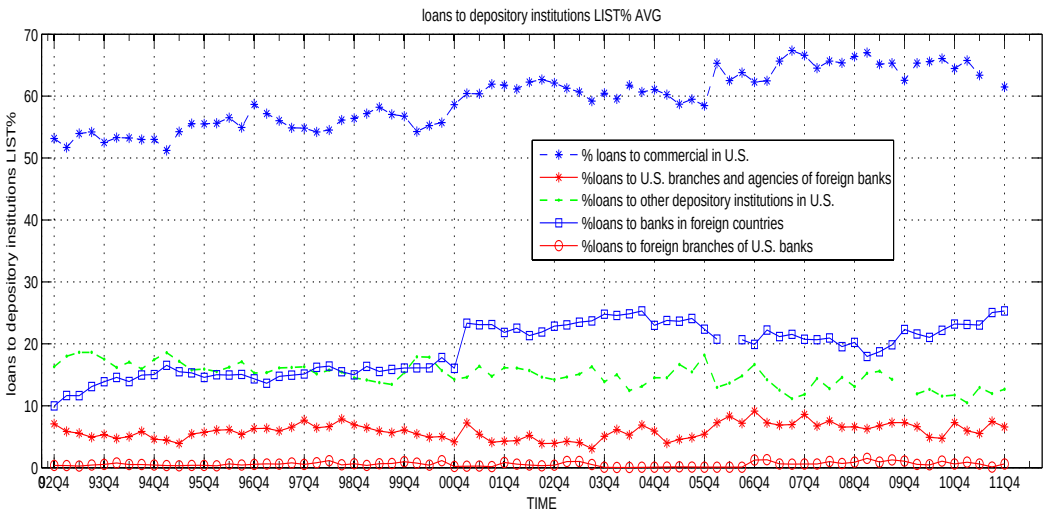


Figure 25: Large Banks Have More Interbank Loans





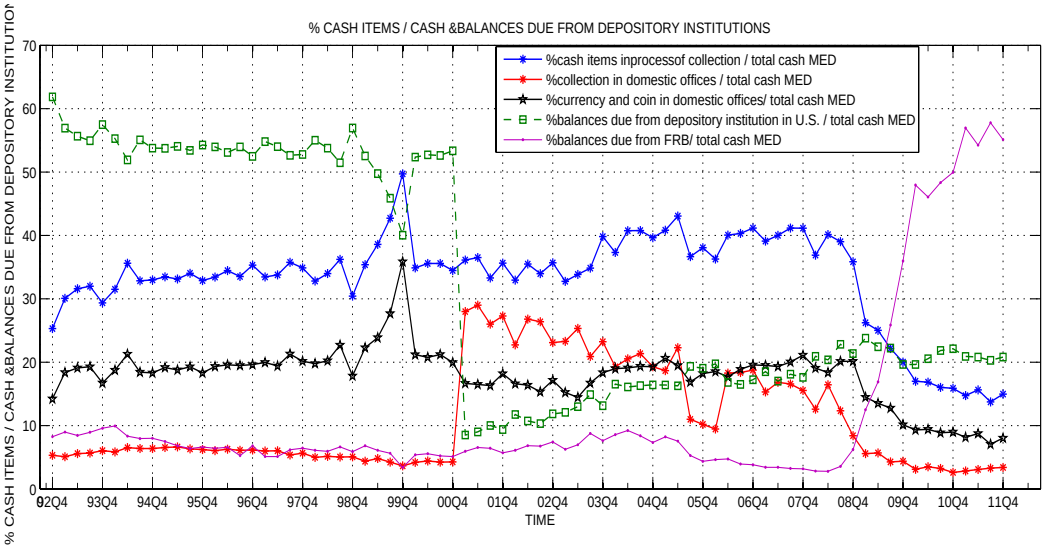


Figure 26: The interbank lending profile for large banks

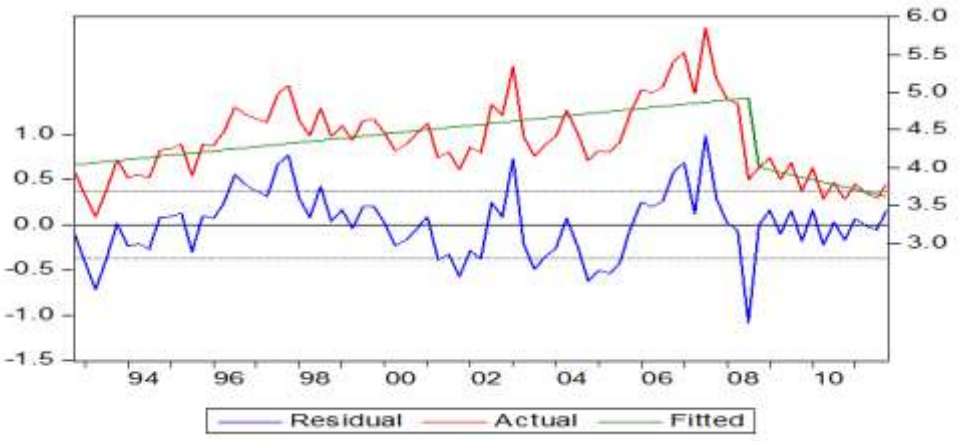


Figure 27: The estimated regressions of key ratios for interbank loan for small bank

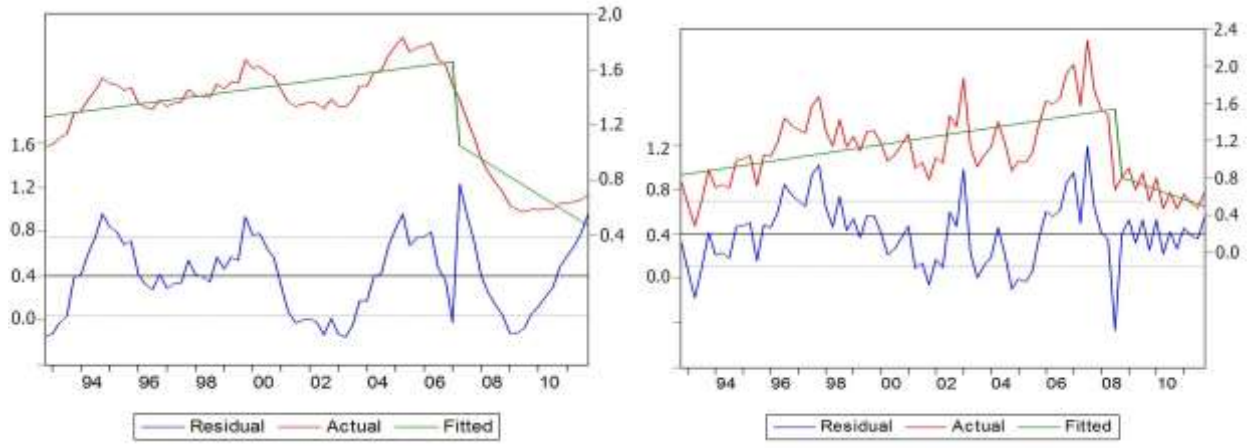


Figure 28: NPLs to total gross loans ratio for both large(Left) and small banks(Right)[28]

[28] NPLs to total gross loans ratio increase in run up to a crisis, indicating that financial systems recognize poor asset quality; it bottomed itself by the end of 2007 for large banks, which is quicker than small banks. This follows the

There are a number of possible explanations for why large banks act differently:
One explanation is that large banks benefit from economies of scale, and this affects their business model. Large banks benefit from too-big-to-fail subsidies, although their value is also uncertain and varies across countries and over time. See Chapter 3 of the IMF's April 2014 Global Financial Stability Report for a review of the current thinking on the too-big-to-fail subsidies (IMF, 2014). First, size allows better diversification, which reduces risks and allows banks to operate with lower capital and less-stable funding. It may also facilitate market-based bank activities. And, large banks also may operate in a different market segment than small banks. Large banks may have a comparative advantage in market-based activities, which require significant fixed costs and enjoy economies of scale. Market-based activities may invite more leverage and unstable funding, because securities can be used as collateral in repos. Small banks may stick to their comparative advantage in traditional, relationship-based lending.

The literature on the economies of scale in banks is inconclusive; therefore it is difficult to determine optimal bank size. Early studies have found economies of scale to be limited to relatively small banks, with no evidence of economies of scale in banks beyond US$10 billion to US$50 billion in assets (Benston, Hanweck, and Humphrey, 1982; Berger and Mester, 1997; Peristiani, 1997). More recent studies question these results and find economies of scale for large banks. There are valid economic reasons for why the evidence may have changed: with the advance of information technologies and the proliferation of scalable market-based operations, optimal bank size may have increased. Most studies on economies of scale focus on cost economies-the ability of banks to efficiently use overhead. Kovner, Vickery, and Zhou (2013) estimate the total value of such economies in the U.S. banking system for banks over US$50 billion in assets to range between US$16 billion and US$45 billion a year, corresponding to 0.1 to 0.25 percent of GDP.

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result of Cihakand and Schaeck (2000). One possible explanation of those is that banks start to increase loss allowance and decrease the long-term loan lending in order to protect them from illiquidity. All in all, NPLs verified the structure break date of 2006Q3 for large banks and 2008Q2 for small banks during the financial crisis. We only found a statistically significant break date of 2007Q4 for loan loss allowance to noncurrent loans ratio for both group of banks. It seems to also indicate that provisioning lags behind the recognition of NPLs before crisis, which may affect linter alia perceptions of vulnerability and changes were consistent with the assumption. The NPLs worked well as it gave a good warning sign just before the financial crisis began.

Another view is that large banks respond to (inefficient) too-big-to-fail subsidies. Due to a perception that the creditors of large banks will be bailed out in case of bank distress, the cost of debt for large banks is lower. This makes banks more willing to use leverage and unstable funding, and to engage in risky market-based activities. Some researchers take into account the diversification abilities of large banks. Studies that allow for possible changes in the input and product mix of banks find significant economies of scale (Hughes and Mester, 2013; Wheelock and Wilson, 2012). Large banks diversify by moving from traditional deposit-taking and lending to more cost-effective but riskier wholesale funding and market-based activities. However, the negative returns to scope for banks that engage in market-based activities is evident in lower market valuations (Laeven and Levine, 2007; Schmid and Walter, 2009), higher risk (Brunnermeier, Dong and Palia, 2012; De, 2010; Demirgüç-Kunt and Huizinga, 2010; DeYoung and Torna, 2013), and lower risk-adjusted returns (Baele, De Jonghe, and Vander Vennet, 2007; Stiroh, 2004; Stiroh and Rumble, 2006). This evidence points not only to the destruction of shareholder value but also to potential costs for other stakeholders in the bank, including taxpayers, from the risk of failure. Yet it may be that banks' involvement in market-based activities creates surplus to bank customers. In this case, from a social welfare perspective, the returns to scope in banking may still be positive. Interestingly, the source of these negative returns is not technological. Indeed, a large literature points to the benefits of the efficient use of information from lending in the market-based activities of banks (Drucker and Puri, 2005; Kroszner and Rajan, 1994; Puri, 1996). Rather, the source of the negative returns to scope is the agency costs in banks that engage in market-based activities (Boot and Ratnovski, 2016).

The third view is that excess bank size is a consequence of managerial empire-building, and that large banks suffer from bad corporate governance. Managers may reach for size to receive larger compensation (Murphy, 1985; Gabaix and Landier, 2008) or because they enjoy private benefits from the prestige of running a large firm (Jensen, 1986). Managers can boost bank size by attracting additional funding and increasing bank leverage, or through mergers and acquisitions of other banks. While the consolidation process has improved access to finance for U.S. firms and households, it has destroyed corporate value for many banking firms in the process, especially those that combined traditional banking with investment banking activities (Levine, 2007; Reinhart and Rogoff, 2009) and those that spread geographically (Goetz, Laeven, and Levine, 2013).

The corporate governance challenges in large banks are especially significant given that large banks tend to be more highly leveraged, have more complex organizations, and engage in trading activities to a greater extent. First, there are limits on the concentration of ownership and takeovers (Caprio and Levine, 2002; Laeven, 2013). For example, U.S. regulation effectively limits nonbank ownership of banks to no more than 10 percent of the voting stock. Limits on ownership also limit takeovers. Uncoordinated shareholders and an absence of the takeover threat reduce the influence that bank shareholders wield over bank managers. Second, banks are highly leveraged institutions. This means that their shareholders may have aggressive risk preferences, which are not in the interest of other stakeholders - depositors, creditors, and the government. Indeed, there is evidence that banks where shareholders exercise more control tend to take more risk (Saunders, Strock, and Travlos, 1990; Laeven and Levine, 2009).Third, the risks associated with the trading activities of banks may be genuinely difficult to control, either by shareholders or management (Mehran, Morrison, and Shapiro, 2011; Glode, Green, and Lowery, 2012; Ellul and Yerramilli, 2013). Banks have much scope to manufacture "tail risks" that are hard to quantify in normal times (Acharya *et al.*, 2013), and, given the difficulty in assessing the riskiness of such positions, it is almost impossible to establish any neglect of management's fiduciary duty to shareholders. Given the distorted incentives of bank shareholders, a natural proposition might have been to expand the control over banks to other stakeholders, such as creditors or government representatives (Macey and O'Hara, 2003). However, the literature points out that this is not a panacea, as creditor or government control may lead to directed or affiliated lending, compromising credit quality (Sapienza, 2004).

All of the explanations above have some validity. The explanation that large banks are so large and operate in the way in which they do because of economies of scale is benign: It suggests that bank size is economically beneficial. Explanations based on too-big-to-fail subsidies and bad corporate governances imply that distortions may be present. Banks may be too large compared to what is socially optimal, and have no incentives to shrink because of private interests of shareholders or managers. Taken together, this implies that there may be a trade-off with large banks reaping economies of scale and scope but contributing to systemic risk.

3.5.2 Episode analysis

The 2007/08 financial crisis was characterized by non-bank FIs acting as one of the main triggers of the distress, the so-called "*the non-bank clue*" (FCIC, 2010), which is a novel property of the financial crash and is presented as a three-stage process (3 episode) in **Appendix 10**. In this section, those statistically significant changes of slope and/or trends of financial indicators are summarised and mapped by 3 sub-periods including the run-up to the recent financial crisis 2007-2008, the 3 episode of the crisis, and post stage of the crisis:

Episode1 The Liquidity Crisis of 2007

1. Failure of mortgage lenders (early 2007)
2. Hedge fund losses (end of July)
3. Run on commercial paper (summer of 2007)
4. The government response

Episode2 The run on Bear Stearns (early 2008)

1. Financial guarantors
2. Run on auction-rate securities
3. Bear Stearns and the run on repo and other collateral
4. The government response

Episode3 The panic of 2008

1.The failure of Lehman Brothers (September 2008)

2.The government response

Groups	Break Point	QUANDT-ANDRES UNKNOWN BREAKPOINT	CHOW TEST	BAI_PERRON TEST	Zivot-Andrews Test	BAI_PERRON TEST	Two- Break Lee Strazicich Test			
	Maximum LR/WALD F-STATISTIC				Break point	Break point	Model	Break point	Model	Break point
Capital adequacy	2001Q4	2006Q4	Y	2008Q1	2001Q1	2007Q1	C	2006Q1	C	2006Q1
Asset quality	2008Q1	2001Q4	Y	1995Q2	2001Q2	2006Q2	C	2007Q2	C	2006Q3
Profitability	2009Q2	2007Q1	Y	2004Q1	2008Q1	2006Q3	C	2007Q1	C	2007Q1
Liquidity	2001Q3	2008Q1	Y	2008Q1	2002Q3	2001Q3	C	2001Q3	C	2001Q3/ 2007Q1
Interbank loans	2007Q4	2008Q2	Y	1996Q1/2007 Q4	1997Q3	2007Q3	C	2009Q1	C	2008Q4

Table 3: Structural shifts identified by different methods

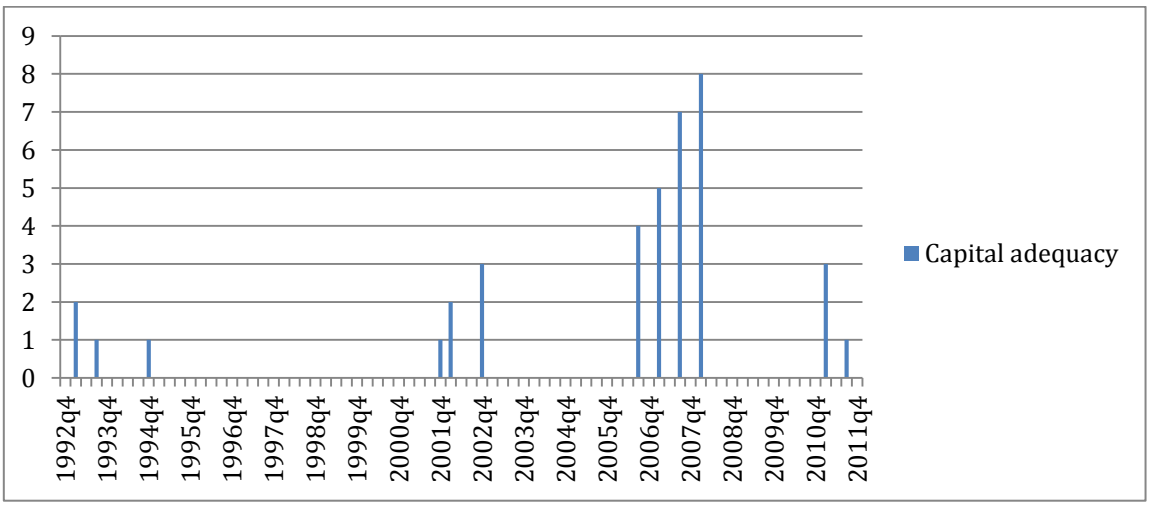


Figure 29: The breaks identified by capital adequacy ratios in aggregate level

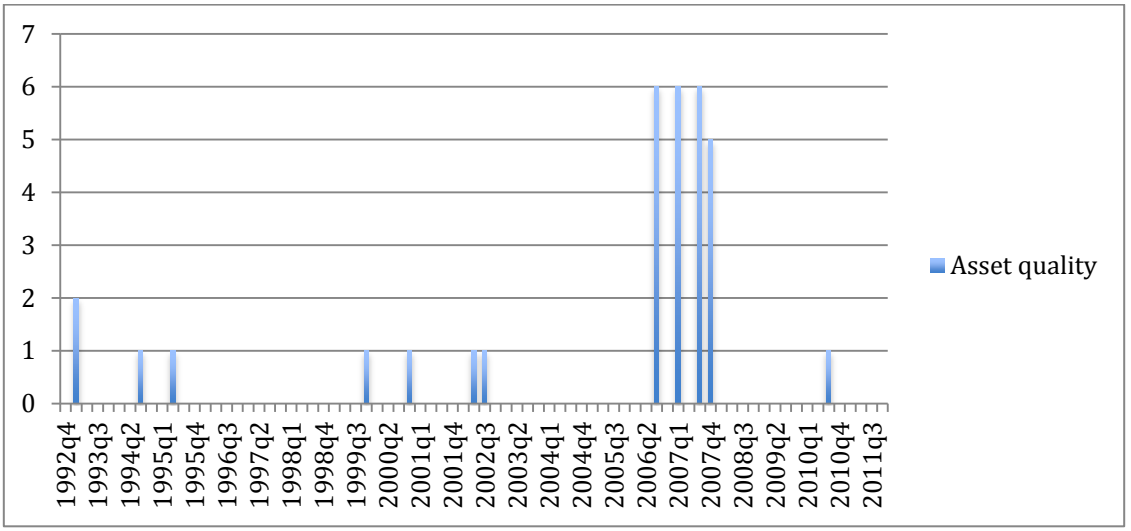


Figure 30: The breaks identified by asset quality ratios in aggregate level

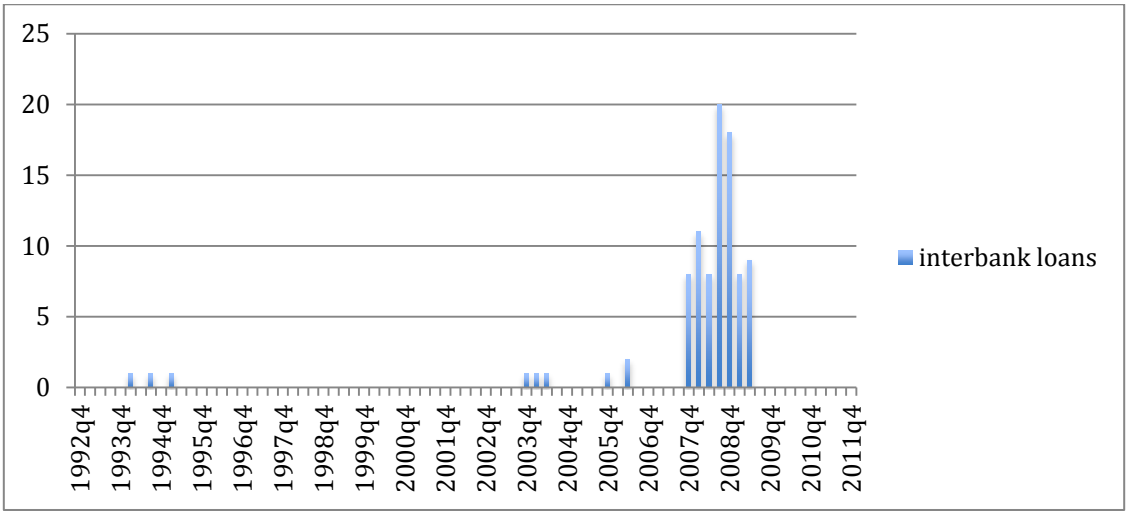


Figure 31: The breaks identified by interbank loan ratios in aggregate level

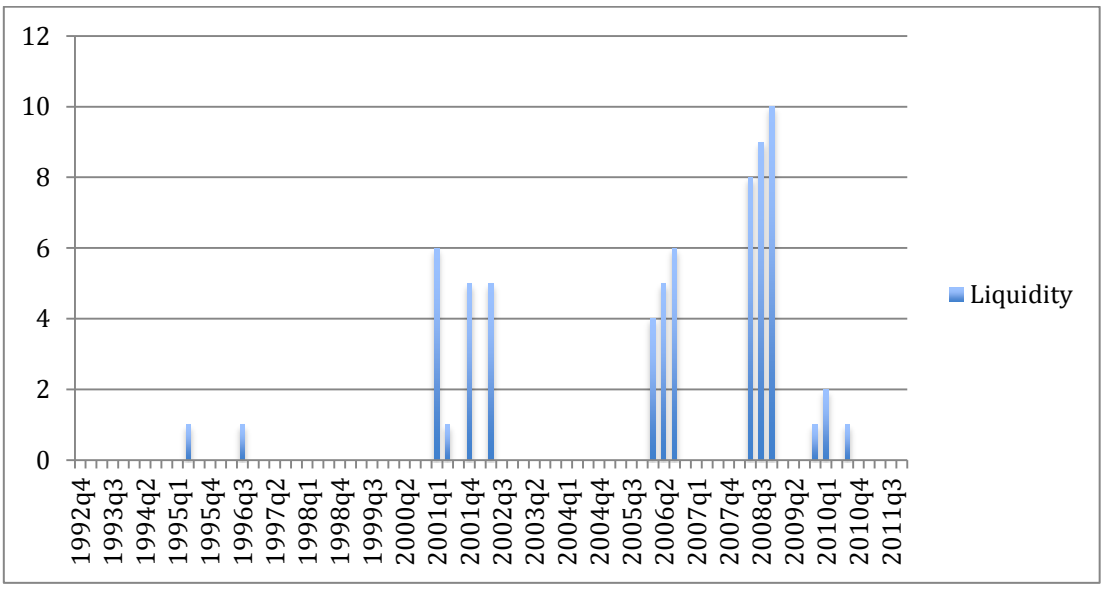


Figure 32: The breaks identified by liquidity ratios in aggregate level

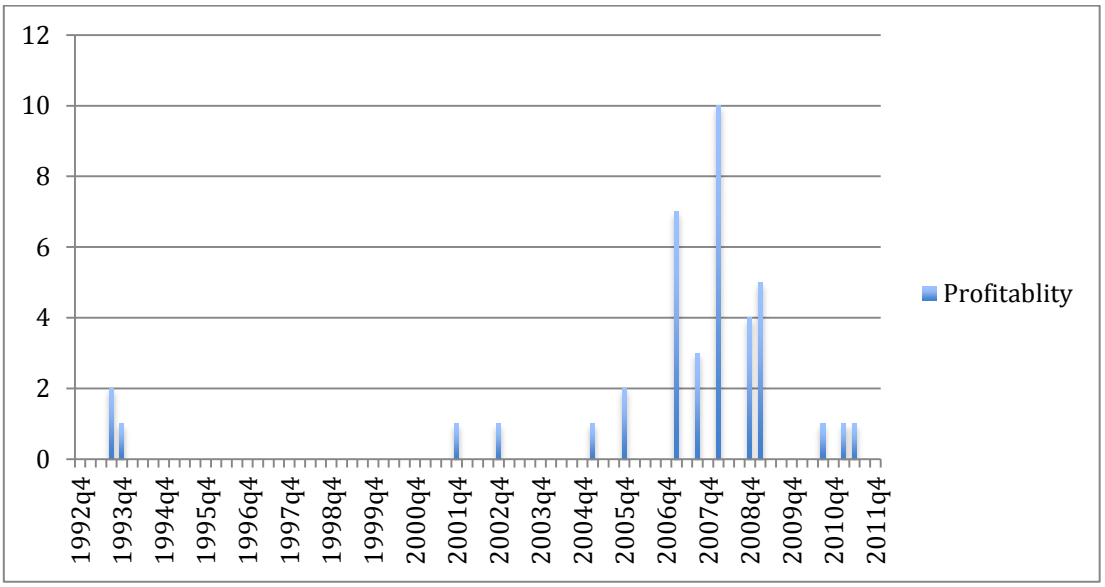


Figure 33: The breaks identified by profitability ratios in aggregate level

	All banks		Large banks		Small banks	
Groups	NO. of ratios	NO. of beaks	NO. of ratios	NO. of beaks	NO. of ratios	NO. of beaks
Capital adequacy	24	38	24	42	24	30
Asset quality	26	32	26	26	26	34
Profitablity	30	40	30	35	30	41
Liquidity	40	65	40	76	40	65
Interbank loans	50	91	50	95	50	80

Figure 34: Numbers of breaks in 5 sub-group ratios by sizes

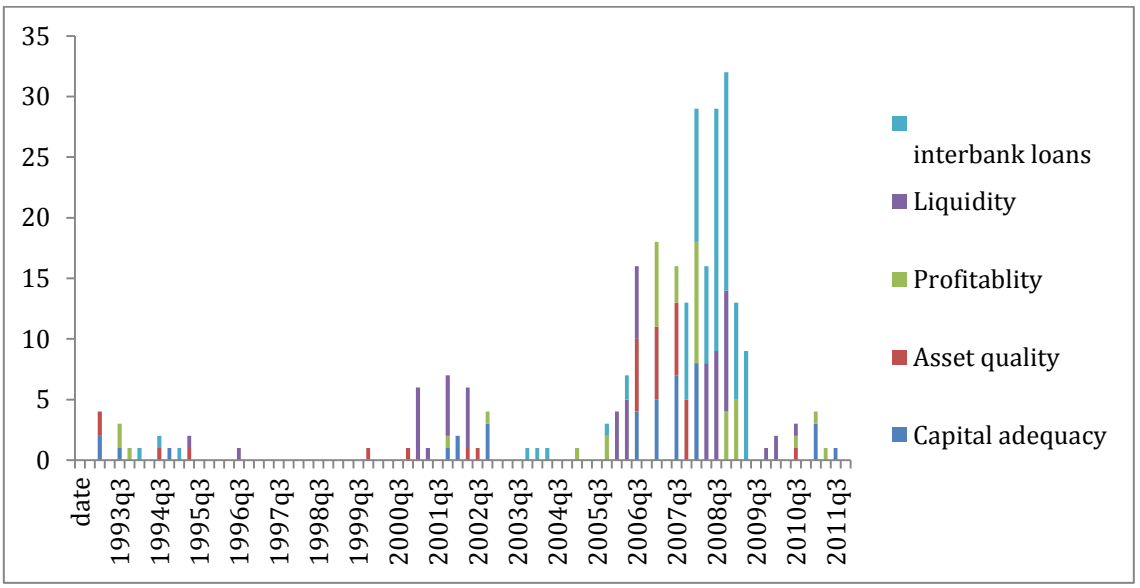


Figure 35: The summary of timing of breaks in aggregate level

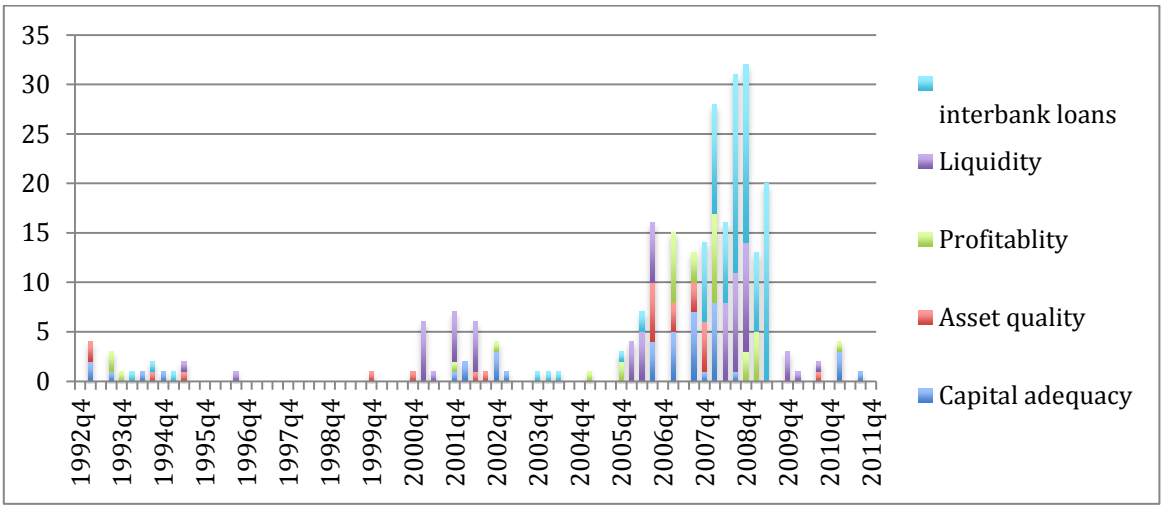


Figure 36: The summary of timing of breaks in aggregate level for large banks

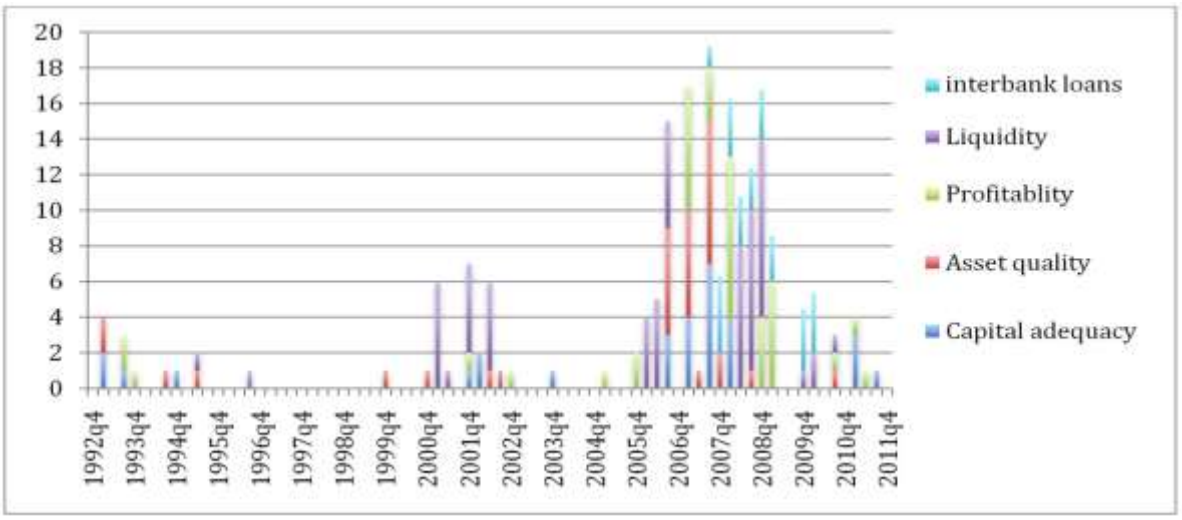


Figure 37: The summary of timing of breaks in aggregate level for small banks

From Figures above, we find that the failure of mortgage lenders started in early 2007, which is Episode 1; in what follow, government responses are observed through all three stages.

For capital adequacy ratios, there are 38 structural breaks found in aggregate level, 42 for large banks and 30 for small banks. And, those breaks happened mainly from 2nd quarter 2006 to last quarter of 2007, and in late 2008 for all banks, which are in the first and third stage of crisis. There is barely a ripple in the series in the period 2004 to 2006 when the vulnerability to the financial crisis was building up. What is remarkable is how tranquil the Capital adequacy ratios are before the crisis; they failed in playing a key role of being a first waring sign of financial crisis. There is clear empirical evidence from the global financial crisis (GFC) and earlier that risk-weighted capital buffers were not good predictors in practice, which is verified in our case (Estrella, Park, and Peristiani, 2000). Northern Rock for example was fully compliant with risk-weighted measures shortly before its failure (Mayes and Wood, 2009). Concentration just on capital adequacy, for example, while capturing most occurrences, would miss many of the problems cases. This does not imply that there should be any reduction in the use of risk – weighted measures in deciding how much capital a bank should hold in normal times but that when things start to go wring, a simple leverage ratio, which is transparent and more difficult to manipulate, would be the better indicators of problems.

Even though ratios for asset quality and profitability, have obvious structure breaks and slumps across whole crisis, but they didn't help in identify the timing of the financial crisis.

The structural shifts of key ratios for examining liquidity reveals a distinctive behaviour of all banks just before the crisis, and after the failure of Lehman Brothers in September 2008. For ratios of interbank loans, structural breaks are found after the end of 2008 for large banks, but changes comes earlier for small banks. Those groups of ratios identify the main changes in liquidity and interbank lending during the crisis. And liquidity ratios successfully gave the waring before the crisis. The evidence shows the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of financial crisis. The results of liquidity ratios and interbank loans support the observed liquidity hoarding behavior of banks and less active moments in interbank loan market. The crisis prompted a surge in demand for liquid assets in the entire U.S. financial system, in turn, rather than lend surplus liquid assets out, most banking preferred to hold, in case their own need might increase. With the increasing level of

uncertainty and counterpart risks, banks became increasing unwilling to lend and thus the size of interbank loans in average plummeted by the end of 2008; For example, the big fall happened after the failure of Lehman Brothers in September, particularly in the interbank market. The situation only got to be controlled by the end of 2009 after a large scale of government injection and banks' liquidity hoarding. Moreover, we find that the market's perception of the risk of a bank can depend on the size of the bank. 'Size matters' is also provided by Black, Collins and Robinson (1997) and Schweitzer (2003). It is interesting to see how bank size plays a significant role for liquidity hoarding, which will be present in our chapter 5.

The results from the empirical investigations, which can be assumed to be valid in principle for most banking systems, provides us with some guidance on the banks' dynamic actions in the interbank loan market that we should be able to use in our research design in chapter 4 and 5 (Brunnermeier, 2009; Cornett, McNutt, Strahan, and Tehranian, 2011; Gorton and Metrick, 2012).

3.6 Conclusions

This chapter has investigated bank behaviors around the 2007/08 global financial crisis by examining the structural changes of a number of aggregate level bank accounting ratios in three sub-periods: pre-crisis, crisis and post crisis.

First of all, it is also the first paper, as far as we know that uses structural shifts to assess the relative likelihood of success of selective financial ratios as early warning indicators. We also identify real banks' preemptive actions from a wide range of balance sheet ratios that experienced a significant structural change in response to the crisis at aggregate level.

In aggregate level, the bulk of our results suggest that certain indicators such as leverage and coverage ratio are appropriate indicators for the detection of banking system vulnerabilities. And coverage ratio additionally serves as an indicator for the timing of a crisis. However, capital ratios failed to provide signals for systemic banking problem. Concentration just on capital adequacy, for example, while capturing most occurrences, would miss many of the problems cases. This does not imply that there should be any reduction in the use of risk - weighted measures in deciding how much capital a bank should hold in normal times but that when things start to go wring, a simple leverage ratio, which is transparent and more difficult to manipulate, would be the better indicators of problems.

What's more, the findings in our financial ratios analysis clearly suggest that the aspects of the actual dynamic behavior of banks might be a determinant for the likelihood of a banking crisis. We found that whereas capital levels were closely monitored, heavy reliance of banks on whole-sale funding was overlooked. Banks that seemed to be safe experience bank run that ultimately led to their defaults. The sudden decrease in interbank market activity and increase in the banks' liquidity hoarding behavior were observed as well. However, new interbank loans might be granted, extended and withdrawal as the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of financial crisis.

In addition to this, we've also discussed the consequence of 'too big to fail' (TBTF) and show differences in the applicability of banking accounting ratios for the identification of banking problem between large, median and small banks. We've found Bank size does matter in context of applicability of banking accounting ratios serve as early warning signals. Our results suggest

that certain indicators such as nonperforming loans ratio (NPLs), loan deposit ratio, loan provision ratio and interbank lending ratios are appropriate indicators for the detection of banking system vulnerabilities for both big and small banks. And nonperforming loans ratio (NPLs) additionally serves as an indicator for the timing of a crisis. However, again capital ratios failed to provide signals for systemic banking problem.

The results from the empirical investigations in this chapter, which can be assumed to be valid in principle for most banking systems, provides us with some guidance on the banks' dynamic actions in the interbank loan market that we should be able to use in our research design. It proposes a framework that allows us to take into account the banks' preemptive actions on the interbank loan market after an initial common shock hitting the system. To capture more aspects of real banking systems, we are proposing a new way of simulating and interpreting interbank market contagion by combining banks' preemptive actions during the crisis in the chapter 5. Finally, we could investigate real banking systems by using actual banking system in the future, which could extend our framework to determine an optimal regulation.

However, there are limitations to our research and future works. First, one may argue that the U.S. interbank market is only considered rather than other countries in our study. What's more, while we acknowledge that the regulatory and institutional settings as well as macroeconomic variables are considered to be one determinant of financial system sounder, we do not account for this in our study since it is beyond the scope of this research to investigate the interaction between bank data on the aggregate level.

Chapter Four: An Empirical Examination of Effect of the Bank Size in Interbank Risk-taking

4.1 Introduction

Interbank lending makes a great contribution to the efficiency of financial markets. It helps meet large volume funding liquidity requirements, and allows banks with a temporary surplus of cash to invest it reliably for period maturities from overnight to one year. In particular, as one of the most important but vulnerable systems in the whole economy, over the last 20 or so years, there has been a significant growth of interest in the question whether the U.S. interbank market amplifies shocks to the whole banking sector or individual banks.

Even for many banks that are mostly funded by deposits, interbank loans may be a critical marginal source of additional funds. How those interbank transactions resolve short-term imbalance of supply and demand? In any normal day, some banks receive more deposits than expected, while others receive less than expected. Similarly, some banks experience an unexpected demand for loans from either homeowners or investors in equities while other banks face the opposite situation. If banks could not reliably lend and borrow on any particular day to offset those unanticipated ebbs and flows, a large volume of cash would be needed to insure itself against the possibility of unexpected payment inflows or outflows. However, extra-large amount of cash holding is a big waste and those resources could be invested profitably elsewhere. The interbank market helps banks to solve this problem by satisfying temporary, localized excess demand for funding liquidity that is necessary for the smooth function of other financial organizations.

However, the interbank market plays a role in risk sharing between banks with credit linkages (Allen and Gale, 2000). Contagion from one bank to the next could be propagated via the interbank market (Rochet and Tirole, 1996; Stiglitz, 2010; Allen and Gale, 2001). Figure 38 below displays a simple framework of interbank markets with relation to contagion risk. On the one hand, contagion could occur in the event of a shortage of aggregate liquidity asset, which has been manifested in the settlements systems (Freixas and Parigi, 1998). The interbank market reapportions excess liquidity towards other banks that may have shortages only in case of no overall excess demand for liquidity, as interbank deposits cannot increases the aggregate

liquidity. The lender of last resort (LLR) will be the only solution if the interbank market fully freezes. If this lender is apathetic, those banks that would be the first to experience difficulties with a large numbers of withdraw depositors. Thus fragility and panic will be propagated and spread through the interbank market, especially when there exists a chain of bilateral relationships in the market where the gross outstanding positions (rather than the net ones) are exposed to liquidity risk. On the other hand, for those banks who survive from the initial shock, they perceive the situation of the entire system as being in distress and may start hoarding liquidity, thus generating cash outflows for their counter-banks and exacerbating their funding issues. However, banks can also issue new loans from interbank market with high quality collaterals or high interest rates. Eventually, the banks will suffer from a liquidity shortage and file for bankruptcy due to illiquidity. Both channels may subsequently cause a strand of rounds of contagion.

Figure 38 : The Framework of Interbank Markets

The interbank markets also have significant influence on the modern economy through monetary policy (Matsuoka, 2012). In the U.S., the Fed funds rate, also known as overnight interbank rate, works as a main channel in monetary policy. Usually, the rate of interbank loans is lower than the rate for other trading partners as banks are seen as low-risk confidence borrowers and investors require a smaller risk premium and even without collateral. However, events occasionally strain the interbank lending: such as physical disruption on 11th September 2001 as well as financial crisis of 2007-09. Uncertainty about banks' own needs combined with concerns about potential shortfalls prompted banks to be more unwilling to lend for more than a few days, and even then only at every high interest rates. The higher rate and reduced availability of interbank lending would create a vicious circle of over caution, extraordinary increase in demand for liquidity, reduced willingness to lend and higher cost. The contagion effect is more significant in a downturn. For example, the average of 3-month interbank rates in the U.S. financial markets

increased from 1.05% in 2004 to 5.31% in 2007[29] (4.72% in 2006), as involvement in the interbank market may trigger a higher level of risk-taking for lending banks. For the neither collateralized nor insured against interbank loans, one financial institution's failure may trigger a chain of subsequent failures and eventually force the central bank to intervene to stop the contagion process in the bud. Interbank lending also could reduce the transparency of banks' balance and off-balance sheet and complicate the measurement of actual banking liquidity as well as solvency ratios for prudential purposes.

It was predicted according to some recent economic theoretical models that the interbank lending market would freeze at the beginning of summer of 2007 just following the bankruptcy of Lehman Brothers as it did during the Asian banking crisis of the late 1990s (Allen and Gale, 2001; Freixas and Parigi, 1998). This may impose adverse implications in the whole financial system as it could be contagious and spills over from one to the others. Therefore, Central bank as a LLR must conduct large-scale interventions to prevent a large scale of economic deterioration under this circumstance (Bagehot, 1873). However, the observed evidence in the Fed funds market in the immediate aftermath the collapse of Lehman Brothers, did not support the hypotheses above. In addition, the run on Northern Rock very likely reflected not the failure of the Bank's lender of last resort policy but inadequacies in the UK's provision of deposit insurance, the ill thought out separation of financial supervision and regulation from the central bank and political pressure (Milne and Wood, 2008). On the other hand, a moral hazard problem is generated from LLR intervention: it encourages all banks to make an effort to be large by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail) while the expansion of bank activities, especially non-traditional actives, may increase risk (Gandhi and Lustig, 2015; Laeven, Ratnovski and Tong, 2014). Simaan (2017) proposed a unique diversification index to capture the risk-taking behaviors of banks; and he found robust evidence that large banks are more likely to take excessive risk than their smaller peers.

Figure 39 below displays the structure of the U.S. interbank market pointed out by Freixa *et al.* (2000). It is characterised as an interconnected multiple money centre banks market, the same as Germany and Austria, where the money centre banks connected between each other. Lending banks are money centre banks that have a significant impact on the rest of the economy, as the

[29] Data source: OECD, see figure 4 in chapter 1

contagion can be spread to other money centre banks through the credit linkages. Therefore, the central bank is willing to provide potential protection for big banks, which might enable them to be involved in risky activities. In other words, to some extent, the implication of the multiple money centre banks market structure is consistent with the policy of 'too big to fail' (TBTF), where they are protected by central bank and moral hazard problem could be observed. The size effect, therefore, is significant in determining a bank's risk level through interbank market.

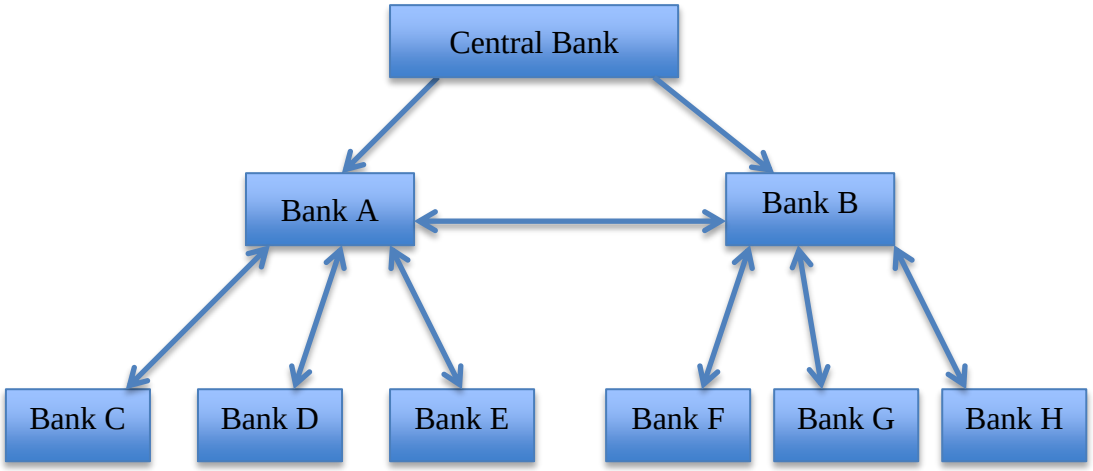


Figure 39: Interconnected Multiple Money centre Bank Market Structure (Freixas, Parigi and Rochet, 2000)

The recent subprime mortgage crisis of 2007-08 leads us to question the advantage of relying on interbank markets to provide liquidity, considering the systemic risk. In this chapter, we focus on the issue on whether involvement in interbank lending increases the risk level of banks while the size effect will particularly be considered. Exiting empirical research on the relationship between interbank lending and bank size is very limited and has found only marginal effects (Furfine, 2001; Aschcraft and Bleakley, 2006). One possible explanation is that interbank exposures in the countries which have been the focus of previous studies are with very short-term maturity (Overnight). In addition the interbank borrowing banks is U.S. are the largest banks so that too-big-too fail considerations reduce the lenders' incentives to control for borrower's risk. In this research, a micro-level datasets from FDIC has been used. The sample includes 13973 banks and the time span has been restricted from the fourth quarter of 1992 to the last quarter of 2011[30]. The analysis places special emphasis on the influence of bank size, activities, and complexity on bank risk, given the debate on the optimal size of banks, but also considers whether bank size interacts

[30] It characterized by long-term interbank exposures

with interbank lending to influence bank risk. We also detect differences in U.S. bank activities and risk taking in three sub-periods: pre-crisis, crisis and post-crisis.

A nonlinear (U-shaped) relationship is found in our study of the impact of bank size and interbank lending on bank risk-taking during the normal times. The empirical analysis documents that large banks, on average, create more individual risk than smaller banks, especially when they have insufficient capital or unstable funding - both common features of large banks. Additionally, large banks are riskier than small banks when they engage more in interbank market activities in non-crisis period; but interbank lending reduces the large banks' risk-taking during financial crisis.

These findings have an important bearing on the current policy debate on financial structure. They generally support the path taken by the Basel III regulatory framework, which focuses on strengthening bank capital and liquidity requirements. There are two additional novel implications. First, policy needs to take into account the disproportional role of large banks. This argument goes beyond the literature's traditional focus on whether large financial systems are optimal from an allocative efficiency point of view (Arcand, Berkes and Panizza, 2015; Philippon, 2010). Accordingly, second, measures targeting bank interbank activities and complexity may need to be undertaken in the context of a wider macro-prudential framework.

The rest of this section is organised as follows: Section 4.2 summaries the literature on bank size and interbank activities; research methodologies as well as the model specification are discussed in section 4.3, results and empirical analyses are presented in section 4.4, and the last section concludes.

4.2 Literature Review

4.2.1 Basic Facts about Large Banks

Since the 1970s, the U.S. global financial system has been transformed by a wave of financial innovation and deregulation. The origin of both can be traced to the information technology revolution, which increased the availability of information, made a variety of assets more tradable, and led to a proliferation of financial markets. Financial innovation and deregulation have expanded access to finance, bringing substantial welfare benefits. For example, interest rate deregulation for U.S. banks (Regulation Q) was in part motivated by competition from financial markets (mutual funds) that could offer financial products with more attractive interest rates.

At the same time, financial innovation and deregulation have affected the structure of the banking system; such as, the removal of prohibitions on mergers between commercial banks, investment banks, securities firms, and insurance companies in 1999 (the Gramm-Leach-Bliley Act). First, U.S. banks, especially the largest of them, have grown in size. The consolidation process in U.S. banking following deregulation in the 1970s has led to an increase in bank concentration, with large banks growing in size and geographical spread. Figure 40 shows how the balance sheet size of three largest U.S. banks at least doubled, and in some cases quadrupled, over the 10 years prior to the financial crisis. The crisis was followed by some deleveraging, also in large banks, so their size has been relatively stable since the crisis.

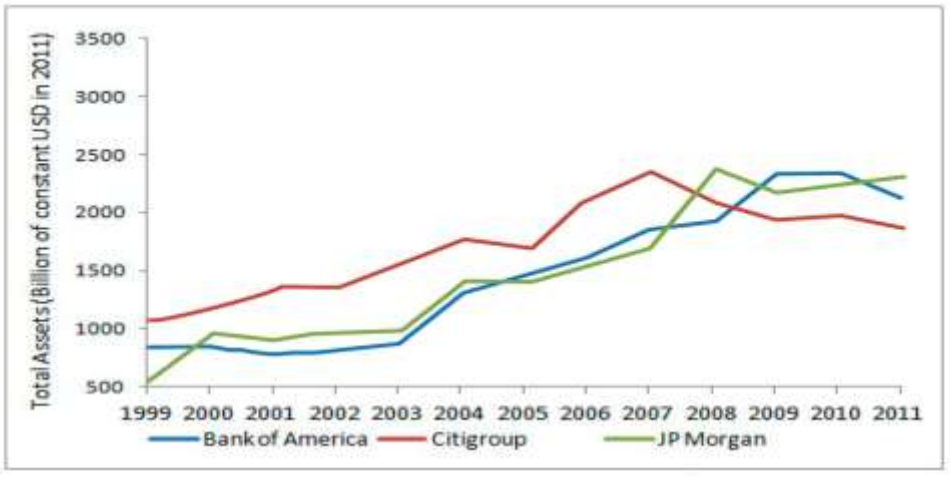
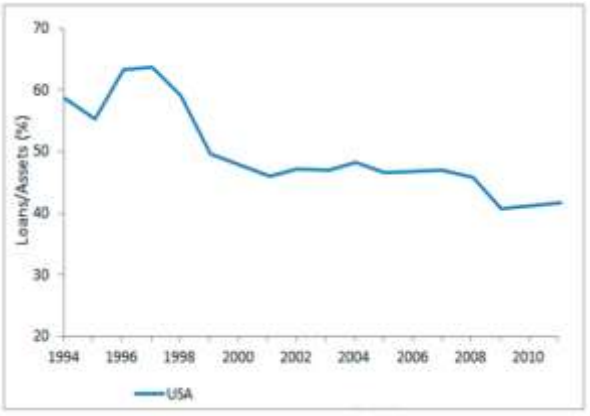


Figure 40: Increase in the Asset Size of Selected Largest Banks
Sources: Bankscope; IMF

Second, large banks have expanded the range of their activities. They added a wide range of market-based operations to the traditional business of making loans. These include investment banking, proprietary trading, market-marking, venture capital, security brokerage and asset

securitization; and, more generally, a provision of various financial market services, from advisory to hedging, to customers. Figures 41 and 42 illustrate the shift of four largest banks toward market-based activities using two alternative measures: a reduction of loans as a share of assets, and an increase in noninterest income as a share of income.



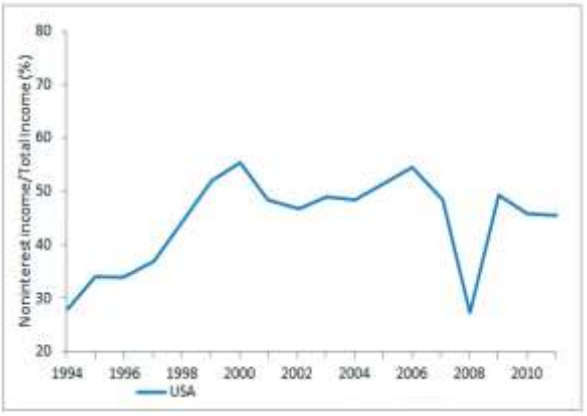


Figure 41: Decrease in Loans to Assets Ratio
Sources: Bankscope; IMF

Figure 42: Increase in Share of Noninterest Income

Recall section 3.5, while the changes in the financial system affected all banks, they had a particularly large impact on the largest banks (compare Figure 41 and 42 to Figure 1, 2 and 3 in section 1.1). The business model of large banks became clearly distinct from that of small or medium-sized banks (see Section 3.5.1, Figure 20 to Figure 28). First, large banks today engage disproportionately more in market-based activities. Second, large banks hold less capital than small banks, as measured either by a tier 1 capital ratio or a leverage ratio. Third, large banks have less stable funding than small banks, as measured by the ratio of deposits to total assets. Finally, large banks engage more interbank activities, as measured by interbank loan. Although the 2007/08 financial crisis triggered unprecedented strains in interbank lending, we found that the interbank market was large and active for large banks in early 2008. With the increasing level of uncertainty and counterpart risks, all banks became increasing unwilling to lend and thus the size of interbank loans in average plummeted by the end of 2008; the big fall happened after the failure of Lehman Brothers in September. The situation was constantly becoming worse when interbank loans created a vicious circle of increased caution, greater demand for liquidity, reduced willingness to lend and higher loan rates, the waves of precautionary behaviors, such as liquidity hoarding, were observed for all banks.

4.2.2 Interbank Market Structure and TBTF

There are two different structures of interbank markets: one is the incomplete market with credit chains, in which a bank has a connection only with its neighbor; and the other is the complete interbank market with diversified lending where a bank has symmetric links with all others (Allen and Gale, 2000; Bhattacharya and Gale, 1987). Lower risk-taking was found in the complete market as the risk of interbank lending can be shared by more than one lending bank.

The existing empirical models have studied the effect of the interbank market structure on risk-taking using matrix analyses. In these studies, balance sheet data or large interbank exposures data are used as a proxy to determine the structure of interbank markets. 25 matrices of bilateral exposures in terms of maturity and bank categories are applied in a study of Upper and Worms (2002) to examine the Germany interbank market. They find that the German interbank market is two-tier: in the upper tier, the structure of interbank exposures is close to a complete interbank market structure, while in the lower tier, the interbank market is associated with an incomplete structure. They also point out that the contagion risk is lower in a complete market structure than in an incomplete market structure.

Considering the role of the central bank in the context of the interbank market, Freixas *et al.* (2000) extended the original model of Freixas *et al.* (1998). They present a disconnected multiple money centre market structure (Figure 43), where borrowing banks have a connection with the money centre banks (A and B). As shown in Figure 39, the money centre bank is connected with other small banks, large non-financial firms and even the government. Therefore, the failure of the money centre bank could lead to serious consequences for the financial system. Here, as the lender of last resort (LLR), role of the Central Bank (CB) is highlighted. It indicates that the optimal strategy of the CB is to provide additional protection for money centre banks in order to minimize the costs of intervention under TBTF. Figure 39 in mentioned introduction above displays the structure of the U.S. interbank market pointed out by Freixa *et al.* (2000). It is characterised as an interconnected multiple money centre banks market, the same as Germany and Austria, where the money centre banks connected between each other. Lending banks are money centre banks that have a significant impact on the rest of the economy, as the contagion can be spread to other money centre banks through the credit linkages. Therefore, the central bank is willing to provide potential protection for big banks, which might enable them to become involved in risky activities.

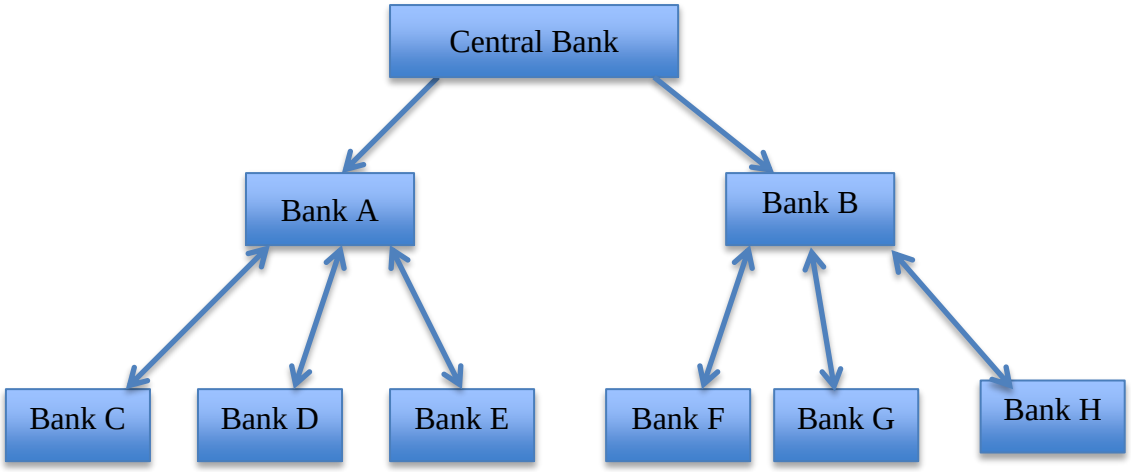


Figure 43: Disconnected Multiple Money centre Bank Market Structure (Freixas, Parigi and Rochet, 2000)

The results from a UK study conducted by Well (2004) are consistent with the implications of the multiple money centre bank structure as suggested by Freixas *et al.* (2000). Also, Degryse and Nguyen (2004) analyze the contagion risk by using data from Belgian banks between 1993 and 2002. They emphasize the importance of interbank market structure in determining the level of contagion risk. A change in market structure from a complete market to a multiple money centres market allows contagion risk to be reduced. The failure of borrowing banks (small banks) linked to a money centre bank cannot lead to the failure of the money centre bank protected by CB, which is consistent with the implications of the framework suggested by Freixas *et al.* (2000). However, a different structure exists in the Portuguese interbank market (Cocco *et al.*, 2009). In this market, large banks tend to be net borrowers as they have more opportunities to invest while small banks specialize in deposit taking but have few investments, so they have sufficient liquidity to lend to large banks.

To some extent, the implication of the multiple money centre banks market structure is consistent with the policy of 'too big to fail' (TBTF), where they are protected by central bank and moral hazard problem could be observed. The size effect, therefore, is significant in determining bank risk level. The U.S. interbank market used in our study is an example of interconnected multiple money centre bank market.

4.2.3 Interbank Lending and Bank Size

The importance of effective monitoring of the interbank assets of lending banks has been highlighted in a theoretical model introduced by Rochet and Tirole (1996). Good monitoring can reduce the risk of interbank lending and maintain a stable financial system. Dinger and Hagen (2005) introduce a theoretical model to examine the impact of bank size on bank risk level. They suggest that large banks have more advantages, such as efficient management and economies of scale, in monitoring borrowing banks, and hence can reduce the risk level of interbank lending. There are several assumptions made in this model. First, they assume two firms: one with good projects and the other with bad projects. The rate of return on a good project is R_g with probability of π_g, 0 otherwise; the rate of return on a bad project is R_b with probability of π_b, 0 otherwise; and $R_g\pi_g - 1 > 0 > R_b\pi_b - 1, R_g < R_b \; and \; \pi_g > \pi_b$. Second, under the money centre bank market structure, there is only one large bank acting as a lending bank with n small banks as borrowing banks. Due to the policy of 'too big to fail', the large banks receive government protection on its deposits.

For the large bank, the interest rate of deposit (i_{lb}) which is lower than that of the small banks (i_{sb}). The payment for depositors in the large bank is $D_{lb} = 1$ due to its risklessness and for small banks, the nominal repayment is D=1+ i_{sb}. Moreover, the large bank also provides interbank loans at the interbank i_{ib}, which varies according to the risk level of borrowing banks and would be required to pay at a higher rate if a borrowing bank usually finances bad projects. The repayment for one unit of interbank asset is d=1+ i_{ib}. Here, they also assume that small banks can refinance through either the interbank market or deposit-taking. Thus, the amount of credits from the interbank market for small banks is *1-E-p*: *E* is the equity, and a higher level of equity reduces the amount of credit financed by either deposit-taking or the interbank market, and provides additional protection for banks. *p* is the deposit for small banks and thus the marginal cost of gathering deposits is c(p). Considering the moral hazard problem, small banks are willing to finance the bad project due to its higher return rate; the small banks prefer to finance a good project only if the net return of the good project is not lower than that of the bad project:

$$\pi_g(R_g - R_i) - (1 - \pi_g)(1 - E) \geq \pi_b(R_b - R_i) - (1 - \pi_b)(1 - E)$$

In their paper, the net expected return (NER) of the large bank is discussed in four cases:

1. both good and bad project success;

2. bad project failure and good project success;
3. good project failure and bad project success;
4. both good project and bad project failure.

In sum, the large bank prefers to monitor borrowing banks and assure them to finance good projects in order to maximize the net expected return, which reduces the default risk level of interbank lending. However, the monitoring only occurs if the benefit of screening is not lower than the fixed costs C:

$$(1 - E - p)d(\pi_g - \pi_b) \geq C \qquad (4\text{-}1)$$

$$(1 - E - p) \geq \frac{C}{d(\pi_g - \pi_b)}$$

Where the repayment of interbank assets for the large bank is $d_g$when small banks finance a good project, and $d_b$when financing a bad project: $d_g < d_b$and $d_g\pi_g > d_b\pi_b$. The large bank start to monitor the borrowing banks if the amount of interbank lending excesses the critical value $\frac{c}{d(\pi_g - \pi_b)}$.

In 2009, Dinger and Hagen applied this theoretical model into an empirical study in estimating the effect of interbank borrowing on bank risk using data on Central and Eastern European banks from 1995 to 2004. They suggest that the borrowing banks are associated with lower risk-taking, as the lending bank is willing to monitor the borrowing banks' activities to maximize its expected return. Banks with good capitalization are indicative of lower risk-taking. The reduced-form empirical model is shown as:

$$RISK = (INB, SIZE, SIZE^2, EQU, MV) \qquad (4\text{-}2)$$

Where,

RISK is risk-taking measured by loan loss provision, loan loss reverse and net charge-off to equity, respectively.
INB is measured by interbank borrowing to total assets.
SIZE is log bank assets.
$SIZE^2$ is size squared.
EQU is the equity ratio used to measure capitalization.

MV is macro-variables, including GDP and inflation.

In addition, the probability of bank failure is higher for small banks than large banks, which is found by Allen and Gale (2000) and Freixas *et al.* (2000) under a given interbank market structure, implying that large banks participate in a potential bail-out provided by Central Bank. Dinger and Hagen's (2005) also documented a nonlinear (U-shaped) relationship between bank size and risk-taking. In other word, the level of risk varies accordingly to whether the bank size is under or above a certain critical value. However, this study does not take TBTF into account in investigating bank behaviors; therefore, in this chapter, we would like to modify this model by considering the difference between large and small banks (size effect), following the argument of Freixas *et al*. (2000), to investigate the impact of interbank market activities on bank risk-taking.

4.2.4 Interbank Lending and Macroeconomic Shocks

Elsinger *et al.* (2006) employed a set of data on Austrian banks to investigate two types of bank failure: one is due to fundamental risk-taking, e.g. the exposure to market, and another one is due to contagion risk resulting from other bank failures. The result shows that the majority of bank defaults (97%) are driven by fundamental shocks of banking system, while only 2.7% of bank defaults result from a chain reaction of other bank failures in the financial system. They suggest that fundamental risk factors are the source of bank default, systemic crises and financial instability. The result is consistent with their earlier work in 2002 (Elsinger *et al.*, 2002). A set of macroeconomic shocks, such as interest rate risk, was examined in the context of interbank markets. They found that the default risk of the interbank market mainly results from macroeconomic shocks. Therefore, in order to the explicit credit linkage, macroeconomic shocks that drive contagion risk should be included in our work.

4.3 Introduction of Methodology and Sample

4.3.1 Hypotheses

According to our previous empirical studies and literature review, there are three hypotheses we attempt to test in this research:

Hypothesis 1*: The bank size is positively associated with risk-taking when the bank size goes beyond a certain level under TBTF.*

Recalling what we discussed in literature review: First, due to the economies of scale, the larger the bank size is, the lower long-run average costs of bank activities (Kovner, Vickery and Zhou, 2013). In addition, with respect to the theoretical work of Dinger and Hagen (2005), they suggest that large banks prefer to monitor borrowing banks in order to maximize the profit and reduce the default risk level of bank assets. However, those are not consistent with the findings in the empirical study of Freixas *et al*. in 2000 as well as ours findings in chapter 3. Therefore, we may question the conclusion from Dinger and Hagen (2005).

Hypothesis 2*: The interbank activities are negatively associated with risk-taking for large banks during the financial crisis.*

It was widely believed that CB as a LLR must conduct large-scale interventions to prevent a large scale of economic deterioration under this circumstance (Bagehot, 1873). A moral hazard problem could be generated from LLR intervention: it encourages all banks to make an effort to be large by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail) while the expansion of bank activities, especially non-traditional actives, may increase risk (Gandhi and Lustig, 2015; Laeven, Ratnovski and Tong, 2014). Therefore, large banks in U.S. interbank market may have less incentive to monitor interbank lending under TBTF. However, Dinger and Hagen (2007) argue that interbank lending might be also associated with substantially lower risk taking by borrowing banks, which are consistent with monitoring by lending banks. The observed evidence, in the Fed funds market in the immediate aftermath the collapse of Lehman Brothers, indicated the Fed rarely acted as the LLR it was designed to be. Therefore, the banks' precautionary behaviours may be observed, which arises from a more general loss of confidence of confidence trust; and it maybe change the positive relationship between interbank lending and banks' risk taking. Following the work of Freixas *et al.* in 2000, here we may

question the effect of policy of TBTF in the context of interbank market during the financial crisis.

***Hypothesis 3**: Higher equities and/or less nonperforming loans can protect all banks against the liquidity problem, particularly for small banks that lack protection from Central Bank.*

It is widely believed that all banks with higher capital holding, especially above the minimum capital requirement are involved in less risky activities (Dinger and Hagen, 009; Milne and Wood, 2008); which is contrary to the findings of Calem and Rob in 1999 as well as our empirical results in chapter three. We've found that large banks are risker: they tend to have lower capital and more active in interbank market than small bank.

4.3.2 Non-linear Empirical Model

Our empirical work in this chapter is based on the theoretical model introduced by Dinger and Hagen (2005) and our empirical results in previous chapter 3, which also take consideration of the effect of policy of TBTF suggested by Freixas *et al.* (2000) in the context of U.S. interbank markets. Consistent with our hypotheses, bank size and interbank lending are our main concerns in the estimation. Higher equities and less nonperformance loans would provide additional protections for banks, which are also considered.

A few assumptions are required in order to make our models of banks feasible for analysis. First, for bank risk taking, we primarily measure bank risk using the Z-score of each back as suggested by Laeven and Levine (2009). It can be calculated for listed and unlisted banks. Nonperforming loans to total gross loans ratio is utilized as a proxy of deteriorating asset quality. What's more, from our previous empirical studies, visual inspection of the behaviour of banking accounting ratios around the crisis date captures NPLs as a good precursor for deteriorating banking system soundness. This follows the study carried out by Cihakand and Schaeck (2007). Therefore, NPLL (Nonperforming loans to total gross loans) will be included in our independent variables as an appropriate indicator for asset quality in our study. In addition, Elsinger *et al.* (2002, 2006a, 2006b) theoretically and empirically show the effect of fundamental systemic risk on bank performance, so the macro-variables should be used. Therefore, the explanatory variables in this work consist of interbank loans (IL), size effect (SIZE), deposit ratio (LD), NPLL

(Nonperforming loans to total gross loans), equity (EA) and macro-variables (MV) - interbank rate (I) as a measure of the risk level of interbank markets.

Firstly, following Dinger and Hagen (2009), we estimate a non-linear regression to identify the significant difference in risk-taking between large and small banks, further suggesting whether we can split the whole sample in terms of bank size. If we find significant results with different signs of bank size and bank size squared, then we can make estimation based on the large and small banks sub-samples respectively. Thus, the non-linear empirical model includes 6 independent variables, IL, SIZE, LD, EA, NPLL and I. The estimated function is shown below:

$$RISK_{it} = Lasset_{it} + Interbankloanratio_{it} + Depositratios_{it} + \text{Nonperformingloansratio}_{it} + Equityratio_{it} + Interbankrate_{t} + c + \varepsilon \quad (4\text{-}3)$$

The preliminary results in terms of this function are shown as below:

$$Z\text{score}_{it} = SIZE_{it} + IL_{it} + LD_{it} + NPLL_{it} + EA_{it} + I_{t} + c + \varepsilon \quad (4\text{-}4)$$

Where,

Risk is measured by Z-score[31]

SIZE, Lasset is bank size and is the log-transformation of bank total assets.

IL, Interbank asset ratio is defined as the ratio of interbank assets to total bank assets.

LD, Deposit ratio is defined as bank loans to total deposits.

NPLL, Nonperforming loans ratio is defined as the ratio of nonperforming loans to total gross loans.

EA, Equity ratio is defined as total equity to total bank assets.

I, Interbank rate is 3-month interbank rate.

C is a constant.

Z-score measures bank risk suggested by Laeven and Levine (2009), which equals the return on assets (ROA) plus the capital to asset ratio (CAR) divided by the standard deviation of asset returns (σ(ROA)). Roy (1952) introduces Z-score as a measure of the distance from insolvency.

[31] It is the natural logarithm of Z-score, which is defined as the inverse of probability of insolvency.

Insolvency is defined as a state in which losses surmount equity (Equity, E< -π, Profits). The probability of insolvency, therefore, can be expressed as prob(-ROA< CAR). If profits are normally distributed, then the inverse of the probability of insolvency equals (ROA+CAR)/ σ(ROA)). Following the literature, we define the inverse of the probability of insolvency as the Z-score. A lower Z-score indicates that the bank is less stable. Because the Z-score is highly skewed, we use the natural logarithm of the Z-score, which is normally distributed. For brevity, we use the label 'Z-score' in referring to the natural logarithms of the Z-score in the remainder of this thesis.

SIZE is the bank size and it is defined as the log-transformation of total bank assets. SIZE is a threshold through which we can estimate the differences in bank behaviors and risk-taking between large and small banks based on the framework of Dinger and Hagen (2005). We expect a negative coefficient for large banks under the policy of "too big to fail".

LD is a ratio defined as total bank loans to total deposits and is also presented as a percentage to reflect liquidity risk. It is an endogenous variable, since banks can change their portfolios according to the risk level. As suggested by Lepetit *et al.* (2008), the increase in the loan-deposit ratio indicates higher level of liquidity risk, which might force banks to be active in interbank markets. In addition, a large loan base might require higher loan loss provision as a buffer against potential risk-taking due to adverse selection. Thus, the sign is expected to be negative.

NPLL (Nonperforming loans to total gross loans) will also be included in our independent variables as an appropriate indicator for asset quality in our study. Deteriorating asset quality Deteriorating asset quality can be proxied by two ratios (Nonperforming loans net of provisions to capital and Nonperforming loans to total gross loans). From our previous empirical studies, visual inspection of the behaviour of banking accounting ratios around the crisis date captures NPLs as a good precursor for deteriorating banking system soundness. This follows the result of Cihakand and Schaeck (2007). The sign is expected to be negative.

EA is the ratio of the total equity to total bank assets and is presented as a percentage. It is included to capture the effect of capital regulation on bank risk. A higher equity ratio indicates

that shareholders have more incentive to monitor bank behaviors, which in turn reduces the level of risk-taking (Dinger and Hagen, 2005). Thus, the expected sign is to be positive.

IL is defined as the ratio of interbank loans to depository institutions to total bank assets and is presented as a percentage. Regarding the theoretical work of Dinger and Hagen (2005, 2007), they suggest that large banks prefer to monitor borrowing banks in order to maximize the expected return and reduce the default risk level of interbank assets. However, this prediction is against the findings in their further work in 2009, which documented that large banks in U.S. interbank market have less incentive to monitor interbank lending considering TBTF, though they do not present an investigation into this issue. We may question this conclusion. Thus, the sign is expected to be negative for large banks.

I is the 3- month U.S. interbank rate and reflects the scenario of the money market. It is a proxy of the effect of the macro-economy on bank risk-taking in the context of interbank markets based on Elsinger *et al.* (2002, 2006a). A higher interbank rate indicates a higher level of potential risk-taking in interbank markets, which in turn increases the marginal costs of lending (Panetta *et al.*, 2004). Thus, the expected sign is to be negative.

4.3.3 Threshold Model and Bank Size

A threshold model is employed in our empirical work to find this critical value of bank size to divide the whole sample. Based on our hypotheses, we are interested in the results of bank size. A negative and significant coefficient of bank size and a positive and significant coefficient of bank size squared indicate that there is a U-shaped relationship between risk-taking and bank size, following the result of Dinger and Hagen (2009), which suggests that there might be difference in the risk level of bank activities between large and small banks. Thus, we could endogenously find this critical value of bank size to divide the whole sample by using a threshold model. Hansen (1996, 2000) develops an econometric method to estimate the threshold model. The applications of a threshold model include sample splitting and separating, and multiple equilibriums. The basic estimated threshold model is shown as:

$$y_{it} = \alpha_i + \theta_1' x_{it} I(K_{it} \leq \tau) + \theta_2' x_{it} I(K_{it} > \tau) + \varepsilon_{it} \quad (4\text{-}5)$$

Where,

i is the number of individual sections, and i=1,2....N

t is time period, t=1,2...N

y_{it} is a dependent variable.

α_i is an individual effect.

x_{it} is a m-vector of independant variables.

$\theta_1 and\ \theta_2$ are the coefficients for different regimes divided by the threshold parameter τ.

K_{it} is a threshold variable.

τ is a threshold variable.

I is an indicator function.

ε_{it} is an error term and follows a zero-mean process, $\varepsilon_{it} \sim (0, \sigma^2)$.

Two categories are classified by the threshold value τ, and using the ordinary least squares method, the slope coefficients $\theta_1 and\ \theta_2$ can be estimated.

Khan and Senhadji (2001) extend the threshold model and apply it to an unbalanced panel. By using conditional least squares, the threshold value is determined by minimizing the sum of square residuals. In our research, with an unbalanced data set, bank loans to total deposits ratio, and total equity to assets ratio are identified as two endogenous variables, because in some circumstances banks having a higher risk level are concerned about risky assets, so they tend to change their portfolios by reducing the amount of loans or increasing equities. The relevant test of the endogeneity of these two variables will be shown in the next section. This allows us to use the method developed by Hansen (2000) and Caner and Hansen (2004), who show a threshold model considering instrumental variables. Based on their work, the estimated model is given as:

$$y_{it} = \theta_1' z_{it} I(K_{it} \leq \tau) + \theta_2' z_{it} I(K_{it} > \tau) + \varepsilon_{it} \quad (4\text{-}6)$$

Where,

i is the number of individual sections, and i=1,2....N

t is time period, t=1,2...N

y_{it} is a dependent variable.

z_{it} is a m-vector and is correlated with the error term ε_{it}, which are endogenous.

$\theta_1 and\ \theta_2$ are the coefficients for different regimes divided by the threshold parameter τ.

K_{it} is a threshold variable.

τ is a threshold variable.

I is an indicator function.

ε_{it} is an error term and follows a zero-mean process, $\varepsilon_{it} \sim (0, \sigma^2)$.

If we set a k-vector $(K \geq m)$ as instrumental variables for z_{it}, then the reduced form model from above on the conditional expectation of z_{it} is:

$$z_{it} = \psi(x_{it}, \beta) + u_{it} \tag{4-7}$$

Where,

z_{it} is a m-vector of endogenous variables.

x_{it} is a k-vector $(K \geq m)$ of exogenous variables, which is correlated with the endogenous variables but is uncorrelated with the error term.

β is coefficient vector.

u_{it} is a m*1 vector of the error term, here we assume that $E(u_{it}|x_{it}) = 0$.

Now if we substitute Eq. 4-7 into Eq. 4-6, the expression will be transformed as shown below:

$$y_{it} = \theta_1' \psi_{it} I(K_{it} \leq \tau) + \theta_2' \psi_{it} I(K_{it} > \tau) + \omega_{it} \tag{4-8}$$

Where,

$$\omega_{it} = \theta_1' u_{it} I(K_{it} \leq \tau) + \theta_2' u_{it} I(K_{it} > \tau) + \varepsilon_{it}$$

In next step, we will follow the three-step method suggested by Caner and Hansen (2004). The coefficient β of the reduced-form function will be estimated firstly by using the least squared method. The second step is to identify the threshold parameter τ by using the predicted values of endogenous variables in the first step. Finally, given exogenous threshold value, the coefficients θ

are estimated by using 2SLS method. In our case, the bank size is the threshold variable as we attempt to estimate the difference in risk-taking between large and small banks, and deposit ratio and capital ratio are identified as endogenous variables. According to this three-step method suggested by Caner and Hansen (2004), in the first step, we predict the endogenous variables (deposit ratio and equity ratio) by using the one-year lagged variables of deposit ratio and total equity to total bank assets ratio as instruments; the relevant test of the validity of the instruments will be given in the next section. The second step is to estimate the threshold variable (bank size) by using the predicted values of the endogenous variables. The third step is to estimate the slope coefficients by using 2SLS on two regimes identified by an estimated threshold parameter. Therefore, the basic nonlinear model Eq.4-4 can be changed in terms of the threshold model, which aims to estimate the differences in the bank risk level and bank activities between large and small bank groups. This is shown below:

$$Z\text{score}_{it} = \begin{cases} \alpha_1 SIZE_{it} + \alpha_2 ILA_{it} + \alpha_3 LD_{it} + \alpha_4 NPLL_{it} + \alpha_5 EA_{it} + \alpha_6 I_t + c(SIZE \geq \tau) \\ \lambda_1 SIZE_{it} + \lambda_2 ILA_{it} + \lambda_2 LD_{it} + \lambda_4 NPLL_{it} + \lambda_5 EA_{it} + \lambda_6 I_t + c(SIZE < \tau) \end{cases} \quad (4\text{-}9)$$

Recall the Eq.4-8 $z_{it} = \psi(x_{it}, \beta) + u_{it}$, and thus the predicted value of are $\hat{z}_{it} = \psi(x_{it}, \hat{\beta})$. As there are two endogenous variables $\hat{z}_1$ and $\hat{z}_2$, given any threshold values, we can run the regression of on $\hat{z}_1$ and $\hat{z}_2$ by using the least squares method. The estimator of the critical threshold value τ can be generated by minimizing the sum of squared residuals $S(\tau)$: $\hat{\tau} = \min(S(\tau))$.

The result of the threshold model is obtained using the code of Matlab provided by Hansen (2000) and Caner and Hansen (2004)[32]. In Figure 44, the critical threshold value (5.299027) is the point where the Likelihood ratio (LR) strikes 0. The asymptotic confidence interval for the threshold value is robust to heteroskedasticity as illustrated by Caner and Hansen (2004). An asymptotically valid 90% confidence region is set, and the likelihood ratio of the threshold value approaches $\eta^2 C$ ($LR(\tau) \rightarrow \eta^2 C$)[33], where C is the 90% of the distribution function of a

[32] The code can obtained in this address: http://www.ssc.wisc.edu/~bhansen/papers/

[33] Set confidence interval =$\{\tau$: Likelihood ratio (τ) $\leq \widehat{\eta^2} Criticalvalue\}$.

random variable ξ . The ξ follows function $p(\xi \leq x) = (1 - \exp\left(\frac{-x}{2}\right))^2$, and the Criticalvalue $= -2\log(1 - \sqrt{1-\alpha})$ (Hansen, 2000). The points are those points where Likelihood ratio $(\tau) \leq \widehat{\eta^2} Criticalvalue$ in the confidence region in figure 44. Also, we have to estimate η^2 in the case of heteroskedasticity ($\eta^2 \neq 1$).

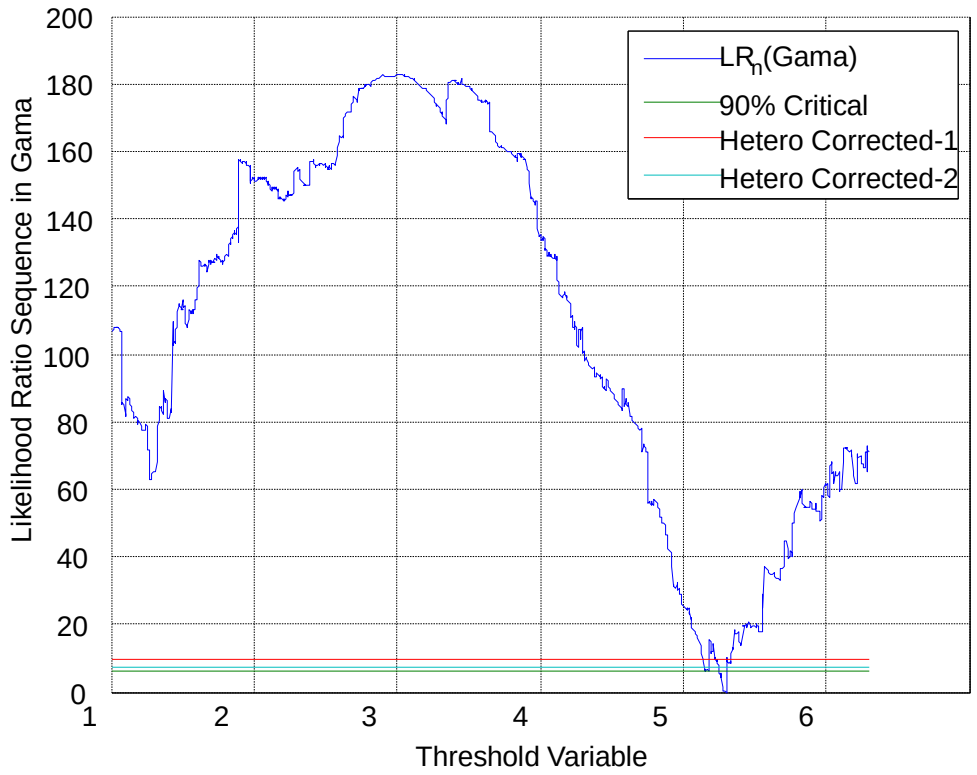


Figure 44: Confidence Interval Construction for Threshold

As $\eta^2 \neq 1$, we then attempt to detect whether heteroskedasticity exists or not in Stata. We use a modified Wald test for groupwise heteroskedasticity in a fixed effect model. Based on Greene (2000, p598), the null hypothesis for this test is no heteroskedasticity. The results of this test are indicated in Table 8 below; and it is significant at the 1% significant level, given that *p*-value is 0, which suggests that errors in the fixed effect model are heteroskedastic. In order to maintain the consistency of estimators, we need to correct standard errors in the estimations. Normally, the solution is to make standard errors robust to heteroskedasticity. We

use a programme [34]introduced by Schaffer (2010) in Stata to construct "robust" standard errors given the presence of endogeneity, so *t*-statistics reported in Table 8 are corrected for heteroskedasticity.

We found that there is correlation between explanatory variables and unobservable error terms. Therefore, we need to estimate the slope coefficients by using two stage least squares method on two regimes identified by an estimated threshold parameter (Caner and Hansen, 2004; Wooldridge, 2002). An instrumental variable vector should be included in the estimations to eliminate endogeneity. Here we recall the Eq. 4-6.

In our case, we set z_{it} is a m-vector and $z_i = (z_{1i}\ , z_{2i}\ )$. We assume that the $z_{1i}$is endogenous[35], which is correlated with the error term ε_{it}; the explanatory z_{2i} is exogenous. Set $\hat{X}_1$and $\hat{X}_2$ as the matrices of verctors $x_i' I(K_{it} \leq \tau)$, and $x_i' I(K_{it} > \tau)$; and $\hat{Z}_1$ and $\hat{Z}_2$ are the matrices of vectors $z_{1i}' I(K_{it} \leq \tau)$, and $z_{1i}' I(K_{it} > \tau)$. The vectors of the expectation value of $\theta_1 and\ \theta_2$ thus can be estimated as follows:

$$\hat{\theta}_1 = \left(\hat{Z}_1'\hat{X}_1\left(\hat{X}_1'\hat{X}_1\right)^{-1}\hat{X}_1'\hat{Z}_1\right)^{-1}(\hat{Z}_1'\hat{X}_1(\hat{X}_1'\hat{X}_1)^{-1}\hat{X}_1'Y)$$

$$\hat{\theta}_2 = \left(\hat{Z}_2'\hat{X}_2\left(\hat{X}_2'\hat{X}_2\right)^{-1}\hat{X}_2'\hat{Z}_2\right)^{-1}(\hat{Z}_2'\hat{X}_2\left(\hat{X}_2'\hat{X}_2\right)^{-1}\hat{X}_2'Y)$$

The Hausman specification test in Stata has the null hypothesis of that the tested variables are exogenous and not correlated with the error term. Hence, the 2SLS and OLS estimators should differ only by sampling error, and in other words, OLS is preferred. The alterative hypothesis is that the difference between the 2SLS and OLS estimators is statistically significant, then, 2SLS can be employed. The Hausman test result is shown in Table 4.

From Table 4 below, the value of the Chi-square test statistic is large (65.19) enough to reject

[34] http://idears. repec.org/c/boc/bocode/s456501.html

[35] In order to identify the endogeneity of variables, the Hausman specification test (Wooldridge, 2002) has to be employed. The original form of this test can be found in Wooldridge (2002).

the null hypothesis at the 1% significant level. We found the difference between the OLS estimators and 2SLS estimators is systemically significant, thus, 2SLS is preferred here. Therefore, the reduced-form equation in the first stage of 2SLS (Eq.4-7) should be used. β is coefficient vector in Eq.(4-7) z_it=ψ(x_it,β)+u_it. Here we need to use correlation test to verify the instruments.

	(b) 2SLS	(B) OLS	(b-B) Difference	SQRT (diag (V_b-V_B))
SIZE	-1.0764	-2.0421	0.9657	0.9827
EA	0.2808	0.1685	0.1123	0.3351
LD	0.6552	0.0468	0.6084	0.7800
IL	-2.2291	-3.6971	1.4680	1.2116
NPLL	3.5345	5.4114	-1.8769	.
I	-1.0764	-0.4212	-0.6552	.
Test:	H0: difference in coefficients not systematic			
	Chi2(6)=(b-B)'[(V_b-V_B)^(-1)](b-B)=65.19			
	Prob>Chi2=0.000			

Table 4 : Results of the Hausman Specific Test

In our study, we consider banks would rebalance their assets and liabilities using previous performance. Therefore, the one-year lagged values of the ratio of equity to total asset and the ratio of loan to deposit are predetermined at t-1. Then, they can be employed as instrument variable to estimate the endogenous variables as they are not correlated with the current error term. The correlation test is used to test the validity of instruments variables (IVs), and the result is shown in Table below. The null hypothesis of the test is $H_0: \hat{\beta} = 0$ (the instrument variable is not valid).

IVs	t-statistics	P>|t|
EA ratio(-1)	143.76	0.000
LD ratio (-1)	136.69	0.000

Table 5 : Results of the Correlation Test

As suggested by t-statistics, all coefficients of IVs are significantly different from 0 at the 1% significant level in the reduced form equations. The *P*-value shows that we can reject the null hypothesis. Thus, one-year lagged values of the equity to asset ratio and loan to deposit ratio as IVs are valid in the 2SLS estimations.

4.3.4 Sample and Ratios

In this research, we use the dataset described in section 3.3. The sample includes 13973 banks [36]and the time span has been restricted from the fourth quarter of 1992 to the last quarter of 2011. Data for some of the banks are only available for certain research time periods, which results from the restructuring or failures of banks. We give NIL under this circumstance. The sample we use here is the same as the sample we used in Chapter 3, but in individual level. All data are measured in million US dollar[37] and ratios are presented as percentages. The summary statistics of each variables employed in this chapter are listed in table 6 and 7.

The U.S.	Minimum	Median	Mean	Maximum
ZSCORE	2.321	3.118	3.203	4.056
IL	0.000	2.401	35.072	66.100
SIZE	2.890	4.213	4.366	6.996
EA	1.681	8.083	9.672	57.240
LD	0.010	84.170	93.200	139.200
NPLL	0.001	0.121	5.100	9.011
I	1.000	4.286	3.783	6.301

Table 6: The statistics for the main regression variables

	ZSCORE	IL	SIZE	EA	NPLL	LD
ZSCORE	1					
IL	0.206**	1				
SIZE	-0.389**	0.415**	1			
EA	0.012	0.127**	-0.16	1		
NPLL	-0.236**	-0.045	0.004	0.007	1	
LD	-0.191**	-0.274**	0.054	-0.253**	0.387**	1

Table 7: The correlation matrix of the main regression variables

Note: **indicate significance at 5% level

[36] In total 16520 banks, some of them have been a failure, or merged by other banks. To deal with mergers and acquisitions, I drop bank observations with asset growth greater than 10 percent and winsorize variable at the 1st and 99th percentiles.

4.4 Results and Analyses of Empirical Work

4.4.1 Non-linear Empirical Model

The basic model is shown as Eq.(4-9) and the results of the regression are presented in Table 8.

Table 8: Results of Basic Model

Notes: whole sample is split into in two groups according to a threshold value of log bank total assets (5.299027). t-statistic values are denoted in []. ***, **, * indicates statistical significance at the 1%, 5% and 10% level, respectively.		
Dependent variable: ZSCORE	Size ≥ 5.299027	Size < 5.299027
SIZE	-0.401***	0.227**
	[3.96]	[1.71]
IL	-1.689**	0.482
	[4.16]	[0.72]
LD	-0.012 **	-0.009**
	[1.74]	[1.77]
NPLL	-1.802**	-1.905 ***
	[1.79]	[2.79]
EA	0.154	0.227**
	[0.06]	[1.51]
I	-0.657	-0.758
	[0.76]	[0.51]
No. of banks	3783	10190
Hausman test Chi2 (6)	56.97***	67.21***
Heteroskedasticity Chi2	1.6e+32***	3.6e+32***
R-square	0.49	0.37

First, regarding to the effect of bank size, a nonlinear (U-shaped) relationship between bank size and risk-taking is found: strong negative coefficient of bank size is found in large banks where bank size is over the threshold ($SIZE \geq 5.299027$); whereas a significant positive coefficient is found in the small banks where bank size is smaller than the threshold estimate. Both coefficients are statistically significant at 5% significant level. It is consistent with our first hypothesis, which is given an interconnected multiple money centre bank market, under TBTF, large banks are positively associated with risk-taking. On possible reason is, large banks benefit from economies of scale; and large banks diversify by moving from traditional deposit-taking and lending to more cost-effective but riskier wholesale funding and market-based activities (Boot and Ratnovski, 2016; Brunnermeier, Dong and Palia, 2012; De, 2010;

Demirgüç-Kunt and Huizinga, 2010; DeYoung and Torna, 2013; Wheelock and Wilson, 2012).

Second, the coefficient of the interbank loan ratio in large banks is negative and statistically significant; whereas an insignificant positive coefficient is found in the small banks. Thus, interbank lending, which implies positive interbank assets, is associated with a higher level of risk taking for large banks. It indicates that large banks in U.S. interbank market have less incentive to monitor interbank lending due to a perception of TBTF. This is consistent with the empirical findings of Freixas *et al.* (2000), but not with Ding and Hagen (2005). One possible explanation to this might be that, if the monitoring costs are higher than the difference in the repayment between "good" and "bad" borrowers, lending banks are not willing to monitor borrowers, which may increase the risk level of interbank assets. A moral hazard problem can be generated from LLR intervention. It encouraged large banks to make an effort to be larger by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail). In addition, the insignificant positive coefficient in small banks may suggest interbank positions do not add to individual bank risk. And, it shows that large banks play more important roles in interbank market, which is consistent with our findings in Chapter three as well as in Chapter one. However, concerning the macroeconomic variable, interbank rate seems not have significant impact on risk.

Third, a positive relationship between equity holding and risk level is only found in the small bank group, but it is statistically insignificant in large banks. It supports our third hypothesis that small banks with more equities are less likely to be associated with lower risk-taking. This is also consistent with the empirical findings of Dinger and Hagen (2005, 2009) and Clarke *et al.* (2003). One possible explanation to this might be that shareholders of small banks have more incentive to monitor bank activities on behalf of their interests because of a lack of protection from CB. Thus, this highlights the importance of monitoring from shareholders to reduce the risk-taking of small banks owing to the lack of protection from CB.

An insignificant result in terms of large banks suggests that shareholders have less incentive to monitor bank activities due to a potential bail-out provided by CB; thus, we may argue that TBTF generates a moral hazard problem that is not only related to bank managers pursuing higher interests, but also related to shareholders or even depositors having less incentive to

screen banks. This might be a possible reason for the recent crisis, in that neither regulators nor shareholders paid much attention to the risk-taking of large banks and allowed them to get involved in risky activities. The corporate governance challenges in large banks are especially significant given that large banks tend to be more highly leveraged (Caprio and Levine, 2002; Laeven, 2013). Banks are highly leveraged institutions. This means that their shareholders may have aggressive risk preferences, which are not in the interest of other stakeholders - depositors, creditors, and the government. Indeed, there is evidence that banks where shareholders exercise more control tend to take more risk (Saunders, Strock, and Travlos, 1990; Laeven and Levine, 2009).

Forth, the coefficients of the loan-deposit ratio are negative and highly statistically significant in both groups of banks, which support the assumption that banks, which have more deposits, are assumed to be more stable and less risky, as suggested by Dinger and Hagen (2005). Moreover, as suggested by Lepetit *et al.*, (2008), the increase in the loan-deposit ratio suggests higher level of liquidity risk, which might force banks to be active in interbank markets. This result is confirmed by the empirical findings of Fisher *et al.* (2000) and Demirguc-Kunt and Huizinga (1998). A large loan base increases risk level and deteriorates loan quality, as banks may lend to borrowers with bad credit by charging higher interest rates due to adverse selection. Thus, an increase in the amount of loans triggers a higher level of loan loss provision as a buffer against potential risk. Core deposits represent an important funding source to increase the holdings of government securities and MBS of small banks (Berger and Bouwman, 2009), given that small banks generally have more restricted access to interbank markets and the central bank's discount window.

The last but not least, from our previous empirical studies, visual inspection of the behaviour of banking accounting ratios around the crisis date captures NPLs as a good precursor for deteriorating banking system soundness. Thus, NPLL (Nonperforming loans to total gross loans) is included in our independent variables as an appropriate indicator for asset quality. The coefficients of nonperformance loan ratio are negative and highly statistically significant in both groups of banks, which support the assumption that banks which have more deposits and fewer nonperformance assets are assumed to be more stable and less risky, as suggested by Hughes and Mester (2013). This follows the result of Cihakand and Schaeck (2007). A nagative and highly statistically sign indicats that financial systems recognize poor asset quality. It seems also

indicate that level of risk-taking increases in responding to the recognition of increase in nonperforming loans. Grier (2007) argued that poor asset quality was the main reason of major bank failures. Therefore, the risk of loan losses derived from delinquent loans is the primary risk faced by the banks, because the loan is one of most important asset category and thus the asset quality assessment in order to manage credit risk is necessary, though may be difficult (Frost, 2004).

4.4.2 Non-linear Empirical Model with Interaction Variables

Continuing the studies we conduct in Chapter three, we are interested at the time specific effect on bank risk-taking, which leads us to divide the sample period into three sub-periods since we are interested in the differences in the effect of bank activities in the run-up to the financial crisis, the financial crisis period itself and post financial crisis period. Therefore, we present extended empirical models with the threshold in terms of sub-periods for large and small banks. In order to define three sub-periods, we use Quant-Andres unknown break point test (1960) and Chow test (1960) to verify the breakpoints obtained by Break point Maximum LR/wald F-STATISTIC (same econometric tools used in section 3.3; see all details in Appendix 2).

Recall Figure 36 and 37 in section 3.5.2. They present summaries of timing of breaks in aggregate level for big and small banks respectively. We collect majority of structural breaks during the period of 2007Q4 to 2009Q3; which is consistent with the financial crisis three-stage process assumption made by FCIC (2010)[37]. Therefore, we can split the whole sample period into sub-periods: 1992Q4 -2007Q3, 2007Q4 -2009Q3, and 2009Q4-2011Q4. We date the subprime mortgage crisis starting from 2007Q4 and ending at 2009Q; which is also consistent with findings in Stijn and Kose (2013)[38].

Also GDP growth is used as additional macro-economic level indictor since the interbank rate is insignificant for both large banks and small banks in our basic model. Wells (2004), Elsinger *et al.* (2006a, b), Upper (2007) and Dinger and Hagen (2009), suggest a positive sign in GDP growth in the estimated model. It indicates the cyclical impact of macro-economic growth on bank risk-taking. The risk level of interbank assets is highlighted particularly in a recession,

[37] Refer to section 3.5.2

[38] It is useful to keep in mind that this identification is impact. A large body of work has been devoted to identification and dating crises, but ambiguities remain.

which indicates banks increase provision as a buffer against shocks from the macro-economy. And the extended model using interaction variables (based on Eq4-9) is shown below:

$$Zscore_{it} = \begin{cases} \alpha_1 SIZE_{it} + \alpha_2 IL_{it} + \alpha_3 LD_{it} + \alpha_4 NPLL_{it} + \alpha_5 EA_{it} + \alpha_6 I_t + \alpha_7 GDP_t + \sum_{\mu=1}^{7} \sigma_\mu \, Interaction\_Vari_\mu \\ \qquad + c(SIZE \geq \tau) \\ \lambda_1 SIZE_{it} + \lambda_2 IL_{it} + \lambda_2 LD_{it} + \lambda_4 NPLL_{it} + \lambda_5 EA_{it} + \lambda_6 I_t + \lambda_7 GDP_t + \sum_{\mu=1}^{7} \sigma_\mu \, Interaction\_Vari_\mu \\ \qquad + c(SIZE < \tau) \end{cases} \quad (4\text{-}10)$$

Where,

μ =1,…7, which is the number of independent

$Interaction\_Vari_\mu$ takes value of one for the period from the 4th quarter of 2007 up to 3rd quarter of 2009 (Subprime mortgage crisis period), and zero otherwise.

In this section, those three hypotheses we proposed in section 4.3.1 will be examined again by splitting whole sample into two banks groups with three sub-periods. Results are presented in table 9 below. Overall, the R-square is higher for interaction model than the R-square for our basic model.

A negative relationship has been found again between interbank lending and banks' risk taking for large banks, but only during the normal times. It is also interesting to see that the significant positive coefficient is found in small banks in normal times. It may suggest small banks are more willing to monitor borrowing banks in order to maximize the expected return and reduce the default risk level of interbank assets. But this relationship becomes insignificant during the financial crisis, which suggests that interbank lending market freezes, at least to small banks, at the beginning of summer of 2007 as it did during the Asian banking crisis of the late 1990s. It was consistent with a recent study in interbank market by Afonso, Kovner, and Schoar in 2011.

According to the significant positive coefficient of the interbank loan ratio in large banks during the financial crisis, someone may argue that the interbank market was large and active in the U.S.

as outstanding loans, typically overnight lending, to other banks averaged close to $440 billion in 2008. With the increasing level of uncertainty and counterpart risks, banks, especially small banks who were not fit in policy of TBTF, became increasing unwilling to lend and thus the size of interbank loans on average plummeted by the end of 2008, the big fall happened after the failure of Lehman Brothers in September. Thus only large banks were active in interbank market during the crisis, but they became more willing to monitor borrowing banks in order to reduce the default risk level of bank assets (the sign is negative in normal time, but positive in financial crisis). The situation was constantly becoming worse when interbank loans created a vicious circle of increased caution, greater demand for liquidity, reduced willingness to lend and higher loan rates, the waves of precautionary behaviors were observed. The empirical analysis in our Chapter 3 also demonstrates that the funding fragility and the changes of interbank loans both in level and trend at third quarter of year 2008 were highly statistically significant.

Interbank market works as the most immediate liquidity source within banks; therefore it can be a core indicator of the functioning of the banking market. However, the financial crisis started from 2007, triggered unprecedented, sustained strains in interbank lending. The crisis prompted a surge in demand for liquid assets in the entire U.S. financial system, in turn, rather than lend surplus liquid assets out, most banking preferred to hold, in case their own need might increase. Insufficient bank liquidity could lead to inadequate allocation of capital if any problems happen in this market. This may impose adverse implications in the whole financial system as it could be contagious and spills over from one to the others. Our results highlight that interbank lending is associated with substantially lower risk taking by borrowing banks in financial crisis, which are consistent with monitoring by lending banks. However, this good relationship was broken up during the normal times for large banks.

Although a positive relationship between equity holding and risk level is only found in the small bank group with our previous basic model, but it is statistically significant in both large banks and small banks during the financial crisis with extent model. In the crunch, banks with high capital are less likely to be associated with higher risk-taking. My results indicate that bank capital and deposits are important for both large and small banks when they face finance stress, but they seem to be more relevant for small banks. It is consistent with Estrella, Park and

Peristiani (2000) and Mayes and Wood (2009). It also suggests that risk-weighted capital buffers were not good predictors in practice.

Interbank rate reflects the scenarios of the money market for both large and small banks during the financial crisis, but only have a significant impact on risk for small banks in normal times. In a downturn, insufficient bank liquidity could lead to inadequate allocation of capital, which increases a higher interbank rate as well as higher marginal costs of lending; and thus a higher market risk level (Iori et al., 2008; Matsuoka, 2012). Recall Figure 4 in section 1.1, 3-Month Interbank Rates plunged around 2007 (Subprime Crisis 2007-2008). It emphasizes the important of an effective monetary policy. GDP growth as additional macro-economic level indictor has significantly positive impacts on banks' stable level for both large banks and small banks. It indicates the cyclical impact of macro-economic growth on bank risk-taking. The risk level of interbank assets is highlighted particularly in a recession, which indicates banks increase provision as a buffer against shocks from the macro-economy. It is consistent with the findings of in Wells (2004), Elsinger *et al.* (2006a, b), Upper (2007) and Dinger and Hagen (2009).

Table 9: Results of Interaction Model

Notes: whole sample is split into in two groups according to a threshold value of log bank total assets (5.299027). T-statistic values are denoted in []. ***, **, * indicates statistical significance at the 1%, 5% and 10% level, respectively.		
Dependent variable: ZSCORE	Size ≥ 5.299027	Size < 5.299027
SIZE	-0.492***	0.326**
	[3.07]	[1.73]
IL	-1.024***	0.128**
	[2.76]	[1.59]
LD	-0.010 **	-0.006**
	[1.69]	[1.68]
NPLL	-1.702	-1.107 *
	[1.01]	[1.39]
EA	0.221	0.281**
	[0.76]	[1.79]
I	-0.256	-0.358**
	[0.96]	[1.81]
GDP	0.401**	0.426**
	[1.92]	[1.68]
Inter_SIZE	-0.689***	0.474***
	[2.16]	[2.72]
Inter_IL	0.752 *	0.679
	[1.34]	[0.27]
Inter_LD	-0.020 ***	-0.015 ***
	[2.69]	[2.38]
Inter_NPLL	-1.954*	-1.227*
	[1.36]	[1.51]
Inter_EA	0.552***	0.667***
	[4.76]	[4.51]
Inter_I	-0.314**	-0.474**
	[1.96]	[1.81]
Inter_GDP	0.534***	0.632**
	[3.96]	[1.71]
No. of banks	3783	10190
Hausman test Chi2 (14)	43.76***	75.82***
Heteroskedasticity Chi2	2.1e+32***	3.9e+32***
R-square	0.49	0.37

4.5 Conclusions

In this chapter, the interbank lending and the bank size effect have been particularly considered in bank risk-taking. We have found that the bank size plays a core role in determining overall bank risk level: the hypothesis of the significant effect of TBTF on large banks holds. We also propose an interaction model as a robustness check to detect differences in U.S. bank activities and risk taking in three sub-periods.

First, a nonlinear (U-shaped) relationship between bank size and risk-taking has been found, which suggests the risk level increase when the bank size goes beyond a certain level. A non-linear threshold model has been employed in our empirical work to find this critical value. A strong negative coefficient of bank size has been found in large banks when bank size is larger than the threshold point while a significant positive coefficient has been found in the small banks where bank size is smaller than the threshold estimate. Due to a perception that the creditors of large banks will be bailed out in case of bank distress, the cost of debt for large banks is lower. This makes banks more willing to use leverage and unstable funding, and to engage in risky market-based activities.

Our findings indicate that bank capital and deposits are important for both large and small banks during the financial crisis, though they seem to be more relevant for small banks in normal times. For one side, it suggests that shareholders of large banks have less incentive to monitor bank activities due to a potential bail-out provided by CB; thus, we may argue that TBTF generates a moral hazard problem that is not only related to bank managers pursuing higher interests, but also related to shareholders or even depositors having less incentive to screen banks. This might be a possible reason for the recent crisis, in that neither regulators nor shareholders paid much attention to the risk-taking of large banks and allowed them to get involved in risky activities. Concertation just on capital adequacy, for example, while capturing most occurrences, would miss many of the problem cases. It also may conclude that Basel III is correct in including the leverage ratio in its requirements for improved supervisors and those supervisors would be wise to adopt it. From another side, this result is consistent with the view that core deposits are a more important source of funding for smaller banks, given that small banks generally have more restricted access to interbank markets and the central bank's discount window. Moreover, in liquidity management, banks take into account the stability of their funding sources such as

equity capital and deposits. Empirical study by Berger and Bouwman (2009) shows that bank capital is a key determinant for liquidity creation. They also present evidence that liquidity creation varies by bank size. In our next empirical chapter 5, we will further test whether that capital plays a significant role in the increased holdings of liquid assets during the financial crisis.

It is interesting to see that the interbank lending is negatively associated with Z-score for large banks in the normal times, but positively links to the stable level of banks during the financial crisis. One possible explanation for this negative sign is a moral hazard problem generated from LLR intervention, which encourages large banks to make an effort to be larger by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail) while the expansion of bank activities, especially non-traditional actives, may increase risk. In an interconnected multiple money centre banks market (U.S.), where the money centre banks are connected between each other, lending banks are money centre banks that have a significant impact on the rest of the economy, as the contagion can be spread to other money centre banks through the credit linkages. Therefore, it was also widely believed that Central bank as a lender of last resort (LLR) must conduct large-scale interventions to prevent a large scale of economic deterioration.

However, the financial crisis started from 2007, triggered an unprecedented, sustained strains in interbank lending. During the financial crisis, although banks can also issue new loans from interbank market, but with high quality collaterals or high interest rates, all banks suffer from a liquidity shortage in this case. What's more, the observed evidence aftermath the collapse of Lehman Brothers did not support the TBTF statement above: a more general loss of confidence of confidence trust arose. Therefore, during the financial crisis, preemptive behaviors, such as liquidity hoarding, have been observed in large banks and they became more willing to monitor borrowing banks in order to reduce the default risk level of bank assets.

The coefficient of the interbank loan ratio in small banks is positive and only statistically significant in normal times; whereas an insignificant positive coefficient is found during financial crisis. It may indicate that the large banks dominate the interbank market, especially during the financial crisis in the U.S.. During financial crisis, fragility and panic will be propagated and spread through the interbank market. For those banks who survive from the initial shock, they perceive the situation of the entire system as being in distress and may start hoarding liquidity,

thus generating cash outflows for their counter-banks and exacerbating their funding issues. In this case, the situation is constantly becoming worse to small banks when interbank loans create a vicious circle of increased caution, greater demand for liquidity, reduced willingness to lend and higher loan rates. Thus we suggest policymakers re-consider the bank size effect in determining bank risk level.

Significantly positive signs in GDP indicate the cyclical impact of macro-economic growth on bank risk-taking. The risk level of interbank assets is highlighted particularly in a recession, which indicates banks increase provision as a buffer against shocks from the macro-economy.

Many observers have argued that ineffective regulation contributed or even caused the collapse. If that is the case, we would expect difference in the regulation of financial institutions regarding to bank size to be helpful in maintain the stable of financial system. Other observers have criticized the governance of banks and suggested that better governance would have led to better performance during crisis. It needs to be pointed out that banks are affected differentially simply because they have different balance sheet and thus the probable gains and losses to individual banks need to be measured to prior to proposing polices.

Chapter Five: Liquidity Hoarding and the Interbank Lending Reluctance: An Empirical Investigation

5.1 Introduction

Through the interbank market, banks can coinsure against idiosyncratic liquidity risk by reallocating funds from those with an excess to others with a deficit (Allen, Carletti, and Gale, 2009; Castiglionesi, Feriozzi, Lóránth, and Pelizzon, 2014). However, in the absence of a well-functioning interbank market, idiosyncratic liquidity risk may be hard to coinsure against (Castiglionesi *et al.*, 2014), leading to credit rationing, liquidity hoarding for self-insurance, and higher funding costs. Whereas capital levels were closely monitored, heavy reliance of banks on whole-sale funding was overlooked. Banks that seemed to be safe experienced bank run that ultimately led to their defaults.

Recall our previous empirical chapters in this thesis, we've found that new interbank loans might be granted, extended and withdrawn as the interbank market was not fully frozen and still quite active, at least in issuing new interbank loans in the early stage of 2007/08 financial crisis. However, the sudden decrease in interbank market activity and increase in the banks' liquidity hoarding behavior were observed at the onset of the financial crisis in the late 2007. Short-term funding markets experienced a severe disruption: securitization markets - in particular the market for asset-backed commercial paper - collapsed and interbank markets froze (Strahan, 2008; Brunnermeier, 2009). Although conditions improved in early 2008 relative to late 2007 due to an aggressive policy response and a massive liquidity injection into the banking sector, funding markets experienced significant distress again during the fall of 2008 after Lehman Brothers and AIG failed, and Fannie Mae and Freddie Mac were placed under conservatorship.

As Gorton (2009) argues, the financial crisis resembled a banking panic that took the form of a run of financial firms on other financial firms. The panic centered on the repurchase agreement market, which suffered a run when lenders withdrew their funds by declining to roll over their loan agreements, and by raising their repo haircuts. This created an indiscriminate distrust of counterparties to any financial transactions. Concerned about the size and location of the exposure to subprime-related assets, banks stopped lending to other banks, and decided to hoard

liquid buffers in response to several factors: widespread concerns about the solvency of their counterparties in interbank operations, increased risks in their asset portfolios, and potential liquidity risk arising from draw-downs of committed lines of credit. As a result, a large number of financial institutions found it increasingly difficult to access interbank funding and manage their liquidity risk. Afonso, Kovner, and Schoar (2011) show that the number of lenders in the Federal funds market fell from approximately 300 in the summer of 2008 to 225 after Lehman Brothers'default, and the Fed funds rate experienced a one-day jump by more than 60 basis points on September 15, 2008, the date on which Lehman Brothers filed for bankruptcy.

Systemic risks command much attention as the preoccupation of the banking industry, and the current research is manifold; whereas scarce previous research has considered the possibility that banks can protect themselves during a financial crisis and therefore affect the propagation of losses through financial linkages, such as the interbank market. In chapter 3, we have investigated bank behaviors in three sub-periods: pre-crisis, 2007/08 financial crisis and post crisis; and we've found the aspects of the actual dynamic behavior of banks might be a determinant for the likelihood of a banking crisis. In addition to this, the sudden decrease in interbank market activities and increase in banks' preemptive actions, such as liquidity hoarding, have been also found in chapter 4. However, previous studies on the liquidity hoarding and funding ability in the interbank market offer mixed results (Acharya and Skeie, 2011; Castiglionesi et al., 2014; Cornett et al.; 2011; McAndrews, Sarkar, and Wang, 2008; Taylor and Williams, 2009), motivating us to conduct a further study in this area; which would allow further proposal of more reliable policy implications.

Using a large quarterly dataset of all U.S. banks from year 1992 to 2011, the main determinants of bank liquidity hording and the precautionary motive hypothesis of liquidity are carefully tested in this chapter. We also study the financial impact of disruptions of the interbank market on banks' liquidity creation during the interbank lending crunch.

Our research contributes to the recent literature in several ways. First of all, we find that, the same factors leading to precautionary liquidity hoarding also contributed a sharp decline in bank lending. When the interbank market was reluctant to offer liquidity coinsurance, banks with net interbank borrowing positions sought self-insurance by hoarding liquidity and rationed lending,

while banks with net interbank lending positions also hoarded liquidity due to heightened counterparty risk. Net interbank borrowing banks raised rates to draw external funding. Second, we find that banks held more liquid assets in anticipation of future losses from securities write-downs and loans charge-off. Unrealized security loss and exposure to expected loan losses represent key measures of banks' on-balance sheet liquidity risks, in addition to off-balance sheet liquidity risk stemming from unused loan commitments. Therefore, we propose two on-balance sheet proxies for banks' liquidity risk: unrealized security loss ratio (unrealized losses on available-for-sale securities to available for sale securities) and loan loss allowance ratio (allowance for loan losses to total loans[39]). Moreover, consistent with the view that deposits represent a stable source of funds for bank operations, we find evidence of inflows of core deposits during the financial crisis to banks that chose to hoard liquidity (flight-to-quality effect in deposit flows). On the policy frontier, besides credit and securities lending programs targeted at the interbank market, we suggest interbank lending subsidization as well.

The remainder of the chapter is organized as follows. Section 5.2 briefly describes balance sheet data of liquidity hoarders. Section 5.3 discusses my hypotheses compared with the related literature and the research methodology. The empirical results for the determinants of bank liquidity hoarding are presented in Section 5.4. Section 5.5 concludes.

[39] See Appendix 1 for full definition.

5.2 Liquidity Hoarding and Liquidity Hoarders

Recall our previous empirical studies in chapter 3 and 4. Using a large quarterly dataset of all U.S. banks from year 1992 to 2011, disruptions of the interbank market on banks' liquidity creation during the interbank lending crunch are observed. In this section, we will look into more details of the balance data about banks' liquidity hoarding behaviors before we further conduct our empirical study.

First, we begin with the definition of total liquidity assets. According to Cornett *et al*. (2011), 'total liquid assets' are calculated as the sum of cash (including balances at other banks and reserves at the central bank), Fed funds (including reverse repos), and investment securities (government securities). In this chapter, our definition of liquid assets includes mortgage-backed securities. Cornett *et al.* (2011), considered that all MBS and ABS became illiquid during the crisis, and therefore dropped them from their definition of liquid assets. Their rationale was that these securities would be held due to their inability to be sold or used as collateral in rolling over short-term funding after the collapse of the market for securitized assets. However, most of these securitized assets are comprised of agency MBS. With implicit government guarantee, it is not entirely clear that the majority of these securities should be excluded and considered illiquid as their market values were not really impaired during the collapse of the funding and securitization markets. In fact, most of the security losses in banks' balance sheets result from the write downs of ABS and non-agency MBS.

Figure 45 below depicts the changes in the composition of U.S. banks' assets in 2008 and 2009. By far the most striking change in aggregate bank balance sheet conditions occurred in the holdings of safe and liquid assets. Holdings of cash and securities (both treasuries and agency) increased $869 billion from 2008 to 2009 ($375 billion and $494 billion, respectively). Since most of the Federal Reserve's liquidity programs, such as the TAF, CPFF and AMLF (refer section 2.3.4 for further details), were specifically designed to foster the normal functioning of particular financial markets, it is not entirely surprising that securities holdings by commercial banks increased as a result of the liquidity provision of these specific programs. Indeed, the observed expansion of securities holdings may reflect the successful propping up of liquidity in specific short-term funding markets.

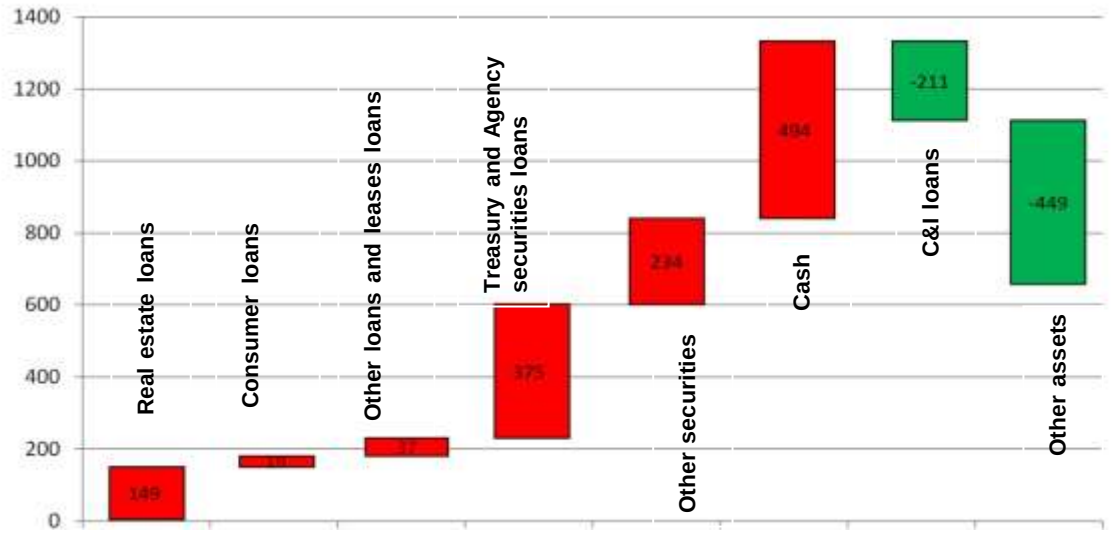


Figure 45: Changes in all U.S. Banks' Assets in 2008 and 2009 ($ Billion, mean)

Source: Federal Deposit Insurance Corporation (FDIC).

The sharp increase in the holdings of liquid assets contrasts with the evolution of bank loans during these years, especially Commercial and Industrial loan (C&I) loans which declined $211 billion. In other words, the aggregate bank balance-sheet information (see more details in section 3.4.2) and monetary aggregate figures (see further information in section 1.1 and section 2.3.4) seem to suggest that the majority of the funds that have been injected into banking organizations did not result directly in additional lending. Instead, banks chose to hoard these liquidity and capital provisions to build up a cushion to protect against further capital losses and expected write-downs. Another manifestation of the liquidity pressures banks faced during the crisis are the large reductions in trading assets and Fed funds sold to non-bank institutions (decline in other assets of $449 billion).

Recall section 3.4.4, regarding the liability side of their balance sheets, most of the counterpart changes in liquid assets over 2008 and 2009 were also explained by a significant increase in bank deposits. Despite the slowdown in deposit growth in 2007, banks experienced significant deposit inflows from investors received. In contrast, most of the liquidity programs set up by the Federal Reserve were not directly aimed at reviving bank lending, although they did by improving the functioning of specific markets and they aim to ultimately contribute to greater credit availability for businesses and households. Thus, one might still expect these liquidity programs to reinforce somewhat banks' willingness to extend loans.

For further investigation, we class all banks into two groups: Liquidity hoarders and non-Liquidity hoarders. Liquidity hoarders in this study are defined as banks for which the average ratio of total liquid assets to total assets increased by more than 3.5-percentage-point from a period before the crisis period (1992:Q4 to 2008:Q2) to **the interbank lending crunch** (2008:Q3 to 2011:Q4). Recall section 3.5.2, for interbank loans and liquidity ratios, majority of structural breaks were found after the end of 2008 for large banks, but changes comes earlier for small banks after fall of 2007. Overall, for all banks, we identify the main changes in liquidity and interbank lending happened after 2008:Q3 when Lehman Brothers bankrupted and the interbank market started shrinking. Although arbitrary, the 3% cut off identifies about 19% of the banks in the sample as liquidity hoarders. We also utilize 2.5, 3, 3.5 and 4 percentage point cut-offs and obtain similar result.

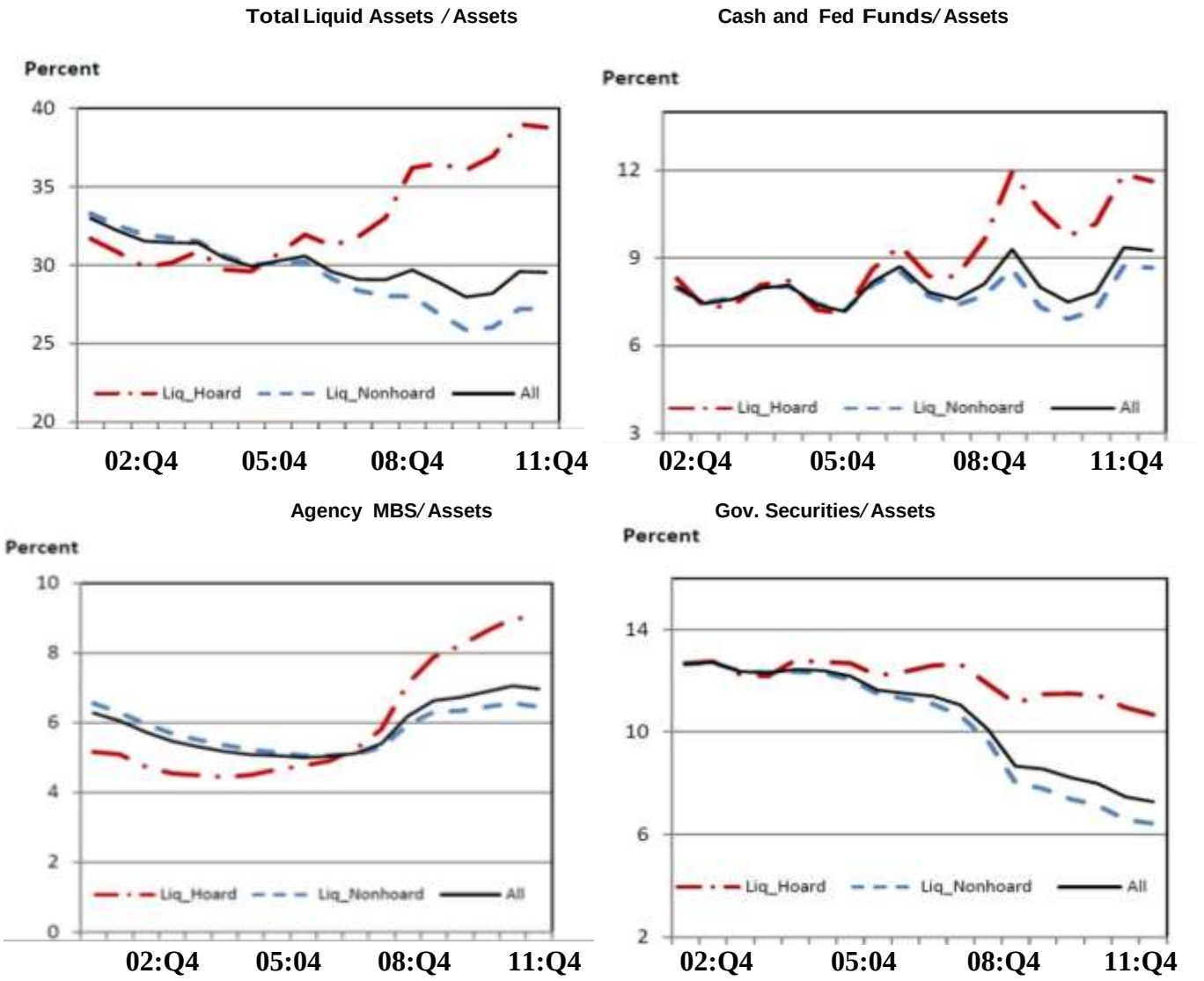


Figure 46: Liquid Assets with Liquidity Hoarding in U.S. Banks

Figure 46 above further presents the evolution of the ratio of total liquid assets to total assets for the U.S. banks (aggregate level) between 2002Q4 and 2011Q4, as well as the share of some of its components: cash and Fed funds, government securities (including Treasuries), and agency MBS (MBS issued or guaranteed by GSEs, which investors perceive as having an implicit government guarantee). As shown in Figure 46, agency MBS represents a large fraction of the liquid assets that banks were hoarding. The striking insight from it is the remarkable gap in the behavior of liquid assets across asset categories between liquidity-hoarding banks and their non-hoarding counterparts. Such disparity confirms that the disposition to hold liquid assets is not uniform across banks or across asset categories, and highlights the advantage of exploiting bank-level variation to study the nature of liquidity hoarding. The difference in the liquid assets ratio across the two groups of banks widens considerably (from 5 to 12 percentage points) between 2008:Q3 and 2010:Q4, precisely the period when the interbank market froze.

Among the liquid asset categories on the balance sheet, banks started hoarding cash (including Fed funds) and agency MBS during the interbank market crunch. The holding of government securities, however, declined after the third quarter of 2008, especially for non-hoarding banks. This decline suggests that banks were selling treasuries and other government securities to cope with increased funding pressures. Since asset categories are moving in opposite directions, each must be examined in tandem to understand the nature of liquidity hoarding.

In addition to this, the flight-to-quality effect during the financial crisis is documented in Figure 47, which was also found in study of Gatev and Strahan in 2006. Figure 47 shows the quarterly growth rate of core and non-core deposits by liquidity-hoarding banks and their non-hoarding counterparts (also recall Figure 15 in section 3.4.4). Before the crisis, the growth rates of both core and non-core deposits were lower for liquidity hoarders (red dash line). This situation reverses during the first year of the financial crisis for core deposits. Deposits increased significantly as liquidity fled other markets and is mainly explained by flows to liquidity-hoarding banks. Non-hoarder seemed to attract core deposits at a lower pace. However, as the crisis deepened during the fall of 2008, liquidity hoarders saw a sharp contraction in their core deposits, whereas non-hoarder continued to receive such deposits. One interpretation for such different behavior between liquidity hoarders and non-hoarders is that banks highly exposed to credit and security losses managed to attract deposits at the beginning of the crisis (during the

first year 2007) by raising their deposit rates. This interpretation is consistent with Acharya and Mora (2012), who find that banks hit by a funding squeeze attempted to attract deposits by raising their deposit rates. At the height of the crisis (during interbank lending crunch), however, depositors lost confidence and these banks were perceived as more risky institutions as some of their losses started to materialize. Less exposed banks (Non-hoarding banks) faced lower risks and managed to continue receiving core deposits. In contrast to the surge in core deposits, non-core deposits decreased sharply for both hoarders and non-hoarders at about the same pace. Taken together, these findings suggest a flight-to-quality effect from non-core to core deposits. Non-core deposits flew out of both types of banks at similar rates, and returned in the form of core deposits to liquidity hoarders at first, and to non-hoarders at the peak of the crisis.

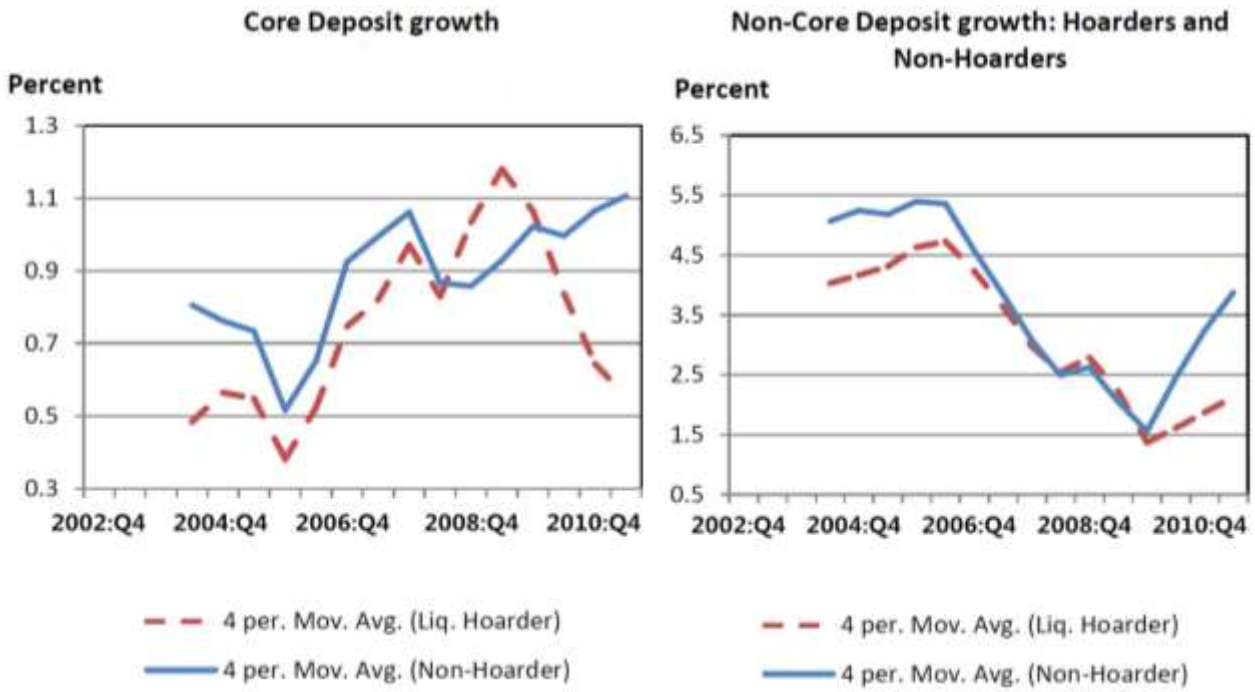


Figure 47: Deposit Growth for Hoarder and Non-Hoarder (Quarterly growth rates, 4-period moving average)

5.3 Hypotheses and Methodology

5.3.1 Hypotheses with Literature Review

The actual dynamic behavior of banks in interbank market might be a determinant for the likelihood of a banking crisis (Chapter 3 and 4), and there are remarkable gaps in the behaviors between liquidity-hoarding banks and their non-hoarding counterparts (Section 5.2). In addition to this, recall our previous literature review (section 2.3.4), previous studies on the liquidity hoarding and funding ability in the interbank market offer mixed results, motivating us to conduct a further study in this area. In this section, testable hypotheses with key relevant literature will be pointed out.

First, our first prediction is that banks curbed lending during the interbank lending crunch, when the interbank borrowing channel was broken.

Second, we also study the heterogeneity across different categories of liquid assets. Since asset categories are moving in opposite directions, each must be examined in tandem to understand the nature of liquidity hoarding (See Figure 46 in section 5.2). Liquidity management decisions are not uniform across banks, as they depend on the nature of the risks being faced. Depending on the type of funding pressures they faced, we predict that banks sold assets worth selling, such as treasuries and government securities, because the return on those assets was almost zero. Banks accumulated cash and excess reserves at the central bank because of the interest earned on reserve balances. Banks also accumulated securities such as mortgage backed securities (MBS) issued or guaranteed by Government Sponsored Enterprises (GSEs)[40]. These securities had a positive return due to an implicit government guarantee and provided valuation gains that partly compensated for the losses generated by subprime mortgage-related securities. In this chapter, we will document how liquidity hoarding became manifest during interbank lending crunch by examining the behavior of various assets commonly included in the definition of liquid assets.

Refer to section 2.3.4 in literature review; the main motivations for banks to hoard liquid assets are examined empirically. Banks may decide to hoard liquidity for precautionary reasons if they believe they will be unable to obtain interbank loans when they are affected by temporary liquidity shortages (Allen and Gale, 2004). In the model of Gale and Yorulmazer, banks hoard

[40] Such as Fannie Mae and Freddie Mac

liquidity to take advantage of potential sales (strategic motive). Acharya and Skeie (2011) develop a model in which banks hoard liquidity in anticipation of insolvency of their counterparties in interbank markets (rollover risk). Another strand of the literature derives liquidity hoarding as a result of Knightian uncertainty [41]where due to increased uncertainty banks make decisions based on worst-case scenarios (for example, in Caballero and Krishnamurthy, 2008) and contagion in financial networks.

Unused commitments and Market-to-book value of security holdings as traditional measures proxies for self-insurance motives are widely used (Cornett *et al.*, 2011; Kashyap, Rajan, and Stein, 2002; Gatev and Strahan, 2006; Gatev, Schuermann, and Strahan, 2009). Loan commitments are off-balance sheet bilateral contracts, and are issued by banks for fees. When the funding market toughens, the holders of loan commitments can borrow up to a certain limit at a certain rate as specified in the bilateral contracts. The work of Cornett, McNutt, Strahan, and Tehranian (2011) finds that a measure of off-balance sheet liquidity risk for commercial banks, such as the fraction of unused loan commitments to their lending capacity, is a key determinant of bank liquidity management. They emphasize that large undrawn loan commitments expose banks to sudden liquidity demand from corporations. That risk materialized during the financial crisis, as firms in need of liquidity rushed to draw down funds from their committed credit lines and forced banks to build up liquidity buffers to meet such increased demand. These drawdowns displaced banks' lending capacity and constrained their new credit origination. What's more, Acharya and Mora (2015) find in the context of the recent financial crisis that more exposed banks received less deposit inflows and they consequently scrambled to attract deposits by offering higher rates. Security holdings are used as collateral for secured funding. Defining the percentage deviation of the market value of security holdings from the book value as haircuts (or margins), Brunnermeier (2009) argues that haircuts capture funding risk. In analogy to traditional banking, Gorton and Metrick (2012) show that rising haircuts in the secured funding market are tantamount to deposit withdrawals, forcing sales of securities on a large scale, which in turn further increases haircuts and exacerbates funding problems.

[41] Knightian uncertainty is risk that is immeasurable and not possible to calculate, and it named after University of Chicago economist Frank Knight.

Despite the significance of these results, we argue that an important part of the story during the subprime mortgage financial crisis is still missing. In our work, we anticipate banks increased their holdings of liquid assets also in anticipation of future losses from unrealized security losses and expected loan losses measured by allowance for loan losses. Some evidence can be found in in-balance sheet data both in Figures in section 3.4.2 and Figure 48.

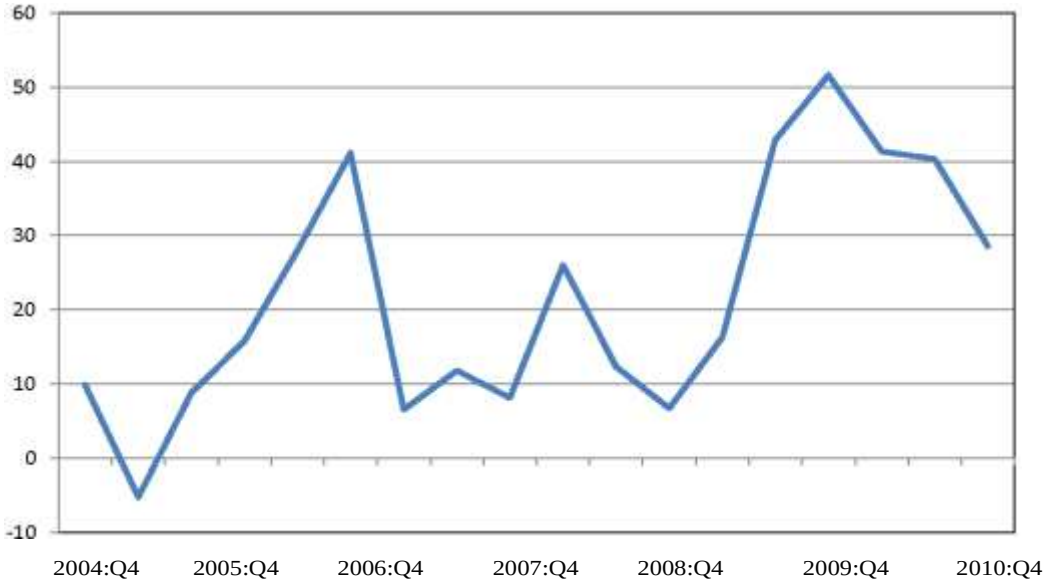


Figure 48: Bank Security Losses ($Billion)

For one side, unlike traditional measures of credit quality, such as net charge-offs and delinquent loans, allowance for loan losses have a forward-looking component that reflects banks' efforts to increase their loan provisioning in anticipation of expected losses, and therefore, provide another motivation to hoard cash in anticipation of such losses. From the Figure 10 in section 3.4.2, loss allowance to loans ratio shows an obvious "U" shaped pattern, reaching a bottom at 1.15% by the end of 2007, and then increased remarkably. The structural break test verifies the significance of change in trend at 4th quarter of 2007 (see Appendix 3 for further details). It indicates banks increased their loan reserves in anticipation of expected losses.

For another side, unrealized losses in securities holdings represent the write-downs of securities, and they reflect the exposure to future capital losses for banks if they had to sell those assets at fire sale prices. This source of liquidity risk has not been explored at length in the previous literature, due perhaps to the few balance sheet items related to credit exposure covered by collateral in those transactions. Figure 48 below shows the aggregate amount of unrealized security losses for the banking sector between 2004:Q4 and 2010:Q4. After falling from about

$40 billion in early-2006 to less than $10 billion over the second mid-2007, unrealized losses increased again during 2008. As financial strains intensified in the fall of 2008, security losses reached a peak of $52 billion at the height of the financial crisis, in 2009:Q2. Large banks were more severely hit by security losses. From Federal Reserve Bulletin (2009), the largest 10 banks held about 45 percent of the available-for-sale securities in investment accounts and accounted for two-thirds of the security losses during 2008-2009. Although security losses had a bigger impact on large banking institutions, they were a widespread problem for all banks including medium and small banks as well.

Third, therefore, we hypothesize that the precautionary motive to hoard liquidity is better approximated by a liquidity risk measure that captures a bank's exposure to expected losses in their balance sheet portfolio in anticipation of future liquidation of assets, as in Diamond and Rajan (2009). My proposed risk measures are therefore: the ratio of security losses (unrealized losses on available- for-sale securities) to available for sale securities and the ratio of loan loss allowance to total loans.

As our focus is more on interbank market, we further class our whole sample into two subgroups: Banks with net lending position (Net Lenders/ liquidity-rich banks) and Banks with borrowing lending position (Net Borrowers/liquidity-poor banks) as our main focus is interbank market. Here, net interbank loan ratio[42] is the sum of loans to depository institutions, Federal funds sold and securities purchased under agreements to resell, less the sum of Federal funds purchased and securities sold under agreements to repurchase, scaled by total assets. Net Borrowers (Net Lenders) are those with net interbank loan ratio less (greater) than its 30th (70th) percentile value in the previous quarter. Net Lenders takes the value of one when net interbank ratio exceeds the 70th percentile value in the previous quarter and zero otherwise; Net Borrowers takes the value of one when net interbank loan ratio is less than the 30th percentile value in the previous quarter and zero otherwise. Since no bank can be a net borrower and a net lender at the same time for any one quarter, (Net Borrowers - Net Lenders) takes the value of minus one for net borrowers, one for net lenders, and zero for all other cases.

[42] They are from Schedule RC and RC-A of Call Reports.

Fourth, we hypothesise that, faced with a strained interbank market, liquidity-poor banks will ration lending and hoard liquidity for precautionary motive. Both Unused commitments and our proposed proxies for self-insurance motive will be used. This prediction resonates with Iyer *et al.* (2013). Using loan level data and controlling for loan demand effects, they find that the freeze of the interbank market caused banks with heavier reliance on interbank borrowing to cut lending and hoard liquidity

Fifth, highly liquid banks will ration lending and hoard liquidity as well due to increased counterparty risk. Freixas and Jorge (2008) show counterparty risk can lead liquidity-rich banks to ration lending to liquidity-poor banks, which in turn cut back on their lending. Heider, Hoerova, and Holthausen (2010) show counterparty risk causes liquidity hoarding by liquidity-rich banks and can lead to a breakdown of the interbank market. Afonso, Kovner, and Schoar (2011) find that counterparty risk played a major role in interbank lending disruptions during the banking crisis of 2008. Similarly, Paolo, Nobili, and Picillo (2011) point out that during the crisis, interbank rates became more sensitive to borrowers' credit worthiness.

Finally, less liquidity banks will try to attract external funding by offering higher rates. A similar manifestation of high costs of self-insurance in funding rates can be found in Acharya and Mora (2015). In recent 2007/08 financial crisis, interbank markets froze and the market for asset-backed commercial paper (ABCP) collapsed in late 2008. In the face of fear and uncertainty in financial markets, large institutional investors withdrew their funds from the collective pool of cash by declining to roll over their loan agreements. If the interbank market was fully functional as a channel for efficient allocation of funds, banks in need of liquidity would not have to seek costly funding outside the interbank market. In normal times, this can even be done without causing significant effects on interest rates. However, with deepening concerns about the credit quality of counterparties and the fact that the magnitude of the exposure to subprime-related assets was unknown, investors withdrew their funds together. This withdrawal created a huge shortage of collateral, which forced institutions to sell securities to meet the increased demand for liquidity. As the repo and interbank markets shrunk, the increased sale of securities drove their prices further down. Such deterioration in the value of securities was a natural source of liquidity risk leading to the precautionary hoarding of liquid assets.

5.3.2 Data and Methodology

In this research, the sample we use here is the same as the sample we used in Chapter 4, and they are in individual level. All data are measured in million US dollar and ratios are presented as percentages.

In our study, total liquid assets are calculated as the sum of cash (including balances at other banks and reserves at the central bank), Fed funds (including reverse repos), and investment securities (including MBS, ABS, and government securities).[43] Since asset categories are moving in opposite directions, each must be examined in tandem to understand the nature of liquidity hoarding. All models and the full definitions of each variables employed in chapter Five will be listed this section.

Appendix 13 first presents descriptive statistics for both liquidity hoarders and non-hoarders before and during the interbank market meltdown. Liquidity hoarders reduce their lending much more than non-hoarders during the crisis (loan growth is considerably smaller for liquidity hoarders). On average, the growth rate of loans for liquidity hoarders dropped 1.255 percentage points (from 1.18 percent before the crisis to negative 0.075 percent during the crisis); over three times the decline in annual growth of their non-hoarding counterparts (0.38 percentage points). Furthermore, liquidity hoarders seem to be slightly larger and better capitalized than their non-hoarding counterparts, both before and when interbank market was in dire straits. Differences in almost all variables across groups before the crisis and during the crisis are statistically significant at the 1% level.

Appendix 14 further presents the mean and median difference in bank-level variables between net lenders and net borrowers. Upper Panel shows, as expected, net lenders have substantially higher Liquid asset growth and Loan growth than net borrowers. Total interest expense rate is higher for net borrowers. These results provide preliminary support for our prediction that net borrowers were subject to lending rationing and strived to attract funds by offering higher rates. Lower Panel shows Deposit growth is higher for net borrowers than net lenders, indicating that net borrowers raised rates to draw additional funding. Such different behavior was also found

[43] See section 5.2 for full details.

between liquidity hoarders and non-hoarders at the beginning of the crisis. At the height of the crisis (during interbank lending crunch), however, depositors lost confidence and a flight-to-quality effect from non-core to core deposits was found. Non-core deposits flew out of both types of banks at similar rates, and returned in the form of core deposits to liquidity hoarders at first, and to non-hoarders at the peak of the crisis.Net borrowers are substantially larger in size, implying that larger banks are more dependent on interbank borrowings perhaps because they have higher liquidity risk. Consistent with our characterization that net borrowers are liquidity poor and financially weak, net borrowers generally have higher unused commitments and more exposures to expected loss in anticipation of future liquidation of assets. Again, Differences in almost all variables across both groups are statistically significant at the 1% level.

To investigate the how banks curbed lending during the interbank lending crunch occurred during the financial crash of 2007-2008, as well as how the preemptive behaviors of banks contribute to or mitigate the onset of a financial crisis; we use regression frameworks similar to that in Cornett *et al.* (2011) as below:

$$
\begin{aligned}
&LoanGrowth_{it} \\
&\quad = \frac{\Delta Loans_{it}}{Assets_{it-1}} = \alpha_1 SIZE_{it} + \alpha_2 Tier1\ Capital\ ratio_{it} \\
&\quad + \alpha_3 Core\ Deposits/Assets_{it-1} + \alpha_4 Illiquid\ Assets/Assets_{it-1} \\
&\quad + \alpha_5 Unused\ Commitments\ ratio_{it} + \alpha_6 \text{Unrealized Security Loss ratio}_{\ it} \\
&\quad + \alpha_7 \text{Loan Loss Allowance ratio}_{\ it} + \alpha_8 \text{Fed Rate}_{\ it} + \alpha_9 \text{TED}_{\ it} \\
&\quad + \sum_{\mu=1}^{9} \sigma_\mu\ Interbank\ Lending\ Crunch_\mu + \sum_{t=1}^{T} \theta_t\ T_t + B_i + C + \varepsilon_{it}
\end{aligned}
\tag{5-1}
$$

$$
\begin{aligned}
&Liquid\ Assets\ Growth_{it} \\
&\quad = \frac{\Delta Liquid\ Assets_{it}}{Assets_{it-1}} = \lambda_1 SIZE_{it} + \lambda_2 Tier1\ Capital\ ratio_{it} \\
&\quad + \lambda_3 Core\ Deposits/Assets_{it-1} + \lambda_4 \text{Illiquid Assets/Assets}_{it-1} \\
&\quad + \lambda_5 Unused\ Commitments\ ratio_{it} + \lambda_6 \text{Unrealized Security loss ratio}_{\ it} \\
&\quad + \lambda_7 \text{Loan Loss Allowance ratio}_{\ it} + \lambda_8 \text{Fed Rate}_{\ it} + \lambda_9 \text{TED}_{\ it} \\
&\quad + \sum_{\mu=1}^{9} \sigma_\mu\ Interbank\ Lending\ Crunch_\mu + \sum_{t=1}^{T} \theta_t\ T_t + B_i + C + \varepsilon_{it}
\end{aligned}
\tag{5-2}
$$

We specify the 1st model for loan growth, which is defined as the changes of bank loans to the changes of total assets[44]. The 2nd regression analysis considers the share of liquid assets in total assets as the dependent variable[45], expressed as changes normalized by total assets. Our 1st, 2nd, and 3rd predictions will be tested by using formula 5-1 and 5-2.

The full definitions of explanatory variables employed in those models are listed below:

SIZE is the logarithmic total assets of the banks. Afonso, Santos, and Traina (2014) as well as our empirical studies in chapter 3 and 4 show large banks engage in riskier lending activities and produce a larger volume of impaired loans due to implicit government guarantees (i.e., too big to fail subsidy).

Tier1 capital ratio is defined as a percentage of risk-weighted assets as defined by the appropriate Federal regulator for prompt corrective action during that time period (Dinger and Hagen, 2005).

Core deposit to asset ratio is the share of core deposits (the sum of transaction deposits and other insured deposits) in total assets. It is a proxy of stable sources of funding.

Illiquid assets to assets is the ratio of total illiquid assets to total assets.

Unused commitment ratio is measured by the percentage of unused commitments to lending capacity (unused commitments plus assets). Recall section 5.3.1, it is a proxy of off-balance sheet funding liquidity stemming from loans.

Loan Loss Allowance ratio[46] is defined as a ratio of allowance for loan losses to total loans. Loan loss allowance is the sum of all estimated (unrealized) credit losses, which is a contra-asset account that reduces the book value of non-performance loans to the amount deemed collectible.

[44] Ratios in this chapter are all scaled by the beginning of quarter value.
[45] Here, we assume a bank with liquid assets and loans on the debit side of the balance sheet, financed by equity and deposits only. Therefore, growth in liquid assets should be equal the sum of changed in deposits and loans. If the changes in deposits are larger than the changes in loans, the deposit inflow will transform into liquidity assets.
[46] Recall section 5.3.1, we hypothesize that the precautionary motive to hoard liquidity is better approximated by a liquidity risk measure that captures a bank's exposure to expected losses in anticipation of future liquidation of assets. My proposed risk measures are therefore: the ratio of security losses and the ratio of loan loss allowance.

Loan loss allowance increases with loan loss provision and recoveries, and decreases with charge-offs. Therefore, failing to control for loan loss allowance and charge-offs could lead to wrong conclusions.

Unrealized security loss ratio is the percentage of unrealized losses on available - for - sale securities to available for sale securities[47]. For the ease of interpretation, I switch the sign and take a positive sign as indicative of a loss.

Fed rate (Federal Funds Rate) is the proxy of aggregate loan demand. It is the rate at which depository institutions trade Federal funds [48]on an overnight and uncollateralized basis. Bernanke and Gertler (1995) consider direct and indirect effects of the central bank's interest rate policy. The central bank controls the short-term interest rate to directly influence the cost of borrowing and spending by households and corporations. Indirectly, interest rate changes affect loan demand. For example, a rise in the interest rate increases the cost of external financing more for borrowers with weak financial standings and thus restricts their demand for credit relative to those with strong financial conditions.

TED Spread is the spread between the 3-month LIBOR and 3-month Treasury rate, and serves as our proxy for counterparty risk[49].

---

[47] We use both gross and net (of taxes) measures of unrealized gains (losses) in available-for-sale securities. Net unrealized gains (losses) are obtained directly from Call Reports (RC-R, RCFD-8434), whereas gross unrealized gains (losses) are computed as the difference between the amortized cost and the fair value of available-for-sale securities as reported in the securities schedule (RC-B) of Call Reports. The amortized cost of securities is their book value (acquisition cost) adjusted for the discount or premium paid at purchase. The difference between amortized cost and fair value is the change in market value (write-up or write-down) of the securities still being held on banks' investment portfolios. Unrealized security losses are reported with a negative sign (a positive sign then indicates a security gain).

[48] It is balances held with the Fed, also known as reserves

[49] In October 2008, after the failure of Lehman Brothers, the conservatorship of Fannie Mae and Freddie Mac, and the AIG bailout, a measure of counterparty risk in interbank markets such as the TED spread (difference in yield between LIBOR and a Treasury Bill of similar maturity) moved up to a record level of 430 basis points. As Acharya and Merrouche (2013) argue, the drying up of short-term liquidity markets caused a significant increase in borrowing rates for all banks, regardless of counterparty risk. The spike in funding costs suggests an interest rate contagion channel through the interbank markets, which is well described by rate spreads such as the TED spread (3-month LIBOR rate minus 3-month Treasury rate) or the LIBOR-OIS spread (LIBOR rate over the corresponding overnight index swap rate). As in Cornett, McNutt, Strahan, and Tehranian (2011), we include interaction terms of the TED spread with the key explanatory variables as the main focus of the analysis.

Interbank Lending Crunch (ILC) takes the value of one for the period from the 3rd quarter of 2008 when Lehman Brothers bankrupted and the interbank market started shrinking, and zero otherwise (for more details please refer to section 5.2). Interbank Lending Crunch is an interaction variable to get interaction variables in terms of 9 independent variables by considering two sub-periods (1992Q4 -2008Q2 and 2008Q3 -2011Q4). It is equal to the original values of independent variables multiplied by 1 in the later sub-period, and 0 otherwise. μ is the number of independent banking variables from 1 to 9.

T_t (t = 1,…,T) is a set of quarter dummies which control for unobserved time-specific effects at the macro level.

B_i (i = 1,…,N) is a set of bank fixed effects which control for time-invariant unobserved banks-specific heterogeneity.

In the rest of models, we also class our whole sample into two subgroups: Net Lenders (Liquidity-rich banks) and Net Borrowers (Liquidity-poor banks); (Net Borrowers - Net Lenders) takes the value of minus one for net borrowers, one for net lenders, and zero for all other cases (see full details in section 5.3.1).

For brevity, we also introduce a set of control variables X_j (j = 1, …, J, J=9) to account for bank-specific characteristics we examines from Eq 5-1 and 5-2. They are bank size, Tier1 Capital ratio, core deposit to asset ratio and illiquid assets to assets as proxies for banks' financial conditions; and Federal Funds Rate as proxies for aggregate loan demand; unused commitment ratio, unrealized security loss ratio and loan loss allowance ratio as proxies for self-insurance motives; and TED Spread as our proxy for counterparty risk. Then Model 5-1 and 5-2 with Net Lenders and Net Borrowers classification can be represented as format below:

$$
\begin{aligned}
LoanGrowth_{it} = \frac{\Delta Loans_{it}}{Assets_{it-1}} \\
&= \lambda_1 Interbank\ Lending\ Crunch + \lambda_2 (Net\ Borrowers - Net\ Lenders)_{it} \\
&+ \lambda_3 Interbank\ Lending\ Crunch * (Net\ Borrowers - Net\ Lenders)_{it} \\
&+ \sum_{j=1}^{9} \gamma_j X_{jit} + \sum_{t=1}^{T} \theta_t T_t + B_i + C + \varepsilon_{it}
\end{aligned}
$$

$$Liquid\ Assets\ Growth_{it} = \frac{\Delta Liquid\ Assets_{it}}{Assets_{it-1}}$$
$$= \lambda_1 Interbank\ Lending\ Crunch + \lambda_2 (Net\ Borrowers - Net\ Lenders)_{it}$$
$$+ \lambda_3 Interbank\ Lending\ Crunch * (Net\ Borrowers - Net\ Lenders)_{it}$$
$$+ \sum_{j=1}^{9} \gamma_j X_{jit} + \sum_{t=1}^{T} \theta_t T_t + B_i + C + \varepsilon_{it}$$

(5-3)

Our 4th prediction poses that net borrowers amassed liquidity to insure against potential liquidity shortfalls. To capture such self-insurance motives of liquidity hoarding, we match Liquid Asset Growth with Deposit Growth[50], and specify the following equation:

$$Liquid\ Assets\ Growth_{it}$$
$$= \frac{\Delta Liquid\ Assets_{it}}{Assets_{it-1}} = \beta_{1_{it}} Interbank\ Lending\ Crunch$$
$$+ \beta_2 Liquidity\ Shortage_{it}$$
$$+ \beta_3 Interbank\ Lending\ Crunch * Liquidity\ Shortage_{it}$$
$$+ \beta_4 Deposit\ Growth_{it} + \beta_5 Deposit\ Growth * Interbank\ Lending\ Crunch_{it}$$
$$+ \beta_6 \text{Deposit Growth} * \text{Liquidity Shortage}_{\ it}$$
$$+ \beta_7 \text{Deposit Growth} * \text{Interbank Lending Crunch} * \text{Liquidity Shortage}_{\ it}$$
$$+ \sum_{j=1}^{8} \gamma_j X_{jit} + \sum_{t=1}^{T} \theta_t T_t + B_i + C + \varepsilon_{it}$$

(5-4)

Where, Deposit Growth is quarterly change in Deposits, scaled by the beginning of the quarter value of total assets. Liquidity Shortage is our liquidity shortage indicator, for which we employ UC90 and URSL90. UC90 takes the value of one for observations where Unused Commitments is greater than its 90th percentile value in the previous quarter and zero otherwise. URSL90 takes the value of one for observations where Unrealized Security Loss ratio is greater than its 90th percentile value in the previous quarter and zero otherwise (Sign is positive for loss). In estimating equation (5-4), when UC90 is used as a liquidity shortage proxy, we leave the unused commitment ratio out of the set of controls; similarly, when URSL90 is used, we leave out the

[50] Here, we assume there are two-group banks with identical characteristics, banks As (have precautionary needs) and banks Bs (do not). In order to cover liquidity shortages, As borrow from the interbank market, but if interbank channel is disrupted, As would have to attract additional deposits. However, Bs have little incentives to hoard liquidity.

Unrealized Security Loss ratio. The remaining variables are as specified above. We estimate equation (5-4) separately for net lenders and net borrowers.

To test our fifth prediction that net lenders piled up liquidity due to counterparty risk, we estimate the following regression model for Liquid Asset Growth:

$$\begin{aligned} &Liquid\ Assets\ Growth_{it} \\ &= \frac{\Delta Liquid\ Assets_{it}}{Assets_{it-1}} = \rho_{1_{it}} Interbank\ Lending\ Crunch \\ &+ \rho_2 (Net\ Lenders - Net\ Borrowers)_{it} \\ &+ \rho_3 Interbank\ Lending\ Crunch * (Net\ Lenders - Net\ Borrowers)_{it} \\ &+ \rho_4 TED_{it} + \rho_5 TED * Interbank\ Lending\ Crunch_{it} \\ &+ \rho_6 TED * (Net\ Lenders - Net\ Borrowers)_{\ it} \\ &+ \rho_7 \text{TED} * \text{Interbank Lending Crunch} * (Net\ Lenders - Net\ Borrowers)_{\ it} \\ &+ \sum_{j=1}^{9} \gamma_j X_{jit} + \sum_{t=1}^{T} \theta_t T_t + B_i + C + \varepsilon_{it} \end{aligned} \tag{5-5}$$

Where, all variables are as specified above. TED is a proxy for counterparty risk.

Lastly, we examine our final predication that lending rates were higher for net borrowers. We estimate the following regression model for Total interest expense rate:

$$\begin{aligned} &\text{Total Interest Expense Rate}_{it} \\ &= \eta_1 Interbank\ Lending\ Crunch + \eta_2 (Net\ Borrowers - Net\ Lenders)_{it} \\ &+ \eta_3 Interbank\ Lending\ Crunch * (Net\ Borrowers - Net\ Lenders)_{it} \\ &+ \sum_{j=1}^{9} \gamma_j X_{jit} + \sum_{t=1}^{T} \theta_t T_t + B_i + C + \varepsilon_{it} \end{aligned} \tag{5-6}$$

Where, total interest expense rate is the ratio of total interest expenses to the quarterly average balance of interest-bearing liabilities. Interest-bearing liabilities are the sum of interest-bearing deposits, Federal funds purchased and securities sold under repurchase agreements, trading liabilities, other borrowed money, subordinate notes and debentures. The remaining variables are as specified above.

5.4 Results and Analyses of Empirical Work

5.4.1 Liquidity Hoarding with Different Asset Categories

In contrast to Cornett *et al.* (2011), we first investigate the main determinants of liquidity hoarding for different asset categories as suggested by Figure 46. Our definition of liquid assets includes mortgage-backed securities. Refer to section 5.2 for full details. In fact, most of the security losses in banks' balance sheets result from the write-downs of ABS and non-agency MBS; and agency MBS represents a large fraction of the liquid assets that banks were hoarding.

Table 10: Results of Fixed Effect Regressions of Various Liquid Assets

	Reference Model	**Model based on Eq5-2**			
	∆Liq.Asset/ Assetst−1 (1)	∆Liq.Asset/ Assetst−1 (3)	∆(Cash + FF)/ Assetst−1 (4)	∆Gov.Sec./ Assetst−1 (5)	∆MBS/ Assetst−1 (6)
Size	-0.032*** (3.769)	-0.033*** (4.875)	-0.028*** (4.113)	-0.001* (1.268)	-0.003*** (5.659)
Size*ILC	-0.115*** (2.887)	-0.113*** (2.676)	-0.163*** (3.005)	-0.004 (0.178)	0.066*** (3.996)
Tier1 Cap ratio	-0.020*** (3.127)	-0.024*** (2.988)	0.013* (1.021)	-0.013*** (3.552)	-0.025*** (3.879)
Tier1 Cap ratio *ILC	-0.362 (0.357)	-0.303 (0.396)	-2.642*** (3.861)	1.264*** (2.985)	0.681*** (3.021)
Core Deposit growth	-0.019*** (3.853)	-0.020*** (2.843)	-0.029*** (3.865)	0.005*** (3.127)	0.001 (0.186)
Core Deposit growth*ILC	-0.262 (0.263)	-0.259 (0.272)	-1.107*** (2.775)	0.509*** (3.436)	0.181** (1.854)
Illiquid Asset/Assett−1	0.226*** (3.556)	0.226*** (4.934)	0.250*** (4.762)	0.004* (1.553)	-0.030*** (2.832)
Illiquid Asset/Assett−1*ILC	0.042 (0.356)	0.251 (0.276)	-0.744*** (3.665)	1.160*** (3.812)	0.012 (0.215)
Unused Commitments ratio	-0.144*** (3.246)	-0.144*** (4.909)	-0.126*** (2.773)	-0.029*** (4.162)	0.004** (1.753)
Unused Commitments ratio*ILC	2.414*** (2.785)	2.331*** (5.763)	1.984*** (2.176)	1.353*** (3.225)	-0.823*** (3.193)
Unrealized Security ratio		-0.002 (0.125)	-0.005 (0.169)	0.009*** (6.783)	0.0001 (0.114)
Unrealized Security ratio*ILC		0.688* (1.587)	0.994** (1.767)	-0.573*** (4.778)	0.346*** (3.297)
Loan Loss Allowance ratio		-0.001 (0.111)	0.0004 (0.183)	0.0004 (0.175)	-0.001*** (3.674)
Loan Loss Allowance ratio*ILC		0.079** (1.811)	0.119*** (2.997)	-0.033* (1.564)	-0.007 (0.201)
Fed rate		-0.004 (0.988)	-0.003* (1.076)	-0.013 (0.552)	-0.025 (0.879)
Fed rate*ILC		-0.004*** (3.396)	-0.002** (1.861)	-0.003*** (2.985)	-0.001* (1.526)
TED		0.0113 (0.811)	-0.004*** (9.181)	0.0004 (0.175)	-0.001*** (3.674)
TED*ILC		0.119** (1.823)	-0.119** (1.781)	0.013* (1.564)	-0.017*** (4.879)
Intercept	0.248*** (3.112)	0.268*** (3.663)	0.189*** (2.675)	0.010 (0.142)	0.058*** (2.889)
Firm Dummies	Yes	Yes	Yes	Yes	Yes
Quart. Dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.220	0.221	0.216	0.106	0.173
Observations	1075921	1075921	1075921	1075921	1075921
ILC stands for 'interbank lending crunch'. Standard errors are in parentheses. *, **, *** denotes significance at 10%, 5% and 1% levels.					

Our regression estimates based on equation 5-2 are shown in table 10 above. The first column in table 10 is included as a reference, as they replicate the findings of Cornett *et al.* (2011). As can be seen, unused commitments ratio appear to be a significant determinant of increased liquidity buffers measured by the liquid asset ratio. Cornett *et al.* (2011) suggest a positive expected sign for loan commitments, but acknowledge the difficulty in establishing ex-ante sign of this variable. As they argue, banks with greater unused commitments may be exposed to liquidity risk, but also experience greater increase in loan demand during the crisis.

Columns 3 through 6 show our estimates by type of liquid assets. Our main findings are:

As documented in prior work, stable sources of funding such as deposits and capital are key determinants of the holdings of liquid assets: holdings of liquid assets also decrease with bank capital and deposits. Consistent with Cornett, McNutt, Strahan and Tehranian (2011), this thesis finds that core deposits substitute for cash and Fed funds as banks use these stable funding sources to fund loans and commitments.

Our proposed measures of on-balance sheet risk, unrealized security loss ratio and loan loss allowance ratio, play a significant role during the interbank lending crunch, and seem to complement off-balance sheet liquidity risk stemming from the possibility of increased drawdown demand for committed loans.

When looking at each individual component of the overall liquid asset ratio, our results suggest that this complementarity between on-balance sheet and off-balance sheet risks is particularly important to explain the hoarding of cash and Fed funds during times of interbank lending crunch. However, that is not the case for the holdings of government securities and agency MBS. Columns 5 and 6 indicate that, in general, large unused commitments seem to reduce the holdings of government securities and to increase the holdings of agency MBS in normal times. However, they seem to act in the opposite direction during times of interbank crisis. These results seem counterfactual if one takes the interpretation that large unused commitments are a source of off-balance sheet liquidity risk. As Figure 46 indicates, rather than hoarding government securities during the financial crisis, most banks were selling them; Tehranian (2011), who examined an overall holdings of agency MBS, found that most banks decided to continue holding them. In

contrast, the unrealized security loss ratio and more importantly, its interaction with the interbank lending crunch, consistently explains the behavior of each category of liquid assets. It significantly explains the increase in cash plus Fed funds and the holdings of agency MBS during financial distress. Security losses and loss allowance also appear to be significant explanatory variables for the decline in government securities, in agreement with the behavior in Figure 46; but not for the holding of agency MBS.

Our results also suggests that core deposits added liquidity to banks that wanted to hoard their liquid funds, which is consistent with Gatev and Strahan (2006). 'The flight-to-quality effect' is found. During the recent financial crisis, many banks had enormous difficulties accessing interbank markets. In those circumstances, it is also likely that within banks where institutions are more harshly competing for liquid funds; banks perceived as a safe haven for deposits (with large holdings of liquid assets) benefited more than less liquid banks and were able to attract inflows in the form of core deposits by raising their rates. Investors regard banks as a "safe haven" only when they can be confident that their deposits are insured or backed by a government guarantee (Gatev and Strahan, 2006; Pennacchi, 2006).

5.4.2 Liquidity Hoarding and Bank Size

As we found in chapter 4, the market's perception of the risk of a bank can depend on the size of the bank. Evidence of 'Size matters' is also provided by Black, Collins and Robinson (1997). Schweitzer (2003) observes a flight to quality as evidenced by changes in institutional ownership of TBTF for bank equity shares. It is interesting to see whether bank size plays a significant role for liquidity hoarding, especially in financial crisis.

To further investigate the role of size, we conducted a regression analysis on liquid asset growth (Eq5-2) and loan growth (Eq5-1) for large banks and small banks, using the bank-size split in our chapter 4. Whole sample is split into two groups according to a threshold value of log bank total assets (5.299027). Results are shown in Appendix 15. As before, the interactions between the interbank lending crunch and the variables that explain liquid risks are of particular interest. Our main findings are:

Core deposits and capital are more relevant for small banks than for large banks. The negative and significant coefficient on the interaction term of the interbank lending crunch and both core deposits and capital suggests that, during times of financial distress, core deposits and capital substitute liquidity assets for small banks. Although Appendix 13 suggests that liquidity hoarders appear to be slightly larger than non-hoarders, the regression results do not support the hypothesis that larger banks hoard more liquid assets. On the contrary the results indicate that the holdings of liquid assets decrease with bank size; this is in line with Ashcraft, McAndrews, and Skeie (2011), who find that small banks hold larger amounts of cash and excess reserves with the Federal Reserve than larger banks.

Our regression results reveal that the complementarity among unused loan commitments, unrealized losses and loan loss allowance, is significantly important in explaining the cash hoarding of small banks during the interbank lending crunch. However, this evidence seems weaker for large banks. To further examine the relationship between unused commitments and unrealized security losses, Figure in Appendix 16 plots the behavior of these two measures of liquidity risk for small and large banks. Unused commitments drop significantly for large banks, starting in September 2007, that is, immediately after the collapse of the interbank and the securitization markets. The unused commitment ratio falls from 18 percent in the 3rd Quarter of 2008 to 12 percent in 2009 summer. This finding is consistent with Berrospide, Meisenzahl and Sullivan (2011), who report evidence of increased drawdowns of corporate credit lines starting in the fall of 2007, that is, earlier than previously documented. The decline in unused commitments continues during 2008, precisely the time when banks were hit by significant losses in their securities holdings. Security losses for large banks rose to almost 2 percent after the collapse of Lehman and AIG in October 2008. Small banks faced a similar situation. Their unused commitments decreased from 9 percent to 7 percent during the financial crisis. Their security losses increased from -1% (gain) to 1.6% between the first and third quarters of 2008.

5.4.3 Liquidity Hoarding with Net Borrowers and Net lenders

We further class our whole sample into two subgroups: Net Lenders (liquidity-rich banks) and Net Borrowers (liquidity-poor banks). For brevity, in this section, we do not show the coefficients for the control variables. Both bank and quarterly time dummies are included in all regressions with the residuals clustered at the bank level.

Table 11 presents the results from estimating Eq(5-3) for Loan Growth and Liquid Asset Growth respectively.

Table 11: Lending rationing by net borrowers

	Loan Growth (1)	ΔLiq.Asset/ Assetst−1 (2)
(Net Borrowers − Net Lenders)	0.0002 (0.0298)	0.0003 (0.1249)
(Net Borrowers − Net Lenders) × ILC	- 0.0153 *** (- 4.1875)	0.005 (1.1256)
Control variables included	Yes	Yes
Bank Dummies included	Yes	Yes
Quarterly Time Dummies included	Yes	Yes
R^2	0.411	0.248
Number of observations	1075921	1075921
Number of banks	13973	13973
Note: This table reports the regression results for Loan Growth and Liquid Asset Growth. T-statistics are in parentheses, and *** , **and * indicate the 1% , 5% and 10% significance levels respectively.		

First of all, we find evidence of lending rationing by liquidity-poor banks, which is in the line with the theory of lending rationing by Arnold and Riley (2009). From column (1), we discover that the difference in Loan Growth rate between net borrowers and net lenders is insignificant before the interbank lending crunch. However, during the financial crisis, when the interbank market was unable to perform efficient allocation of funds, Loan Growth was 1.53 percentage points lower for liquidity-poor banks than liquidity-rich banks. Moreover, this result holds after controlling for loan demand effects. In column (2), unlike Loan Growth, we find no significant difference in Liquid Asset Growth rate between net borrowers and net lenders between the periods before and during the interbank lending reluctance.

In the absence of the well-functional interbank market as a coinsurance channel, Castiglionesi *et al.* (2014) show liquidity-poor banks hoard liquidity for self-insurance against liquidity shortfalls. By model (5-4), we test our prediction on self-insurance motives by liquidity-poor banks. And we present our results in Table 12. We fit equation (5-4) to net borrowers and net lenders respectively.

Column (1) shows net lenders transform 21.91 cents of every dollar of deposit inflows into liquid assets unconditionally. During the interbank lending crunch, they kept 12.19 cents more. Before the crunch, net lenders with unused commitments did not need high levels of liquidity, perhaps

because funds were readily available in the interbank market, and managed to keep 7.61 cents less. This is consistent with Gatev and Strahan (2006) and Gatev, Schuermann, and Strahan (2009) who find that banks with more unused commitments enjoy greater deposit inflows and lower funding costs especially in financial distress. However, in the interbank lending crunch, unused commitments posed a great deal of pressure even on net lenders; net lenders with unused commitments kept 9.45 cents more. Overall, during the interbank lending crunch, net lenders with unused commitments retained 35.94 cents in the form of liquid assets for every dollar of deposit. This result is consistent with Acharya and Mora (2015).

Table 12: Liquidity hoarding by net borrowers for self-insurance

ΔLiq.Asset/ Assetst−1				
	Liquidity Shortages = UC90		Liquidity Shortages = URSL90	
	Net Lenders (1)	Net Borrowers (2)	Net Lenders (1)	Net Borrowers (2)
Deposit Growth	0.2191 *** (31.7254)	0.2559 *** (33.8623)	0.2004 ** (25.8738)	0.231 ** (27.7774)
Deposit Growth × ILC	0.1219 *** (9.1298)	0.2164 *** (16.5395)	0.1366 ** (5.2555)	0.1925 ** (9.5723)
Deposit Growth × Liquidity Shortages	-0.0761 *** (-3.1523)	-0.0880 *** (-3.4661)	0.0500 ** (4.7269)	0.0399 ** (3.5663)
Deposit Growth × ILC × Liquidity Shortages	0.0945 ** (1.9523)	0.1653 *** (4.9336)	0.0571** (1.6301)	0.065 *** (4.7399)
Control variables included	Yes	Yes	Yes	Yes
Bank Dummies included	Yes	Yes	Yes	Yes
Quarterly Time Dummies included	Yes	Yes	Yes	Yes
R^2	0.1098	0.1644	0.1274	0.2324
Number of observations	553630	522291	553630	522291
Number of banks	7190	6783	7190	6783

Note: This table reports the regression results for Liquid Asset Growth using Unused Commitments greater than 90th percentile (UC90) as an anticipated liquidity shortfall proxy for Net Lenders in column (1) and for Net Borrowers in column (2).
T-statistics are in parentheses, and *** , **and * indicate the 1% , 5% and 10% significance levels respectively.

In column (2), a similar pattern is found for net borrowers, except that net borrowers with unused commitments transformed 16.53 cents more into liquid assets during the interbank lending crunch (7.08 cents more than net lenders with unused commitments). For every dollar of deposit, they hoarded 54.96 cents in liquid assets, 19.02 cents more than net lenders with unused commitments. Our results verify our 4th predication that net borrowers could hoard liquidity for self-insurance, especially during the crunch. Robustness test is done by use unrealized security loss ratio as our proxy for liquidity shortage. We've found similar results and net borrowers hoard more liquidity with lower quality security holdings.

Empirical results of Eq5-5 for our fifth prediction that counterparty risk prompted net lenders to hoard liquidity are in Table 13. The same set of controls as for the Liquid Asset Growth regressions are included, and (Net Lenders-Net Borrowers) is used instead of (Net Borrowers-Net Lenders) so that we can draw direct inference about net lenders.

Table 13: Liquidity hoarding by net lenders due to counterparty risk

	ΔLiq.Asset/ Assetst−1
TED	0.0113 *** (19.874)
TED × ILC	- 0.0063 *** (- 9.2321)
TED × (Net Lender - Net Borrowers)	0.0009 (1.5326)
TED × ILC× (Net Lender - Net Borrowers)	0.0023 *** (2.9865)
Control variables included	Yes
Bank Dummies included	Yes
Quarterly Time Dummies included	Yes
R^2	0.0957
Number of observations	1075921
Number of banks	13973
Note: This table reports the regression results for Liquid Asset Growth. The main test variable is TED as a proxy for counterparty risk. T-statistics are in parentheses, and ***, **and * indicate the 1%, 5% and 10% significance levels respectively.	

Table 13 describes that a 1% increase in TED unconditionally leads to a 1.13% increase in Liquid Asset Growth. TED Spread is in percentage and liquid asset growth is in fraction[51]. During the interbank lending reluctance, a 1% rise in TED brought about a 0.63% drop in Liquid Asset Growth for all banks, regardless whether they are net lenders or net borrowers. Before the crisis, TED Spread had no differential impact on liquid asset growth between liquidity-rich banks and liquidity-poor banks. However, during the interbank crunch, we find that a 1% rise in TED prompted net lenders to hoard 0.23% more liquid assets than net borrowers. Therefore, we've find evidence of precautionary liquidity hoarding by liquidity-rich banks due to counterparty risk; which is in the line with the theory of lending rationing by Afonso, Kovner & Schoar, 2011; Ashcraft; McAndrews & Skeie, 2011; and Paolo, Nobili & Picillo, 2011.

[51] Therefore, we adjust the scale inconsistency by multiplying the coefficient estimates by 100.

Table 14 describes the results for our final proposition that net borrowers offered higher rates to attract deposits. As net borrowers scrambled for self-insurance when the interbank market was disrupted, they could have faced higher funding costs. Subsequent to the failure of Lehman Brothers, the Fed started injecting unprecedentedly large amounts of liquidity into the banking sector. In theory, unless every bank holds the injected liquidity with the Fed, the injected liquidity should create deposits as it changes hands (Ennis and Wolman, 2012; Keister and McAndrew, 2009). Our results also indicated the Fed's liquidity injections created considerable amounts of deposit flows.

Table 14: Funding costs for net borrowers

	Total Interest Expense Rate
(Net Borrowers − Net Lenders)	- 0.0012 (- 0.9166)
(Net Borrowers − Net Lenders) × Interbank Lending Crunch	0.0066 *** (4.765)
Control variables included	Yes
Bank Dummies included	Yes
Quarterly Time Dummies included	Yes
R^2	0.6512
Number of observations	1075921
Number of banks	13973
Note: This table reports the regression results for Total Interest Expense Rate T-statistics are in parentheses, and ***, **and * indicate the 1%, 5% and 10% significance levels respectively.	

5.5 Conclusions

In this Chapter, we examine the impact of the disruption of the interbank market on banks' liquidity creation and funding ability. As the recent financial crisis demonstrates, liquidity hoarding affects the normal functioning of short-term funding markets. Our results are consistent with previous work documenting the substantial effects of disruptions in interbank markets.

Due to increased uncertainty and the fear of prolonged restrictions to access interbank loans, banks that choose to hoard liquidity may cause a rise in borrowing costs that have an adverse impact on less liquid banks. Consistent with theoretical explanations for the precautionary motive of liquidity hoarding, the empirical results show that banks choose to build up liquidity in anticipation of future expected losses from holding assets during interbank lending crunch. Specifically, we find evidence of self-insurance motives and lending rationing by net borrowers. We also find net borrowers offered higher rates to attract external funding, and net lenders hoarded liquidity due to heightened counterparty risk.

Compared with previously suggested proxies for banks' liquidity risk, such as the proportion of unused loan commitments to their lending capacity-exposure, security losses in their investment portfolio represents a more accurate measure of liquidity risk associated with the run in repo markets during the financial crisis. This measure of liquidity risk is consistent with the theory of liquidity hoarding and provides supporting evidence for the precautionary motive. We also find evidence that allowance for loan losses are another key factor contributing to the increased holdings of liquid assets, especially for small banks. Although not a substitute for cash, and thus less related to liquidity risk, the forward-looking component of loan loss allowance seems to reflect banks' asset reallocation from loans (which have become riskier due to the reduced creditworthiness of their borrowers) to safe and liquid securities.

We also document an important flight-to-quality effect in deposit flows. Consistent with the view that deposits represent a stable source of funds for bank operations, we find evidence of inflows of core deposits during the financial crisis to banks that chose to hoard liquidity. Non-core deposits flew from both liquidity-hoarding and non-hoarding banks, moving into hoarding banks in the form of core deposits.

On the policy frontier, we argue that the central bank has to ensure the interbank market function well for its expansionary monetary policy to be effective. Besides credit and securities lending programs targeted at the interbank market, such as TAF, TSLF, and PDCF, we suggest interbank lending subsidization as well. The central bank should consider paying a spread over the rate at which banks lend to each other whenever the interbank market is not performing efficiently to incentivize interbank lending. In implementing this policy, the central bank has to constantly and closely monitor the interbank market so that, as full efficiency is reached, it can narrow the spread. In our belief, unlike the interest-on-reserve policy, interbank lending subsidization will work in perfect harmony with liquidity injections.

Chapter Six: Conclusion and Policy Implications

The current research arising from recent subprime mortgage crisis 2007/08 is manifold. For one side, while there are many benefits in knowing whether and if so when a crisis may occur, it has been a challenge to predict crisis. For another side, the view that the structure of the financial network plays a central role in shaping 'Systemic risk' has become conventional wisdoms. However, the banking systems have developed in those network models are free of any actual dynamics: there is a paucity of research in network models has considered the possibility that the banks could make preemptive actions to protect themselves from a common market shock and therefore affect the propagation of losses through the financial linkages, such as interbank market. As a result, further related studies will be required in future; to fine-tune public policy and the policy-making process.

The author started the analysis by identifying banks' behaviours vis-à-vis the 2007/08 global financial crisis from a wide range of balance sheet ratios according to CAMELS model. Methodologically, chapter 3 provided a new and innovative analysis: it analysed structural shifts of those accounting ratios, in response to three chronological periods: pre-crisis, crisis and post crisis, to assess the relative likelihood of success of selective financial ratios as early warning indicators. Following this analysis, we've found that an aspect of the actual dynamic behaviour of banks is a key variable for the onset of a banking crisis. More specifically, the results show that certain indicators such as nonperforming loans ratio, leverage ratio and coverage ratio are appropriate indicators for the detection of banking system vulnerabilities for all banks. And nonperforming loans ratio additionally serves as an indicator for the timing of a crisis. While capital levels were closely monitored, banks' heavy reliance on wholesale funding was overlooked. Banks that seemed to be safe experienced a 'bank run' that ultimately led to their defaults. Finally, although the interbank market was not fully frozen in the early stage of financial crisis for large banks, the sudden decrease in interbank market activities and increase in banks' liquidity 'hoarding' behaviour was observed.

We've also verified differences in the applicability of banking accounting ratios for the identification of banking problem between large, median and small banks: Bank size does matter. While the changes in the financial system affected all banks, they had a particularly large impact on the large banks. The business model of large banks became clearly distinct from that of small

or medium-sized banks. First, large banks today engage disproportionately more in market-based activities. Second, large banks hold less capital than small banks, as measured either by a tier 1 capital ratio or a leverage ratio. Third, large banks have less stable funding than small banks, as measured by the ratio of deposits to total assets. Fourth, large banks engage more interbank activities, as measured by interbank loan. Finally, large banks have poorer asset quality than small banks, as measured by NPLs to total gross loans ratio. The results from this empirical investigation, which can be generalised to the banking system as a whole, provide valuable insights into the operation of the interbank market that we've focused in our chapter 4 and 5.

In Chapter 4, the author further focused on whether involvements in interbank lending increased the risk level of banks; and particular attention was paid to the effect of size. All in all, the empirical evidence supports the 'too big to fail' (TBTF) thesis: there is a close nonlinear (U-shaped) relationship between a bank' size and its risk-taking behavior. In other words, the risk level is increased when the bank size goes beyond a certain level. A non-linear threshold model is employed in my empirical work to find this critical value: a strong positive coefficient of bank size is found in large banks where bank size is over the threshold; whereas a significant negative coefficient is found in the small banks where bank size is less than the threshold. This result indicates that given an interconnected multiple money centre bank market, large banks are associated with higher risk-taking. In addition to this, Chapter 4 also tests an interaction model to detect differences in U.S. interbank bank activities and risk-taking in three sub-periods: *pre-crisis*, *crisis and post-crisis*.

For specifically, a negative relationship between equity holding and risk level was found in the small banks, but not in large banks. This suggests that small banks with fewer equities are more likely to be associated with higher risk-taking. This, in turn, highlights the importance of monitoring from shareholders to reduce the risk-taking of small banks owing to the lack of protection from CB. An insignificant result in terms of large banks might suggest that shareholders have less incentive to monitor bank activities due to a potential bail-out provided by CB; thus, it might be argued that TBTF generates a moral hazard problem that is not only related to bank managers pursuing higher interests, but also related to shareholders or even depositors having less incentive to screen banks; therefore information asymmetry among governments, shareholders and depositors might be the one reason of the recent Subprime Mortgage crisis. This

might be (one) possible explanation for the onset of the 2008 Subprime crisis, in that neither regulators nor shareholders paid much attention to the risk-taking of large banks and allowed them to become involved in risky activities. In addition to this, the author can verify that banks which have more deposits and fewer nonperformance assets are assumed to be more stable and less risky. The increase in the loan-deposit ratio suggests higher level of liquidity risk, which might force banks to be active in interbank markets.

Moreover, a negative relationship has been found between interbank lending and banks' risk taking for large banks in normal times, but it is the significant positive for small banks. A moral hazard problem is generated from LLR intervention, which encourages large banks to make an effort to be larger by increasing the capacity of bank activities in order to benefit from TBTF (too-big-to-fail) while the expansion of bank activities, especially non-traditional actives, may increase risk. It also suggest small banks are more willing to monitor borrowing banks in order to maximize the expected return and reduce the default risk level of interbank assets. But this positive relationship for small banks becomes insignificant during the financial crisis, which suggests that interbank lending market froze to small banks, at the beginning of summer of 2007 as it did during the Asian banking crisis of the late 1990s. This result is consistent a interbank market study by Afonso, Kovner, and Schoar in 2011.

Given the significant positive coefficient between the interbank lending and risk-taking for large banks during the financial crisis, we also argue that the interbank market was only active to large banks. And the observed evidence of precautionary actions of large banks, such as liquidity hoarding, were found aftermath the collapse of Lehman Brothers with deepening concerns about the credit quality of counterparties and the fact that the magnitude of the exposure to subprime-related assets was unknown. In contrary to normal times, large banks became more willing to monitor borrowing banks in order to reduce the default risk level of bank assets. Although banks can also issue new loans from interbank market, but with high quality collaterals or high interest rates, all banks suffer from a liquidity shortage in this case, in turn, rather than lend surplus liquid assets out, most banking preferred to hold, in case their own need might increase. Insufficient bank liquidity could lead to inadequate allocation of capital if any problems happen in this market. This may impose adverse implications in the whole financial system as it could be contagious and spills over from one to the others. Our results highlight that interbank lending is

associated with substantially lower risk taking by borrowing banks in financial crisis, which are consistent with monitoring by lending banks.

Our findings in Chapter 4 demonstrated 'liquidity hoarding' affected the normal functioning of short-term funding markets: due to increased uncertainty and the fear of prolonged restrictions to accessing interbank loans, banks that chose to hoard liquidity may have caused a rise in borrowing costs that had an adverse impact on less liquid banks. Therefore, the author also examined banks' liquidity creation and funding ability during the interbank lending crunch in Chapter 5. All in all, we've found that banks curbed lending during the interbank lending crunch, when the interbank borrowing channel was broken.

First, the empirical findings highlight important differences in the distribution of liquid assets across banks depending on their size. Understanding such differences is crucial in the context of a regulatory reform and must be taken into account in the implementation of capital and liquidity requirements for banking institutions.

Second, to mitigate this problem, the author proposes two on-balance proxies for banks' liquidity risk: (i) the unrealized security loss ratio and (ii) the loan loss allowance ratio. Comparing with previously suggested off-balance proxies for banks' liquidity risk such as unused loan commitments, our finding suggests that unrealized security losses as well as loan loss allowance seem to better capture the risks stemming from banks' asset management during the financial crisis and provide supporting evidence for the precautionary nature of liquidity hoarding. Banks choose to build up liquidity in anticipation of future expected losses from securities write-downs and loans charged-off. For example, unrealized losses in securities holdings represent the write-downs of securities (a large portion of which are used as collateral in repo transactions) that result from mark-to-market accounting of investment portfolios. They reflect the exposure to future capital losses for banks if they had to sell those assets at fire sale prices. This source of liquidity risk has not been explored at length in the previous literature, due perhaps to the few balance sheet items related to credit exposure covered by collateral in those transactions.

In addition to this, the author concludes that the same factors leading to precautionary liquidity hoarding also contributed to a sharp decline in interbank lending. We've found evidences of self-

insurance motives and lending rationing by net borrowers. Moreover, net borrowers offered higher rates to attract external funding, and net lenders hoarded liquidity due to heightened counterparty risk. A 'flight to quality' is also found in my results: non-core deposits seeped out of banks and returned in the form of core deposits, first to hoarding banks and later to non-hoarding banks. Therefore, the dissertation finds evidence of inflows of core deposits at the onset of the crisis to banks that chose to hoard liquidity.

What is more, the findings of this thesis demonstrate the crucial role of the interbank market in ensuring effective transmission of monetary expansion. If liquidity-hoarding banks have sufficient market power to manipulate asset prices, some form of predatory behavior may arise (Acharya, Gromb, and Yorulmazer, 2012). The considerable fear associated with the riskiness of banks' portfolios further limits the ability of policy actions to revamp credit growth and stimulate the real economy.

Taken together, these observations and results offer a number of important implication for the optimal policy vis-à-vis large banks and the interbank market:

First, many financial commentators have argued that ineffective/inadequate state regulation contributed or even caused the 2007/08 Sub-Prime crisis. If that is the case, one would expect to find a difference in the regulation regimes of financial institutions vis-à-vis bank size. Thus, one recommendation of this thesis is that policymakers re-consider the bank size effect in determining bank risk level. Other financial commentators have criticized the governance of banks and suggested that better governance would have led to greater resilience during the financial crisis. Within this context, banks were affected differentially because of different balance sheets; and thus the probable gain and losses to individual banks need be measured to prior to proposing polices.

Recall section 1.1 and section 2.3, the policy actions of the Fed in mitigating the impact of the financial crisis 2007/08 can be summarized in two main fields: (1) liquidity injections; and (2) interest-on-reserve policy. Taken together, however, these policies are highly problematic. Liquidity injections were delivered through credit and liquidity facilities at the onset of the subprime mortgage crisis in late 2007, and were gradually replaced by quantitative easing (QE)

over the course of 2009. The injected liquidity pushed down the Federal funds rate, the policy rate, below the target. To set a floor for the Federal funds rate, the Fed started paying interests on reserves at 0.25% per annum. However, because banks base lending decisions on the spread between the return on loans and its opportunity cost (the return on reserves), low lending rates and interests on reserves discouraged bank lending and encouraged liquidity hoarding during the financial crisis. The average value of Total Interest Income Rate was 3.9% before the interbank lending crunch and 2.7% during the crunch. Further, unrestricted supply of liquidity by the Fed provided banks with all the more reason not to lend but to hoard instead. The Fed moved its focus almost entirely to QE from targeted supports through credit and liquidity facilities including those designed specifically for the interbank market (e.g., TAF, TSLF, and PDCF). However, because QE is performed outside the interbank market, it appears that efficient fund allocation among banks was not the concern of the Fed. The absence of a well-functioning interbank market could cost the Fed unnecessarily large amounts of liquidity injections as banks seek self‐insurance and curb lending.

On this basis, the thesis also recommends that the Fed should focus more on insuring efficient allocation of funds in the interbank market. Whenever liquidity injection is deemed inevitable, the author recommends that the central bank should subsidize interbank lending. The subsidy rate can be a function of the gap between the current state of the interbank market and its desired full efficiency. As such, the central bank should add a fraction of a percentage more to the rates at which banks lend to each other to encourage interbank lending, and taper off as the interbank market moves towards full efficiency. The interbank lending subsidy policy has some important advantages. First, interbank lending subsidy is compatible with liquidity injection policy: a close monitoring of the subsidy rate and the functioning of the interbank market will help the central bank analyze the optimal amount of liquidity to inject. Second, unlike the interest-on-reserve policy, the subsidy rate will not deter bank lending as the interbank market approaches full efficiency. Furthermore, as interbank lending subsidy encourages more lending activities in the interbank market, it can keep the policy rate from falling below the target. However, this requires careful and continuous adjustment by the central bank.

Appendix:

Appendix 1: The main data file

Main data file			
NO.	Short name	Ratio name	Definitions
1	intincy	Yield on earning assets	Total interest income (annualized) as a percent of average earning assets.
2	intexpy	Cost of funding earning assets	Annualized total interest expense on deposits and other borrowed money as a percent of average earning assets on a consolidated basis.
3	nimy	Net interest margin	Total interest income less total interest expense (annualized) as a percent of average earning assets.
4	noniiy	Noninterest income to earning assets	Income derived from bank services and sources other than interest bearing assets (annualized) as a percent of average earning assets.
5	nonixy	Noninterest expense to earning assets	Salaries and employee benefits, expenses of premises and fixed assets, and other noninterest expenses (annualized) as a percent of average earning assets.
6	noijy	Net operating income to assets	Net operating income (annualized) as a percent of average assets.
7	roa	Return on assets (ROA)	Net income after taxes and extraordinary items (annualized) as a percent of average total assets.
8	roaptx	Pretax return on assets	Annualized pre-tax net income as a percent of average assets.<P>Note: Includes extraordinary items and other adjustments, net of taxes.
9	roe	Return on Equity (ROE)	Annualized net income as a percent of average equity on a consolidated basis. Note: If retained earnings are negative, the ratio is shown as NA.
10	roeinjr	Retained earnings to average equity (ytd only)	Net income (year-to-date, annualized), less cash dividends declared (year-to-date, annualized), as a percent of average total equity capital. If retained earnings are negative, the ratio is shown as NA. This ratio is presented on a year-to-date basis only.
11	ntlnlsr	Net charge-offs to loans	Gross loan and lease financing receivable charge-offs, less gross recoveries, (annualized) as a percent of average total loans and lease financing receivables.
12	elnantr	Credit loss provision to net charge-offs	Provision for possible credit and allocated transfer risk as a percent of net charge-offs. If the denominator is less than or equal to zero, then ratio is shown as NA.
13	iderncvr	Earnings coverage of net charge-offs (x)	Income before income taxes and extraordinary items and other adjustments, plus provisions for loan and lease losses and allocated transfer risk reserve, plus gains (losses) on securities not held in trading accounts (annualized) divided by net loan and lease charge-offs (annualized). This is a number of times ratio (x) not a percentage ratio (%). * if the denominator is less than or equal to zero, then ratio is shown as n/a. ris definition = iderncvr = chfla / ntlnlsa
14	eeffr	Efficiency ratio	Noninterest expense, less the amortization expense of intangible assets, as a percent of the sum of net interest income and noninterest income.
15	astempm	Assets per employee ($millions)	Total assets in millions of dollars as a percent of the number of full-time equivalent employees.
16	iddivnir	Cash dividends to net income (ytd only)*	Total of all cash dividends declared (year-to-date, annualized) as a percent of net income (year-to-date, annualized). * this ratio is not available on a quarterly basis. if the denominator is less than or equal to zero, then ratio is shown as N/A. RIS definition = IDDIVNIR = (EQCDIVA / NETINCA) *100
17	lnatresr	Loss allowance to loans	Allowance for loan and lease losses as a percent of total loan and lease financing receivables, excluding unearned income.
18	lnresncr	Loan loss allowance to noncurrent loans	Allowance for loan and lease losses as a percent of noncurrent loans and leases.
19	nperfv	Noncurrent assets plus other real estate owned to assets	Noncurrent assets as a percent of total assets. Noncurrent assets are defined as assets that are past due 90 days or more plus assets placed in nonaccrual status plus other real estate owned (excluding direct and indirect investments in real estate).
20	nclnlsr	Noncurrent loans to loans	Total noncurrent loans and leases, Loans and leases 90 days or more past due plus loans in nonaccrual status, as a percent of gross loans and leases.
21	lnlsdepr	Net loans and leases to deposits	Loans and lease financing receivables net of unearned income, allowances and reserves as a percent of total deposits.

22	idlncorr	Net loans and leases to core deposits	Loan and lease financing receivables, net of allowances and reserves, as a percent of core deposits. The core deposit definition was changed in March 2011. core deposits held in domestic offices now includes: total domestic office deposits minus time deposits of more than $250,000 held in domestic offices and brokered deposits of $250,000 or less held in domestic offices. Prior to the March 2010, core deposits were calculated as total domestic office deposits minus time deposits of $100,000 or more held in domestic offices. RIS definition: IDLNCORR = (LNLSNET / COREDEP) *100
23	eqv	Equity capital to assets	Total equity capital as a percent of total assets.
24	rbc1aaj	Core capital (leverage) ratio	Tier 1 (core) capital as a percent of average total assets minus ineligible intangibles. Tier 1 (core) capital includes: common equity plus noncumulative perpetual preferred stock plus minority interests in consolidated subsidiaries less goodwill and other ineligible intangible assets. The amount of eligible intangibles (including mortgage servicing rights) included in core capital is limited in accordance with supervisory capital regulations. Average total assets used in this computation are an average of daily or weekly figures for the quarter.
25	rbc1rwaj	Tier 1 risk-based capital ratio	Tier 1 (core) capital as a percent of risk-weighted assets as defined by the appropriate federal regulator for prompt corrective action during that time period.
26	rbcrwaj	Total risk-based capital ratio	Total risk based capital as a percent of risk-weighted assets as defined by the appropriate federal regulator for prompt corrective action during that time period.
Net charge-offs to loans			
11-b	ntlnlsr	Net charge-offs to loans	Gross loan and lease financing receivable charge-offs, less gross recoveries, (annualized) as a percent of average total loans and lease financing receivables.
27	ntrer	% Net Loans Charged-off: Total real estate loans	Net charged-off loans that are secured by real estate (annualized) as a percent of average total real estate loans.
28	ntrecosr	% Net Loans Charged-off:Construction & development	Net charged-off construction and land development loans secured by real estate (annualized) as a percent of average total construction and land development loans secured by real estate.
29	ntrenrsr	% Net Loans Charged-off: Commercial real estate	Net charged-off loans secured by nonfarm nonresidential properties (annualized) as a percent of average total loans secured by nonfarm nonresidential properties.
30	ntremulr	% Net Loans Charged-off: Multi-family residential	Net charged-off loans secured by multi-family (5 or more) residential properties (annualized) as a percent of average total loans secured by multi-family residential properties.
30-b	ntreresr	% Net Loans Charged-off: 1-4 family residential	Net charged-off all loans secured by 1-4 family residential properties (annualized) as a percent of average total loans secured by 1-4 family residential properties.
31	ntrelocr	% Net Loans Charged-off: Home equity loans	Net charged-off revolving, open-end loans secured by 1-4 family residential properties and extended under lines of credit (annualized) as a percent of average total revolving, open-end loans secured by 1-4 family residential properties and extended under lines of credit.
32	ntreothr	All other 1-4 family - Percent of loans charged-off, net	Net charged-off all other loans secured by 1-4 family residential properties in domestic offices asa percent of all other loans secured by 1-4 family residential properties. Note: prior to march 2001, listed as a memorandum item
33	idntcir	% Net Loans Charged-off: Commercial and industrial	Net charged-off commercial and industrial loans (annualized) as a percent of average total commercial and industrial loans. ris definitions: ytd - idntcir = (ntcia/lnci5)* 100 qtr - idntciqr = ((ntciq * 4) / lnci22) * 100
34	idntconr	% Net Loans Charged-off: Loans to individuals	Net charged-off loans to individuals for household, family and other personal expenditures (annualized) as a percent of average total loans to individuals. ris definitions: ytd - idntconr = (ntcona/lncon5) * 100 qtr - idntcnqr = ((ntconq * 4) / lncon2) * 100
35	idntcrdr	% Net Loans Charged-off: Credit card loans	Net charged-off credit card loans to individuals (annualized) as a percent of average total credit card and related plan loans. note: prior to 2001, included revolving credit plans other than credit cards. ris definitions: ytd - IDNTCRDR = (NTCRCDA/LNCRCD5) * 100 QTR - IDNTCDQR = ((NTCRCDQ * 4) / LNCRCD2) * 100
36	idntcoor	% Net Loans Charged-off: Other loans to individual	Net charged-off other loans to individuals for household, family and other personal expenditures (annualized) as a percent of average total other loans to individuals. ris definitions: ytd - idntcoor = (ntconota/lnconot5) * 100 qtr - idntcoqr = ((ntconotq * 4) / lnconot2) * 100

37	idntothr	% Net Loans Charged-off: All other loans and lease	Net charged-off loans to depository institutions and acceptances of other banks, loans to foreign governments and official institutions, lease financing receivables, loans to finance agricultural production and all other loans (annualized) as a percent of average total other loans and leases. ris definitions: ytd - idntothr = ((((ntdep + ntforgv + ntother + ntls) * idann) + ntaga) / (lnotci5 + lnag5)) * 100 qtr - idntotqr = (((ntdepq + ntforgvq + ntothq + ntlsq + ntagq) * 4) / (lnotci2 + lnag22)) * 100
38	ntcomrer	% Net Loans Charged-off:Coml. RE not secured by RE	Net charged-off commercial real estate loans not secured by real estate (annualized) as a percent of average total commercial real estate loans not secured by real estate.
Noncurrent loans to loans			
39	nclnlsr	Noncurrent loans to loans	Total noncurrent loans and leases, Loans and leases 90 days or more past due plus loans in nonaccrual status, as a percent of gross loans and leases.
40	ncrer	% Loans Noncurrent: Real estate loans	Real estate loans past due 90 days or more plus loans placed in nonaccrual status as a percent of real estate loans.
41	ncreconr	% Loans Noncurrent:Construction & land development	Noncurrent construction and land development loans secured as a percent of total construction and land development loans secured in domestic offices.
42	ncrenrer	% Loans Noncurrent: Commercial real estate	Noncurrent nonfarm nonresidential real estate loans as a percent of total nonfarm nonresidential real estate loans in domestic offices.
43	ncremulr	% Loans Noncurrent: Multifamily residential	Noncurrent multifamily residential real estate (5 or more) loans as a percent of total multifamily residential real estate loans in domestic offices.
44	ncreresr	% Loans Noncurrent: 1-4 family residential	Noncurrent loans secured by 1-4 family residential properties (including all 1-4 family loans except home equity loans) as a percent of total 1-4 family residential mortgage loans. This only applies to loans held in domestic offices.
45	ncrelocr	% Loans Noncurrent: Home equity loans	Noncurrent revolving, open-end loans secured by 1-4 family residential properties and extended under lines of credit as a percent of total revolving, open-end loans secured by 1-4 family residential properties and extended under lines of credit held in domestic offices.
46	ncrereor	Percent of loans noncurrent - All other family	Noncurrent loans secured by 1-4 other properties (includes all 1-4 family loans except home equity loans) as a percent of 1-4 other property loans.
47	idnccir	% Loans noncurrent:Commercial and industrial loans	Commercial and industrial loans 90 days or more past due and nonaccrual as a percent of total commercial and industrial loans. Note: For banks with assets of less than $300 million prior to 2001, this item includes all other loans (loans to depository institutions, agricultural loans, etc...). ris definition: idnccir = (ncci / lnci) * 100
48	idncconr	% Loans Noncurrent: Loans to individuals	Loans to individuals for household, family and other personal expenditures 90 days or more past due and nonaccrual as a percent of total consumer loans. ris definition: idncconr = (nccon/lncon)* 100
49	idnccrdr	% Loans Noncurrent: Credit card loans	Credit card loans to individuals for household, family and other personal expenditures 90 days or more past due and nonaccrual as a percent of total credit card and related plan loans. note: prior to 2001, included revolving credit plans other than credit cards. ris definition:idnccrdr = (nccrcd / lncrcd)* 100
50	idnccoor	% Loans Noncurrent: Other loans to individuals	Other loans to individuals for household, family and other personal expenditures 90 days or more past due and nonaccrual as a percent of total other loans to individuals (includes single payment, installment and all student loans). RIS Definition: IDNCCOOR = (NCCONOTH / LNCONORP)* 100
51	idncothr	% Loans Noncurrent: All other loans and leases	Other loans and leases (including loans to depository institutions and acceptances of other banks, loans to foreign governements and official institutions, lease financing receivables, and loans to finance agricultural production and other loans to farmers) which are 90 days or more past due and nonaccrual as a percent of total other loans and leases. ris definition: idncothr = ((ncdep + ncfg + ncothln + ncls + ncag) / (lnotci + lnag)) * 100
52	nccomrer	% Loans Noncurrent:Commercial RE not secured by RE	Loans to finance commercial real estate, construction and land development activities (not secured by real estate) which are 90 days past due or nonaccrual as a percent of total loans to finance commercial real estate, construction and land activities (not secured by real estate).

53	idncgtpr	Wholly or partially US Gov. guaranteed noncurrent loans as percent of noncurrent	Noncurrent Loans and leases wholly or partially guaranteed or insured by the U.S. Government as a percent of total noncurrent loans and leases. Noncurrent loans and leases are loans that are past due 90 days or more or in nonaccrual status. The U.S. Government includes its agencies and its government-sponsored agencies. Examples include loans guaranteed by the FDIC (through loss-sharing arrangements in FDIC-assisted acquisitions), the Small Business Administration, and the Federal Housing Administration. Excluded are loans and leases guaranteed or insured by state or local governments, state or local government agencies, foreign (non-U.S.) governments, and private agencies or organizations. Also excluded are loans and leases collateralized by securities issued by the U.S. Government, including its agencies and its government-sponsored agencies. Included in noncurrent total assets. ris definition = idncgtpr =(ncgtypar / nclnls) *100
Net Loans and Leases			
	lnlsnet	loans and leases	Total loans and lease financing receivables minus unearned income and loan loss allowances.
54	lnatres	Loan loss allowance	Each bank must maintain an allowance (reserve) for loan and lease losses that is adequate to absorb estimated credit losses associated with its loan and lease portfolio (which also includes off-balance-sheet credit instruments).
	lnlsgr	Total loans and leases	Total loans and lease financing receivables, net of unearned income.
55	lncon	Loans to individuals	Loans to individuals for household, family, and other personal expenditures including outstanding credit card balances and other secured and unsecured consumer loans.
56	lnfg	Loans to foreign governments and official institutions	Loans (including planned and unplanned overdrafts) to foreign governments and official institutions, including foreign central banks. > This item is not available for TFR Reporters.
57	Lndepac= TDI	Loans to depository institutions and acceptances of other banks	All loans (other than those secured by real estate), including overdrafts, to banks, other depositoryinstitutions, and other associations, companies, and financial intermediaries whose primarybusiness is to accept deposits and to extend credit for business or for personal expenditurepurposes. Also the bank's holdings of all bankers acceptances accepted by other banks thatare not held for trading. Acceptances accepted by other banks may be purchased in the openmarket or discounted by the reporting bank.
Loans to Depository Institutions			
	lndepac	Loans to depository institutions and acceptances of other banks	All loans (other than those secured by real estate), including overdrafts, to banks, other depositoryinstitutions, and other associations, companies, and financial intermediaries whose primarybusiness is to accept deposits and to extend credit for business or for personal expenditurepurposes. Also the bank's holdings of all bankers acceptances accepted by other banks thatare not held for trading. Acceptances accepted by other banks may be purchased in the openmarket or discounted by the reporting bank.
58	lndepcb	To commercial banks in U.S.	Total loans to commercial banks located in the U.S. and acceptances of such banks. Begginning in 2001, this item is not reported by institutions with less than $300 million in total assets.
59	lndepusb	To U.S. branches and agencies of foreign banks	Total loans to U.S. branches and agencies of foreign banks and acceptances of such entities. This item is not reported by institutions with less than $300 million in total assets.
60	lndepus	To other depository institutions in U.S.	Loans to other depository institutions in the U.S. (other than commercial banks domiciled in the U.S.) and acceptances of such entities. This item is not reported by institutions with less than $300 million in total assets.
61	lndepfc	To banks in foreign countries	Loans to depository institutions and their branches that are located outside the U.S. and acceptances of such entities. This item is not reported by institutions with less than $300 million in total assets.
62	lndepfus	To foreign branches of U.S. banks	Loans to foreign branches of U.S. banks and acceptances of such entities. This item is not reported by institutions with less than $300 million in total assets.

63	obsdir	Derivatives	Represents the sum of the following: interest-rate contracts (as defined as the notional value of interest-rate swap, futures, forward and option contracts), foreign-exchange-rate contracts, commodity contracts and equity contracts (defined similarly to interest-rate contracts). Futures and forward contracts are contracts in which the buyer agrees to purchase and the seller agrees to sell, at a specified future date, a specific quantity of underlying at a specified price or yield. These contracts exist for a variety of underlyings, including traditional agricultural or physical commodities, as well as currencies and interest rates. Futures contracts are standardized and are traded on organized exchanges which set limits on counterparty credit exposure. Forward contracts do not have standardized terms and are traded over the counter. Option contracts are contracts in which the buyer acquires the right to buy from or sell to another party some specified amount of underlying at a stated price (strike price) during a period or on a specified future date, in return for compensation (such as a fee or premium). The seller is obligated to purchase or sell the underlying at the discretion of the buyer of the contract. Swaps are obligations between two parties to exchange a series of cash flows at periodic intervals (settlement dates) for a specified period. The cash flows of a swap are either fixed or determined for each settlement date by multiplying the quantity of the underlying instrument (notional principal) by specified reference rates or prices. Except for currency swaps, the notional principal is used to calculate each payment but is not exchanged. This item is not available for TFR Reporters.
Cash and Balances Due			
64	Chbal	Cash & Balances due from depository institutions	Total cash and balances due from depository institutions including both interest-bearing and noninterest-bearing balances.
65-a	chcic	Cash items in process of collection	Cash items in process of collection, including unposted debits and currency and coin. Beginning in 2001, this item is not reported by FFIEC Call filers with less than $300 million in total assets. Prior to 2001, this item also includes balances due from federal reserve banks for filers with total assets of less than $100 million. It also includes noninterest-earning deposits for TFR Reporters.
65-b	chitem	Collection in domestic offices	Cash items in the process of collection and unposted debits (held in domestic offices) which are immediately payable upon presentation. Beginning in 2001, this item is not reported by FFIEC Call filers with total assets of less than $300 million. Prior to 2001, this item also includes balances due from federal reserve banks for filers with total assets of less than $100 million. This item is not filed by TFR Reporters.
65-c	chcoin	Currency and coin in domestic offices	Currency and coin held in domestic offices.
65-d	chus	Balances due from depository institutions in U.S.	Cash balances due from depository institutions in U.S. include all interest-bearing and noninterest-bearing balances whether in the form of demand, savings or time balances, including certificates of deposit but excluding certificates of deposit held for trading. Beginning in 2001, this item is not reported by FFIEC Call filers with total assets of less than $300 million.
65-e	chfrb	Balances due from FRB	The total cash balances due from Federal Reserve Banks as shown by the reporting banks books. This amount includes reserves and other balances. Beginning in 2001, this item is not reported by FFIEC Call filers with total assets of less than $300 million. Prior to 2001, this item was reported in the Cash and balances due categories for FFIEC Call Report filers with total assets of less than $100 million. This item is not filed by TFR Reporters.
66	dep	Total deposits	The sum of all deposits including demand deposits, money market deposits, other savings deposits, time deposits and deposits in foreign offices.
67	asset	Total assets	The sum of all assets owned by the institution including cash, loans, securities, bank premises and other assets. This total does not include off-balance-sheet accounts.

Appendix 2: Unit Root Result

NO.	Short Name of Ratios	ADF	KPSS	NG-PERRON
1	intincy	I(0), 5%[52]	I(0), 5%[53]	I(0), 5%[54]
2	intexpy	I(1), 5%	I(1), 5%	I(1), 5%
3	nimy	I(1), 5% I(0), 10%	I(0), 5%	I(1), 5% I(0), 10%
4	noniiy	I(0), 5%	I(0), 5%	I(0), 5%
5	nonixy	I(0), 5%	I(0), 5%	I(0), 5%
6	noijy	I(0), 5%	I(0), 5%	I(0), 5%
7	roa	I(1), 5% I(0), 10%	I(0), 5%	I(1), 5% I(0), 10%
8	roaptx	I(0), 5%	I(0), 5%	I(0), 5%
9	roe	I(0), 5%	I(0), 5%	I(0), 5%
10	roeinjr	I(0), 5%	I(0), 5%	I(0), 5%
11	ntlnlsr	I(0), 5%	I(0), 5%	I(1), 5% I(0), 10%
12	elnantr	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%
13	iderncvr	I(0), 5%	I(0), 5%	I(0), 5%
14	eeffr	I(1), 5% I(0), 10%	I(0), 5%	I(0), 5%
15	astempm	I(0), 5%	I(1), 5% I(0), 10%	I(0), 5%
16	iddivnir	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%
17	lnatresr	I(0), 5%	I(0), 5%	I(0), 5%
18	lnresncr	I(1), 5% I(0), 10%	I(0), 5%	I(0), 5%
19	nperfv	I(0), 5%	I(0), 5%	I(0), 5%
20	nclnlsr	I(1), 5% I(0), 10%	I(0), 5%	I(0), 5%
21	lnlsdepr	I(0), 5%	I(1), 5% I(0), 10%	I(0), 5%
22	idlncorr	I(0), 5%	I(0), 5%	I(0), 5%
23	eqv	I(1), 5%	I(1), 5%	I(1), 5%
24	rbc1aaj	I(1), 5%	I(1), 5%	I(1), 5%

[52] I(0), 5%: The null hypothesis- The variable contains a unit root- can be rejected using 95% confidence intervals under method of the ADF test; therefore, the series are found to be stationary in their levels.
I(1), 5%: The null hypothesis- The variable contains a unit root- can be rejected using 95% confidence intervals under method of the ADF test; therefore, the series are found to be stationary in their first difference.

[53] I(0), 5%: The null hypothesis- The variable is trend stationary- cannot be rejected using 95% confidence intervals under method of the KPSS test; therefore, the series are found to be stationary in their levels.
I(1), 5%: The null hypothesis- The variable is trend stationary- cannot be rejected using 95% confidence intervals under method of the KPSS test; therefore, the series are found to be stationary in their first difference.

[54] I(0), 5%: The null hypothesis- The variable contains a unit root- can be rejected using 95% confidence intervals under method of the Ng-perron test; therefore, the series are found to be stationary in their levels.
I(1), 5%: The null hypothesis- The variable contains a unit root- can be rejected using 95% confidence intervals under method of the Ng-perron test; therefore, the series are found to be stationary in their first difference.

25	rbc1rwaj	I(0), 5%	I(0), 5%	I(0), 5%
26	rbcrwaj	I(1), 5%	I(1), 5%	I(1), 5%
11-b	ntlnlsr	I(1), 5%	I(1), 5%	I(1), 5%
27	ntrer	I(0), 5%	I(0), 5%	I(0), 5%
28	ntrecosr	I(0), 5%	I(0), 5%	I(0), 5%
29	ntrenrsr	I(1), 5%	I(1), 5%	I(1), 5%
30	ntremulr	I(1), 5%	I(1), 5%	I(1), 5%
30-b	ntreresr	I(0), 5%	I(0), 5%	I(0), 5%
31	ntrelocr	I(1), 5%	I(1), 5%	I(1), 5%
32	ntreothr	I(0), 5%	I(0), 5%	I(0), 5%
33	idntcir	I(0), 5%	I(0), 5%	I(0), 5%
34	idntconr	I(0), 5%	I(0), 5%	I(0), 5%
35	idntcrdr	I(0), 5%	I(0), 5%	I(0), 5%
36	idntcoor	I(0), 5%	I(0), 5%	I(0), 5%
37	idntothr	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%
38	ntcomrer	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%	I(1), 5% I(0), 10%
39	nclnlsr	I(0), 5%	I(0), 5%	I(0), 5%
40	ncrer	I(0), 5%	I(0), 5%	I(0), 5%
41	ncreconr	I(1), 5%	I(1), 5%	I(1), 5%
42	ncrenrer	I(1), 5%	I(1), 5%	I(1), 5%
43	ncremulr	I(1), 5%	I(1), 5%	I(1), 5%
44	ncreresr	I(0), 5%	I(0), 5%	I(0), 5%
45	ncrelocr	I(1), 5%	I(1), 5%	I(1), 5%
46	ncrereor	I(1), 5%	I(1), 5%	I(1), 5%
47	idnccir	I(1), 5%	I(1), 5%	I(1), 5%
48	idncconr	I(1), 5%	I(1), 5%	I(1), 5%
49	idnccrdr	I(0), 5%	I(0), 5%	I(1), 5% I(0), 10%
50	idnccoor	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
51	idncothr	I(0), 5%	I(0), 5%	I(0), 5%
52	nccomrer	I(0), 5%	I(0), 5%	I(0), 5%
53	idncgtpr	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
	lnlsnet			
54	lnatres	I(0), 5%	I(0), 5%	I(0), 5%
	Lnlsgr= TL			
55	lncon	I(1), 5%	I(1), 5%	I(1), 5%
56	lnfg			
57	lndepac	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
	Lndepac=TDI			
58	lndepcb	I(1), 5%	I(1), 5%	I(1), 5%
59	lndepusb	I(0), 5%	I(0), 5%	I(0), 5%
60	lndepus	I(1), 5%	I(1), 5%	I(1), 5%

61	lndepfc	I(0), 5%	I(0), 5%	I(0), 5%
62	lndepfus	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
63	obsdir	I(1), 5%	I(1), 5%	I(1), 5%
64	chbal	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
65-a	chcic	I(0), 5%	I(0), 5%	I(0), 5%
65-b	chitem	I(0), 5%	I(0), 5%	I(0), 5%
65-c	chcoin	I(0), 5%	I(0), 5%	I(0), 5%
65-d	chus	I(0), 5%	I(0), 5%	I(0), 5%
	chusfbk			
	chnus			
	chnusfbk			
65-e	chfrb	I(0), 5%	I(0), 5%	I(0), 5%
	chbalni			
66-a	chcic	I(0), 5%	I(0), 5%	I(0), 5%
66-b	chitem	I(0), 5%	I(0), 5%	I(0), 5%
66-c	chcoin	I(0), 5%	I(0), 5%	I(0), 5%
66-d	chus	I(1), 5%	I(1), 5%	I(1), 5% I(0), 10%
	chusfbk			
	chnus			
	chnusfbk			
66-e	chfrb	I(0), 5%	I(0), 5%	I(0), 5%
	chbalni			
67	chbal	I(1), 5%	I(1), 5%	I(1), 5%
68-a	chcic	I(0), 5%	I(0), 5%	I(0), 5%
68-b	chitem	I(1), 5%	I(1), 5%	I(1), 5%
68-c	chcoin	I(0), 5%	I(0), 5%	I(0), 5%
68-d	chus	I(0), 5%	I(0), 5%	I(0), 5%
68-e	chfrb	I(1), 5%	I(1), 5%	I(0), 5%
69-a	chcic	I(0), 5%	I(0), 5%	I(0), 5%
69-b	chitem	I(1), 5%	I(1), 5%	I(0), 5%
69-c	chcoin	I(1), 5%	I(1), 5%	I(0), 5%
69-d	chus	I(1), 5%	I(1), 5%	I(0), 5%
69-e	chfrb	I(1), 5%	I(1), 5%	I(0), 5%

Appendix 3: structural break tests

NO.	Short Name of Ratios	Break Point Maximum LR/WALD F-STATISTIC	QUANDT-ANDRES UNKNOWN BREAKPOINT TEST	CHOW TEST	BAI_PERRON TEST	Zivot-Andrews Test	
						Break point	t-statistic
1	intincy	2001Q4	2001Q4	N[55]	2008Q1	2001Q1	-5.088595
2	intexpy	2008Q1	2001Q4	N	1995Q2	2001Q2	-4.856170
3	nimy	2003Q2	2007Q1	Y	2004Q1	2008Q1	-4.751490
4	noniiy	2003Q3	2008Q1	Y	2008Q1	2002Q3	-6.587520
5	nonixy	2007Q4	1996Q1	Y	1996Q1/2007Q4	1997Q3	-3.585799
6	noijy	2010Q1	2007Q4	Y	1998Q4/2007Q4	2004Q1	-3.919833
7	roa	1998Q4	2007Q4	Y	2007Q4/2010Q1	2004Q1	-3.848268
8	roaptx	2005Q2	2005Q2	Y	2005Q2	2005Q2	
9	roe	2003Q2	2003Q2	Y	2003Q2	2003Q2	
10	roeinjr	2010Q1	2010Q1	N	2010Q1	2010Q1	
11	ntlnlsr	2009Q2	2009Q2	Y	2009Q2	2009Q2	
12	elnantr	1994Q4	1994Q4	Y	1994Q4	1999Q4	
13	iderncvr	2007Q1	2007Q1	Y	2007Q1	2007Q1	
14	eeffr	2010Q1	2010Q1	Y	2010Q1	2010Q1	
15	astempm	2009Q3	2009Q3	Y	2009Q3	2009Q3	
16	iddivnir	2009Q2	2009Q2	Y	2009Q2	2009Q2	
17	lnatresr	2007Q4	2007Q4	Y	2007Q4	2007Q4	
18	lnresncr	2007Q1	2007Q1	Y	2007Q1	2007Q1	
19	nperfv	2006Q2	2006Q2	Y	2006Q2	2008Q2	
20	nclnlsr	2007Q3	2007Q3	Y	2007Q3	2007Q3	
21	lnlsdepr	2009Q3	2009Q3	N	1995Q2,1999Q3, 2009Q3	2009Q3	
22	idlncorr	2009Q3	2009Q2	N N	2009Q3 2009Q2	2009Q2	
23	eqv	2009Q3	2009Q3	Y	2009Q3	2009Q3	
24	rbc1aaj	2009Q3	2009Q3	Y	2009Q3	2009Q3	
25	rbc1rwaj	1997Q1	1994Q4	N	1997Q1/1994Q4	1994Q4	
26	rbcrwaj	2009Q1	2009Q1	Y	2009Q1	2009Q1	
11-b	ntlnlsr	2008Q3	2008Q3	Y	2008Q3	2008Q3	
27	ntrer	2009Q2	2009Q2	N	2009Q2	2009Q2	
28	ntrecosr	2009Q2	2008Q3	N	2008Q3/2009Q2	2008Q3	
29	ntrenrsr	1995Q3	2008Q4	Y	1995Q3/2008Q4	2008Q4	
30	ntremulr	2008Q4	2008Q4	Y	2008Q4	2008Q4	

[55] N: The null hypothesis- this is no break point - cannot be rejected under method of QUANDT-ANDRES UNKNOWN BREAKPOINT TEST; therefore, there is no breakpoint.
Y: The null hypothesis- this is no break point – can be rejected under method of QUANDT-ANDRES UNKNOWN BREAKPOINT TEST; therefore, there is a breakpoint.
The critical level is 5%.

30-b	ntreresr	2001Q3	2001Q3	Y	2001Q3	2001Q3	
31	ntrelocr	2008Q4	2008Q4	Y	2008Q4(15) 2009Q1(5/10)	2008Q4	
32	ntreothr	1996Q2()	1996Q2	Y	1996Q2 1994Q2	1996Q2	
33	idntcir	1999Q2	1999Q2	Y	1999Q2	1999Q2	
34	idntconr	1997Q2(15)	1997Q2(15)	Y	1997Q2(15) 1996Q2(5)	2007Q2	
35	idntcrdr	2003Q1	2003Q1	N	2003Q1	2003Q1	
36	idntcoor	2010Q2(5)	2001Q1(30)	Y Y N	1997Q1(15) 2010Q2(5) 2001Q1(30)	2001Q1	
37	idntothr	1999Q3	1999Q3	Y	1999Q3	1999Q3	
38	ntcomrer	1994Q1	2008Q4(15)	N N Y	2008Q4(15) 2009Q2(10) 1994Q1	2008Q4	
39	nclnlsr	2009Q4	2009Q4	Y	2009Q4	2009Q4	
40	ncrer	2008Q1	2008Q1	Y	2008Q1	2008Q1	
41	ncreconr	2008Q1	2008Q1	Y	2008Q1	2008Q1	
42	ncrenrer	2008Q3	2008Q3	Y	2008Q3	2008Q3	
43	ncremulr	1998Q1	1998Q1	Y	1998Q1	1998Q1	
44	ncreresr	2008Q4	2008Q4	Y	2008Q4	2008Q4	
45	ncrelocr	1997Q2	1997Q2	Y	1997Q2	1997Q2	
46	ncrereor	2008Q4	2008Q4	Y	2008Q4	2008Q4	
47	idnccir	2008Q3(15)	2008Q3(15)	Y	2008Q3(15) 2009Q1(5)	2008Q3	
48	idncconr	1996Q4	1996Q4	Y	1996Q4	1996Q4	
49	idnccrdr	2001Q2 15	2001Q2 15	N Y	2001Q2 15 2009Q4 5	2001Q2	
50	idnccoor	1997Q1	1997Q1	N	1997Q1	1997Q1	
51	idncothr	1998Q1	1998Q1	N	1998Q1	1998Q1	
52	nccomrer	2008Q1	2008Q1	Y	2008Q1	2008Q1	
53	idncgtpr	2009Q1	2009Q1	Y	2009Q1	2009Q1	
	lnlsnet						
54	lnatres	2009Q1	2009Q1	N	2009Q1	2009Q1	
	Lnlsgr= TL						
55	lncon	1997Q4	1997Q4	N	1997Q4	1997Q4	
56	lnfg						
57	lndepac	2008Q3	2008Q3	Y	2008Q3	2008Q3	
	Lndepac=TDI						
58	lndepcb	2009Q2	2009Q2	N	2009Q2	2009Q2	
59	lndepusb	2006Q1	2006Q1	Y	2006Q1	2006Q1	
60	lndepus	2006Q1	2006Q1	Y	2006Q1	2006Q1	
61	lndepfc	2001Q2	2001Q2	Y	2001Q2	2001Q2	
62	lndepfus	2006Q4	2006Q4	Y	2006Q4	2006Q4	
63	obsdir	1998Q3	1998Q3	Y	1998Q3	1998Q3	
64	chbal	2008Q4	2008Q4	N	2008Q4	2008Q4	

65-a	chcic	2001Q3	2001Q3	Y	2001Q3	2001Q3	
65-b	chitem	2001Q2	2001Q2	N	2001Q2	2001Q2	
65-c	chcoin	2000Q4	2000Q4	Y	2000Q4	2000Q4	
65-d	chus	2001Q3	2001Q3	Y	2001Q3	2001Q3	
	chusfbk						
	chnus						
	chnusfbk						
65-e	chfrb	1998Q1(15)	1998Q1(15)	N	1998Q1(15) 2009Q4(5)	1998Q1	
	chbalni						
66-a	chcic	2000Q2	2000Q2	Y	2000Q2	2000Q2	
66-b	chitem	2001Q3	2001Q3	N	2001Q3	2001Q3	
66-c	chcoin	2000Q2	2000Q2	Y	2000Q2	2000Q2	
66-d	chus	2001Q2	2001Q2	Y	2001Q2	2001Q2	
	chusfbk						
	chnus						
	chnusfbk						
66-e	chfrb	2009Q1(15/10)	2010Q2(5)	Y N	2009Q1(15/10) 2010Q2(5)	2010Q2	
	chbalni						
67	chbal	2008Q4	1997Q1(15)	N N Y	1997Q1(15) 1995Q1(5) 2008Q4	1997Q1	
68-a	chcic	2000Q2	2000Q2	Y	2000Q2	2009Q2	
68-b	chitem	2001Q2	2001Q2	Y	2001Q2	2010Q2	
68-c	chcoin	2000Q2	2000Q2	Y	2000Q2	2000Q2	
68-d	chus	2001Q2	2001Q2	Y	2001Q2	2001Q2	
68-e	chfrb	2010Q2(5)	2009Q1(15)	Y	2009Q1(15) 2010Q2(5)	2009Q1	
69-a	chcic	2000Q1	2000Q1	N	2000Q1	2000Q1	
69-b	chitem	2001Q2	2001Q2	Y	2001Q2	2001Q2	
69-c	chcoin	2000Q2	2000Q2	Y	2000Q2	2000Q2	
69-d	chus	2001Q2	2001Q2	Y	2001Q2	2001Q2	
69-e	chfrb	2010Q2(5)	2008Q4(15)	Y	2008Q4(15) 2010Q2(5)	2008Q4	

Appendix 4: Lee Strazicich Test

NO.	Short Name of Ratios	One Break Lee Strazicich Test			Two- Break Lee Strazicich Test			
		model	t-statistics	Break date	model	t-statistics	Break date1	Break date2
1	intincy	C	-4.6202	1998Q4	C	-5.5008	2001Q3	2006Q2
2	intexpy	C	-4.1928	2005Q3	C	-5.4089	2001Q3	2006Q3
3	nimy	C	-4.6431	2007Q3	C	-6.1227	2004Q1	2007Q4
4	noniiy	C	-3.3568	2002Q3	C	-6.3870	2000Q4	2003Q3
5	nonixy	C	-4.1901	1995Q4	C	-6.6133	1996Q1	2007Q4
6	noijy	C	-3.9191	2004Q1	C	-5.9103	1998Q4	2007Q4
7	roa	C	-4.0127	2004Q1	C	-6.1291	2006Q4	2010Q1
8	roaptx	C		2005Q2	C		2001Q4	2005Q2
9	roe	C		2003Q2	C		1998Q1	2003Q2
10	roeinjr	C		2010Q1	C		1994Q4	2010Q1
11	ntlnlsr	C		2009Q2	C		2009Q1	2009Q2
12	elnantr	C		1994Q4	C		2008Q3	1994Q4
13	iderncvr	C		2007Q1	C		2009Q2	2007Q1
14	eeffr	C		2010Q1	C		2008Q3	2010Q1
15	astempm	C		2009Q3	C		2008Q4	2009Q3
16	iddivnir	C		2009Q2	C		2008Q4	2009Q2
17	lnatresr	C		2007Q4	C		1996Q1	2007Q4
18	lnresncr	C		2007Q1	C		1998Q4	2007Q1
19	nperfv	C		2006Q2	C		1996Q4	2006Q2
20	nclnlsr	C		2007Q3	C		2000Q1	2007Q3
21	lnlsdepr	C		2009Q3	C		1995Q2	2009Q3
22	idlncorr	C		2009Q2	C		2009Q2	2009Q3
23	eqv	C		2009Q3	C		2001Q3	2009Q3
24	rbc1aaj	C		2009Q3	C		2007Q1	2009Q3
25	rbc1rwaj	C		1994Q4	C		1997Q1	1994Q4
26	rbcrwaj	C		2009Q1	C		2007Q1	2009Q1
11-b	ntlnlsr	C		2008Q3	C		1994Q3	2008Q3
27	ntrer	C		2009Q2	C		2006Q1	2009Q2
28	ntrecosr	C		2008Q3	C		2008Q3	2009Q2
29	ntrenrsr	C		2008Q4	C		1995Q3	2008Q4
30	ntremulr	C		2008Q4	C		2009Q1	2008Q4
30-b	ntreresr	C		2001Q3	C		1994Q1	2001Q3
31	ntrelocr	C		2008Q4	C		2008Q4	2009Q1
32	ntreothr	C		1996Q2	C		1994Q2	1994Q2
33	idntcir	C		1999Q2	C		1994Q1	1999Q2
34	idntconr	C		1997Q2	C		1996Q2	1997Q2
35	idntcrdr	C		2003Q1	C		1999Q4	2003Q1
36	idntcoor	C		2001Q1	C		1997Q1	2010Q2

37	idntothr	C		1999Q3	C		2006Q2	1999Q3
38	ntcomrer	C		2008Q4	C		1994Q1	2009Q2
39	nclnlsr	C		2009Q4	C		2008Q4	2009Q4
40	ncrer	C		2008Q1	C		1998Q4	2008Q1
41	ncreconr	C		2008Q1	C		1996Q1	2008Q1
42	ncrenrer	C		2008Q3	C		1998Q4	2008Q3
43	ncremulr	C		1998Q1	C		1996Q4	1998Q1
44	ncreresr	C		2008Q4	C		2000Q1	2008Q4
45	ncrelocr	C		1997Q2	C		2007Q4	1997Q2
46	ncrereor	C		2008Q4	C		2001Q3	2008Q4
47	idnccir	C		2008Q3	C		2009Q1	2008Q3
48	idncconr	C		1996Q4	C		1994Q1	1996Q4
49	idnccrdr	C		2001Q1	C		2001Q2	2009Q4
50	idnccoor	C		1997Q1	C		2008Q1	1997Q1
51	idncothr	C		1998Q1	C		1994Q4	1998Q1
52	nccomrer	C		2008Q1	C		1999Q1	2008Q1
53	idncgtpr	C		2009Q1	C		2008Q3	2009Q1
	lnlsnet	C			C		2009Q2	
54	lnatres	C		2009Q1	C		2008Q3	2009Q1
	Lnlsgr= TL	C			C		2008Q4	
55	lncon	C		1997Q4	C		2008Q4	1997Q4
56	lnfg	C			C		1996Q1	
57	lndepac	C		2008Q3	C		1998Q4	2008Q3
	Lndepac=TDI	C			C		1996Q4	
58	lndepcb	C		2009Q2	C		2000Q1	2009Q2
59	lndepusb	C		2006Q1	C		1995Q2	2006Q1
60	lndepus	C		2006Q1	C		2009Q2	2006Q1
61	lndepfc	C		2001Q2	C		2009Q3	2001Q2
62	lndepfus	C		2006Q4	C		2008Q3	2006Q4
63	obsdir	C		1998Q3	C		1996Q4	1998Q3
64	chbal	C		2008Q4	C		2009Q4	2008Q4
65-a	chcic	C		2001Q3	C		1997Q1	2001Q3
65-b	chitem	C		2001Q2	C		1998Q1	2001Q2
65-c	chcoin	C		2000Q4	C		2008Q1	2000Q4
65-d	chus	C		2001Q3	C		2009Q1	2001Q3
	chusfbk	C			C			
	chnus	C			C		2009Q1	1994Q1
	chnusfbk	C			C			
65-e	chfrb	C		2009Q4	C		1998Q1	2009Q4
	chbalni	C			C			

66-a	chcic	C		2000Q2	C		1994Q3	2000Q2
66-b	chitem	C		2001Q3	C		1999Q1	2001Q3
66-c	chcoin	C		2000Q2	C		2008Q4	2000Q2
66-d	chus	C		2001Q2	C		2008Q4	2001Q2
	chusfbk	C			C			
	chnus	C			C			
	chnusfbk	C			C			
66-e	chfrb	C		2010Q2	C		2009Q1	2010Q2
	chbalni	C			C			
67	chbal	C		1997Q1	C		1995Q1	2008Q4
68-a	chcic	C		2000Q2	C		1999Q4	2000Q2
68-b	chitem	C		2001Q2	C		2008Q4	2001Q2
68-c	chcoin	C		2000Q2	C		2007Q4	2000Q2
68-d	chus	C		2001Q2	C		2008Q1	2001Q2
68-e	chfrb	C		2009Q1	C		2009Q1	2010Q2
69-a	chcic	C		2000Q1	C		2007Q4	2000Q1
69-b	chitem	C		2001Q2	C		2007Q2	2001Q2
69-c	chcoin	C		2000Q2	C		2008Q1	2000Q2
69-d	chus	C		2001Q2	C		2009Q2	2001Q2
69-e	chfrb	C		2008Q4	C		2008Q4	2010Q2

Appendix 5: Estimated regression with a structural break

** and * denote significance at the 5% and 10% levels respectively. TB denotes the break date found by using Maximum LR/Wald F-statistic.

NO.	Ratios	Break point	Coefficients			
			Constant (α)	Dummy in level (D)	Time trend (t)	Dummy in trend (Dt)
1	Yield on earning assets	2008q1	8.388**	5.284**	-0.035**	-0.082**
			(53.837)	(2.076)	(-8.203)	(-2.257)
2	Cost of funding earning assets	2008Q1	3.841**	6.943**	-0.024**	-0.106**
			(24.254)	(2.684)	(-5.581)	(-2.857)
3	Net interest margin	2003Q2	4.580**	-0.055	-0.012**	0.001
			(186.738)	(-0.625)	(-12.264)	(0.866)
4	Noninterest income to earning assets	2003Q3	0.677**	0.238**	0.000	-0.005**
			(101.438)	(9.365)	(0.681)	(-10.231)
5	Noninterest expense to earning assets	1995Q3/Q4	3.412**	-0.270**	-0.008**	0.009**
			(133.472)	(-9.360)	(-2.343)	2.664
6	Net operating income to assets	2010Q1	1.220**	-1.837	-0.006**	0.023
			(46.361)	(-1.206)	(-9.636)	(1.119)
7	Return on assets (ROA)	1995Q2	1.182**	0.167**	-0.007	-0.001
			(18.469)	(2.355)	(-0.769)	(-0.155)
		2009Q4 N Y	1.245**	-1.672	-0.006**	0.0210
			(7.575)	(0.671)	(9.673)	(0.556)
		2010Q1 N Y	1.251**	-1.831	-0.007**	0.023
			(42.326)	(-0.143)	(3.575)	(1.125)
8	Pretax return on assets	2005Q2	1.707**	1.246**	-0.007**	-0.024**
			(57.887)	(6.974)	(-6.617)	(-8.172)
		2009Q4 N Y	1.808**	-2.420	-0.011**	0.031
			(4.682)	(-0.152)	(35.671)	(1.117)
		2010Q1 N Y	1.816**	-2.623	-0.0114**	0.034
			(31.212)	(1.068)	(4.736)	(-0.758)
9	Return on Equity (ROE)	2003Q2	12.762**	6.493**	-0.065**	-0.121**
			(53.502)	(7.575)	(-6.839)	(-7.363)
		2009Q4 N Y	13.244**	-16.889	-0.084**	0.216
			(1.998)	(-0.345)	(21.234)	(-0.007)
		2010Q1 N Y	13.290**	-18.937	-0.086**	0.244
			(7.907)	(1.067)	(65.297)	(1.006)
10	Retained earnings to average equity (ytd only)	2010Q1	9.158**	-12.318	-0.082**	0.175
			(43.366)	(-1.007)	(-15.910)	(1.056)
11	Net charge-offs to loans	2009Q2	0.056**	0.716	0.000	-0.007
			(3.841)	(1.529)	(0.652)	(-1.039)
12	Credit loss provision to net charge-offs	1994Q4	82.146**	-3.211	-2.458	2.898
			(4.170)	(-0.151)	(-0.702)	(0.827)
13	Earnings coverage of net charge-offs (x)	2007Q1	15.855**	40.111**	0.072**	-0.793**
			(19.961)	(4.682)	(3.065)	(-6.231)
14	Efficiency ratio	2010Q1	60.677**	9.360	0.122**	-0.101
			(132.316)	(0.352)	(10.857)	(-0.281)
15	Assets per employee ($millions)	2009Q3	1.859**	0.678	0.026**	-0.006
			(116.321)	(1.102)	(65.468)	(-0.758)
16	Cash dividends to net income (ytd only)*	2009Q2	12.611**	-74.739	0.085	0.805
			(4.575)	(-0.838)	(1.212)	(0.654)
17	Loss allowance to loans	2007Q4	1.432**	-2.259**	-0.005**	0.037**
			(115.155)	(-12.433)	(-14.060)	(14.165)
18	Loan loss allowance to noncurrent loans	2007Q1	156.621**	212.311**	0.869**	-4.898**
			(33.646)	(4.228)	(6.334)	(-6.569)
19	Noncurrent assets plus other real estate owned to assets	2006Q2	1.175**	-7.872**	-0.011**	0.142**
			(19.787)	(-16.022)	(-6.153)	(18.847)
20	Noncurrent loans to loans	2007Q3	Nil	Nil	Nil	Nil
21	Net loans and leases to deposits	2009Q3	64.131**	78.290**	0.320**	-1.229**
			(171.498)	(5.443)	(33.957)	(-6.234)
22	Net loans and leases to core deposits	2009Q3 2009Q2	68.647**	162.004**	0.560**	-2.569**
			(116.735)	(7.162)	(37.784)	(-8.289)
23	Equity capital to assets	2009Q3	8.948**	-4.136*	0.018**	0.055*
			(189.962)	(-2.283)	(14.975)	(2.215)

24	Core capital (leverage) ratio	2009Q3	8.935**	-3.836*	0.011**	0.050*
			(188.062)	(-2.099)	(8.812)	(1.998)
25	Tier 1 risk-based capital ratio	1997Q1/1994 Q4	15.060**	-0.355	0.014	-0.030
			(70.822)	(-1.308)	(0.718)	(-1.500)
26	Total risk-based capital ratio	2009Q1	16.587**	-16.506**	-0.035**	0.245**
			(251.332)	(-9.057)	(-20.694)	(9.663)
11-b	Net charge-offs to loans	2008Q3	0.067**	-0.295	-0.000	0.007*
			(4.674)	(-0.988)	(-0.699)	(1.743)
27	% Net Loans Charged-off: Total real estate loans	2009Q2	0.036**	-0.307	-0.000**	0.007
			(3.695)	(-0.975)	(-2.527)	(1.522)
28	% Net Loans Charged-off:Construction & development	2008Q3/2009 Q2	0.041**	-0.055 -0.258	-0.001**	0.002 0.005
			(4.261)	(-0.031) (-0.142)	(-3.340)	(0.065) (0.186)
29	% Net Loans Charged-off: Commercial real estate	1995Q3/2008 Q4	4.448**	-4.681** 2.889	-0.328**	0.338** -0.005
			(8.793)	(-7.895) (0.586)	(-4.778)	(4.887) (-0.070)
30	% Net Loans Charged-off: Multi-family residential	2008Q4	0.238**	-0.360	-0.003	0.019
			(2.095)	(-0.133)	(-1.157)	(0.493)
30-b	% Net Loans Charged-off: 1-4 family residential	2001Q3	0.220**	-0.906**	-0.004	0.020**
			(4.692)	(-7.822)	(-1.644)	(6.899)
31	% Net Loans Charged-off: Home equity loans	2008Q4	0.187*	0.945	0.001	-0.004
			(1.955)	(0.414)	(0.350)	(-0.119)
		2009Q1	0.174*	1.994	0.001	-0.018
			(1.823)	(0.758)	(0.597)	(-0.504)
32	All other 1-4 family - Percent of loans charged-off, net	1996Q2(15)	0.025	-0.441**	-0.001	0.002
			(-0.133)	(3.692)	(-1.157)	(-1.358)
		1994Q2(5)	0.031	-0.040	-0.003	0.004
			(0.167)	(0.733)	(1.143)	(0.165)
33	% Net Loans Charged-off: Commercial and industrial	1999Q2	-2.794	2.768	0.300*	-0.285**
			(-1.325)	(0.782)	(2.276)	(-2.012)
34	% Net Loans Charged-off: Loans to individuals	1996Q2(5)	0.445**	0.193**	-0.002	-0.005
			(5.786)	(2.103)	(-0.218)	(-0.592)
35	% Net Loans Charged-off: Credit card loans	2003Q1	1.687**	-1.513**	-0.023**	0.031**
			(10.328)	(-2.732)	(-3.441)	(2.819)
36	% Net Loans Charged-off: Other loans to individual	1997Q1(15)	0.204**	0.223**	0.008	-0.012**
			(3.366)	(2.888)	(1.427)	(-2.134)
		2010Q2(5)	0.334**	2.476	-0.002**	-0.033
			(10.816)	(1.079)	(-3.185)	(-1.084)
37	% Net Loans Charged-off: All other loans and lease	1999Q3	-0.144	-2.265	0.043	0.038
			(-0.149)	(-1.348)	(0.739)	(0.595)
38	% Net Loans Charged-off:Coml. RE not secured by RE	2008Q4(15)	2.251	-0.331	-0.013	0.083
			(1.625)	(-0.010)	(-0.348)	(0.178)
		2009Q2(10)	2.009	13.700	-0.002	-0.115
			(1.465)	(0.309)	(-0.057)	(-0.189)
		1994Q1	10.687**	-13.016**	-0.530	0.635
			(2.249)	(-2.631)	(-0.434)	(0.521)
39	Noncurrent loans to loans	2009Q4	0.609**	3.246	0.002	-0.030
			(9.035)	(1.033)	(1.366)	(-0.704)
40	% Loans Noncurrent: Real estate loans	2008Q1	1.008**	-4.112**	-0.013**	0.082**
			(20.857)	(-5.208)	(-9.842)	(7.222)
41	% Loans Noncurrent:Construction & land development	2008Q1	4.3354**	-21.310**	-0.072**	0.427**
			(12.930)	(-3.875)	(-7.695)	(5.414)
42	% Loans Noncurrent: Commercial real estate	2008Q3	2.625**	-5.470*	-0.033**	0.113**
			(18.459)	(-1.844)	(-8.567)	(2.704)
43	% Loans Noncurrent: Multifamily residential	1998Q1	3.192**	-4.072**	-0.070**	0.115**
			(11.007)	(-9.883)	(-3.193)	(5.029)
44	% Loans Noncurrent: 1-4 family residential	2008Q4	0.652**	-2.341**	-0.007**	0.046**
			(25.839)	(-3.885)	(-9.780)	(5.460)
45	% Loans Noncurrent: Home equity loans	1997Q2	1.006**	-0.963**	-0.006	0.019
			(7.774)	(-5.690)	(-0.571)	(1.605)
46	Percent of loans noncurrent - All other family	2008Q4	0.689**	-2.545**	-0.007**	0.050**
			(26.088)	(-4.038)	(-10.217)	(5.625)

47	% Loans noncurrent:Commercial and industrial loans	2008Q3(15)	0.903**	-0.619	-0.014**	0.018
			(23.459)	(-0.771)	(-13.434)	(1.611)
		2009Q1(5)	0.878**	0.819	-0.013**	-0.002
			(21.815)	(0.737)	(-12.167)	(-0.136)
48	% Loans Noncurrent: Loans to individuals	1996Q4	0.449**	0.0160	-0.005**	0.001
			(19.932)	(0.569)	(-2.273)	(0.462)
49	% Loans Noncurrent: Credit card loans	2001Q2	0.715**	0.528**	0.013**	-0.013**
			(14.534)	(4.849)	(5.416)	(-4.308)
		2009Q4	0.811**	3.165**	0.008**	-0.045**
			(21.608)	(2.529)	(8.901)	(-2.631)
50	% Loans Noncurrent: Other loans to individuals	1997Q1	0.338**	0.089**	-0.002	-0.002
			(13.140)	(2.705)	(-0.912)	(-0.793)
51	% Loans Noncurrent: All other loans and leases	1998Q1	1.089**	-0.631**	-0.020**	0.028**
			(14.269)	(-5.820)	(-3.497)	(4.611)
52	% Loans Noncurrent: Commercial RE not secured by RE	2008Q1	2.352**	-2.340	-0.040**	0.063
			(12.197)	(-0.743)	(-7.485)	(1.399)
53	Wholly or partially US Gov. guaranteed noncurrent loans as percent of noncurrent	2009Q1	5.346**	-3.158	-0.027**	0.033
			(39.023)	(-0.861)	(-7.515)	(0.652)
	loans and leases=TL					
54	Loan loss allowance/TL	2009Q1	1.418**	-1.667**	-0.004**	0.029**
			(106.706)	(-4.541)	(-12.337)	(5.616)
	Total loans and leases					
55	Loans to individuals/TL	1997Q4	12.620**	1.359**	-0.059**	-0.089**
			(73.369)	(5.723)	(-4.282)	(-6.201)
56	Loans to foreign governments and official institutions					
57	Loans to depository institutions and acceptances of other banks/TL	2008Q3	4.023**	2.086	0.014	-0.046*
			(42.980)	(1.068)	(5.630)	(-1.688)
	Loans to depository institutions and acceptances of other banks=TD					
58	To commercial banks in U.S./TDI	2009Q2	51.881**	29.422*	0.205**	-0.438**
			(121.233)	(1.953)	(18.696)	(-2.098)
59	To U.S. branches and agencies of foreign banks/TDI	2006Q1	5.860**	6.768**	-0.0143 *	-0.073**
			(20.918)	(3.170)	(-1.617)	(-2.196)
60	To other depository institutions in U.S./TDI	2006Q1	17.144**	3.195	-0.051**	-0.057
			(47.648)	(1.162)	(-4.512)	(-0.057)
61	To banks in foreign countries/TDI	2001Q2	12.145**	12.089**	0.179 **	-0.214**
			(20.194)	(8.534)	(6.135)	(-5.847)
62	To foreign branches of U.S. banks/TDI	2006Q4	0.574**	1.316	-0.004*	-0.004
			(6.982)	(1.627)	(-1.731)	(-0.999)
63	Derivatives/TA	1998Q3	6.010**	4.227*	0.202*	-0.262**
			(3.683)	(1.712)	(1.765)	(-2.193)
64	Cash & Balances due from depository institutions/TA	2008Q4	4.730**	-19.279**	-0.024**	0.311**
			(64.160)	(-10.953)	(-12.131)	(12.635)
65-a	Cash items in process of collection/TA	2001Q3	0.049	3.581*	0.250**	-0.286**
			(0.057)	(1.691)	(6.185)	(-5.453)
65-b	Collection in domestic offices/TA	2001Q2	1.208**	0.698**	0.010**	-0.030**
			(27.596)	(6.776)	(4.623)	(-11.135)
65-c	Currency and coin in domestic offices/TA	2000Q4	0.827**	-0.100	0.013**	-0.015**
			(19.276)	(-1.089)	(5.853)	(-5.822)
65-d	Balances due from depository institutions in U.S. /TA	2001Q3	3.414**	-3.794**	-0.029**	0.069**
			(24.690)	(-11.115)	(-4.454)	(8.234)
	U.S. branches of foreign banks					
	Balances due from foreign banks					

	Foreign branches of U.S. banks					
65-e	Balances due from FRB/TA	1998Q1(15)	0.783*	-2.861**	-0.007	0.076**
			(1.818)	(-4.674)	(-0.228)	(2.244)
		2009Q4(5)	0.466**	-6.644	0.008**	0.141*
			(3.496)	(-1.07)	(2.365)	(1.667)
	Total noninterest-bearing balances					
66-a	Cash items in process of collection/TA	2000Q2	1.275**	0.528**	0.005**	-0.017**
			(32.537)	(6.852)	(2.211)	(-6.822)
66-b	Collection in domestic offices/TA	2001Q3	0.177**	1.224**	0.006**	-0.022**
			(3.482)	(9.765)	(2.439)	(-7.129)
66-c	Currency and coin in domestic offices/TA	2000Q2	0.773**	-0.006	0.004**	-0.008**
			(23.191)	(-0.093)	(2.278)	(-4.056)
66-d	Balances due from depository institutions in U.S. /TA	2001Q2	2.268**	-2.646**	-0.030**	0.048**
			(29.778)	(-14.768)	(-8.252)	(10.248)
	U.S. branches of foreign banks					
	Balances due from foreign banks					
	Foreign branches of U.S. banks					
66-e	Balances due from FRB/TA	2009Q1(15/10)	0.342**	-16.110**	-0.004**	0.251**
			(11.385)	(-19.402)	(-4.557)	(21.756)
		2010Q2(5)	0.176**	-11.341*	0.004*	0.182**
			(2.161)	(-1.875)	(1.784)	(2.239)
	Total noninterest-bearing balances					
67	Cash & Balances due from depository institutions/Total deposit	1997Q1(15)	5.627**	-2.195**	-0.046	0.081*
			(10.967)	(-3.353)	(-0.971)	(1.692)
		1995Q1(5)	5.874**	-1.880**	-0.096	0.121
			(7.992)	(-2.337)	(-0.806)	(1.02)
		2008Q4	5.459**	-21.751**	-0.022**	0.352**
			(60.976)	(-10.176)	(-9.205)	(11.751)
68-a	Cash items in process of collection /Total deposit	2000Q2	1.446**	1.010**	0.010**	-0.027**
			(26.982)	(9.584)	(3.212)	(-8.022)
68-b	Collection in domestic offices/Total deposit	2001Q2	0.221**	1.727**	0.006*	-0.029**
			(3.444)	(11.439)	(1.877)	(-7.360)
68-c	Currency and coin in domestic offices/Total deposit	2000Q2	0.873**	0.123	0.007**	-0.013**
			(22.005)	(1.581)	(3.117)	(-5.092)
68-d	Balances due from depository institutions in U.S. /Total deposit	2001Q2	2.616**	-2.985**	-0.032**	0.052**
			(28.882)	(-14.007)	(-7.328)	(9.481)
68-e	Balances due from FRB/Total deposit	2009Q1(15)	0.413**	19.144**	-0.004**	0.299**
			(10.803)	(-18.126)	(-3.911)	(20.400)
		2010Q2(5)	0.207**	-11.967	0.005**	0.197*
			(2.048)	(-1.597)	(2.009)	(1.956)
69-a	Cash items in process of collection / cash due from depository	2000Q1	29.257**	25.854**	0.315**	-0.731**
			(13.073)	(6.126)	(2.495)	(-5.168)
69-b	Collection in domestic offices/ cash due from depository	2001Q2	3.890**	46.230**	0.160**	-0.790**
			(2.670)	(13.487)	(2.272)	(-8.907)
69-c	Currency and coin in domestic offices/ cash due from depository	2000Q2	16.411**	9.923**	0.246**	-0.433**
			(13.867)	(4.265)	(3.811)	(-5.870)
69-d	Balances due from depository institutions in U.S. / cash due from depository	2001Q2	61.435**	-60.131**	-0.588**	0.874**
			(27.524)	(-11.451)	(-5.434)	(6.436)
69-e	Balances due from FRB/ cash due from depository	2008Q4(15)	8.012**	252.916**	-0.053**	4.070**
			(11.368)	(-15.032)	(-2.861)	(17.278)
		2010Q2(5)	3.848**	66.586	0.125**	1.439
			(2.115)	(-0.493)	(2.840)	(0.794)

Appendix 6: summary of changes around break point

Summary of changes					
NO.	code	ratios	Break point	Slope change	Jump?
1	intincy	Yield on earning assets	2008q1	--- → --- ---	↑
2	intexpy	Cost of funding earning assets	2008Q1	--- → --- ---	↑
3	nimy	Net interest margin	2003Q2	0	0
4	noniiy	Noninterest income to earning assets	2003Q3	0 → --- ---	↑
5	nonixy	Noninterest expense to earning assets	1995Q3/Q4	--- → +	↓
6	noijy	Net operating income to assets	2010Q1	--- → 0	0
7	roa	Return on assets (ROA)	1995Q2	0	↑
			2009Q4 N Y	--- → 0	0
			2010Q1 N Y	--- → 0	0
8	roaptx	Pretax return on assets	2005Q2	0 → --- ---	↑
			2009Q4 N Y	--- → 0	0
			2010Q1 N Y	--- → 0	0
9	roe	Return on Equity (ROE)	2003Q2	0 → --- ---	↑
			2009Q4 N Y	--- → 0	0
			2010Q1 N Y	--- → 0	0
10	roeinjr	Retained earnings to average equity (ytd only)	2010Q1	--- → 0	0
11	ntlnlsr	Net charge-offs to loans	2009Q2	0	0
12	elnantr	Credit loss provision to net charge-offs	1994Q4	0	0
13	iderncvr	Earnings coverage of net charge-offs (x)	2007Q1	+ → --- ---	↓
14	eeffr	Efficiency ratio	2010Q1	+ → 0	0
15	astempm	Assets per employee ($millions)	2009Q3	+ → 0	0
16	iddivnir	Cash dividends to net income (ytd only)*	2009Q2	0	0
17	lnatresr	Loss allowance to loans	2007Q4	--- --- → + +	↑ tiny
18	lnresncr	Loan loss allowance to noncurrent loans	2007Q1	+ → --- ---	↓
19	nperfv	Noncurrent assets plus other real estate owned to assets	2006Q2	--- → + +	↑ tiny
20	nclnlsr	Noncurrent loans to loans	2007Q3		
21	lnlsdepr	Net loans and leases to deposits	2009Q3	+ + → --- ---	↓
22	idlncorr	Net loans and leases to core deposits	2009Q3 2009Q2	+ + → --- ---	↓
23	eqv	Equity capital to assets	2009Q3	+ → + +	↓
24	rbc1aaj	Core capital (leverage) ratio	2009Q3	+ → + +	↓
25	rbc1rwaj	Tier 1 risk-based capital ratio	1997Q1/1994 Q4	0	0
26	rbcrwaj	Total risk-based capital ratio	2009Q1	--- --- → + +	↓ tiny
11-b	ntlnlsr	Net charge-offs to loans	2008Q3	0	0
27	ntrer	% Net Loans Charged-off: Total real estate loans	2009Q2	--- → 0	0

28	ntrecosr	% Net Loans Charged-off:Construction & development	2008Q3/2009 Q2	--- → 0→ 0	0 0
29	ntrenrsr	% Net Loans Charged-off: Commercial real estate	1995Q3/2008 Q4	--- → +→ 0	↓ tiny 0
30	ntremulr	% Net Loans Charged-off: Multi-family residential	2008Q4	0	0
30-b	ntreresr	% Net Loans Charged-off: 1-4 family residential	2001Q3	0 → ++	↓
31	ntrelocr	% Net Loans Charged-off: Home equity loans	2008Q4(15)	0	0
			2009Q1(5/10)	0	0
32	ntreothr	All other 1-4 family - Percent of loans charged-off, net	1996Q2(15)	--- --- → ++	↓
			1994Q2(5)	0	↓
33	idntcir	% Net Loans Charged-off: Commercial and industrial	1999Q2	+ + → +	0
34	idntconr	% Net Loans Charged-off: Loans to individuals	1996Q2(5)	0	↑
35	idntcrdr	% Net Loans Charged-off: Credit card loans	2003Q1	--- → +	↓
36	idntcoor	% Net Loans Charged-off: Other loans to individual	1997Q1(15)	0 → --- ---	↑
			2010Q2(5)	--- → 0	0
37	idntothr	% Net Loans Charged-off: All other loans and lease	1999Q3	0	0
38	ntcomrer	% Net Loans Charged-off:Coml. RE not secured by RE	2008Q4(15)	0	0
			2009Q2(10)	0	0
			1994Q1	0	↓
39	nclnlsr	Noncurrent loans to loans	2009Q4	0	0
40	ncrer	% Loans Noncurrent: Real estate loans	2008Q1	--- --- → ++	↑
41	ncreconr	% Loans Noncurrent:Construction & land development	2008Q1	--- --- → ++	↑
42	ncrenrer	% Loans Noncurrent: Commercial real estate	2008Q3	--- --- → ++	0
43	ncremulr	% Loans Noncurrent: Multifamily residential	1998Q1	--- --- → ++	↓
44	ncreresr	% Loans Noncurrent: 1-4 family residential	2008Q4	--- --- → ++	↑↑
45	ncrelocr	% Loans Noncurrent: Home equity loans	1997Q2	0	↓
46	ncrereor	Percent of loans noncurrent - All other family	2008Q4	--- --- → ++	↑
47	idnccir	% Loans noncurrent:Commercial and industrial loans	2008Q3(15)	--- → 0	0
			2009Q1(5)	--- → 0	0
48	idncconr	% Loans Noncurrent: Loans to individuals	1996Q4	--- → 0	0
49	idnccrdr	% Loans Noncurrent: Credit card loans	2001Q2 15	+ + → -- (close to flat)	↑
			2009Q4 5	+ + → -- --	↑↓
50	idnccoor	% Loans Noncurrent: Other loans to individuals	1997Q1	0	↑
51	idncothr	% Loans Noncurrent: All other loans and leases	1998Q1	--- --- → ++	↑
52	nccomrer	% Loans Noncurrent:Commercial RE not secured by RE	2008Q1	--- → 0	0

53	idncgtpr	Wholly or partially US Gov. guaranteed noncurrent loans as percent of noncurrent	2009Q1	--- → 0	0
	lnlsnet	loans and leases			
54	lnatres	Loan loss allowance/TL	2009Q1	--- → ++	↑
	Lnlsgr= TL	Total loans and leases			
55	lncon	Loans to individuals/TL	1997Q4	--- → --- ---	↓
56	lnfg	Loans to foreign governments and official institutions			
57	lndepac	Loans to depository institutions and acceptances of other banks/TL	2008Q3	+ → 0	0
	Lndepac=TDI	Loans to depository institutions and acceptances of other banks			
58	lndepcb	To commercial banks in U.S./TDI	2009Q2	+ + → -- --	0
59	lndepusb	To U.S. branches and agencies of foreign banks/TDI	2006Q1	0 → --- ---	↑
60	lndepus	To other depository institutions in U.S./TDI	2006Q1	+ → 0	0
61	lndepfc	To banks in foreign countries/TDI	2001Q2	+ → --	↑
62	lndepfus	To foreign branches of U.S. banks/TDI	2006Q4	--- → 0	0
63	obsdir	Derivatives/TA	1998Q3	0 → ---	0
64	chbal	Cash & Balances due from depository institutions/TA	2008Q4	--- → ++	↑
65-a	chcic	Cash items in process of collection/TA	2001Q3	+ → --	0
65-b	chitem	Collection in domestic offices/TA	2001Q2	+ + → -- --	↓
65-c	chcoin	Currency and coin in domestic offices/TA	2000Q4	+ + → --	0
65-d	chus	Balances due from depository institutions in U.S. /TA	2001Q3	--- → ++	↓
	chusfbk	U.S. branches of foreign banks			
	chnus	Balances due from foreign banks			
	chnusfbk	Foreign branches of U.S. banks			
65-e	chfrb	Balances due from FRB/TA	1998Q1(15)	0 → +	↓
			2009Q4(5)	+ → 0	0
	chbalni	Total noninterest-bearing balances			
66-a	chcic	Cash items in process of collection/TA	2000Q2	+ → --	0
66-b	chitem	Collection in domestic offices/TA	2001Q3	+ + → -- --	↑
66-c	chcoin	Currency and coin in domestic offices/TA	2000Q2	+ → --	0
66-d	chus	Balances due from depository institutions in U.S. /TA	2001Q2	--- → ++	↓
	chusfbk	U.S. branches of foreign banks			
	chnus	Balances due from foreign banks			
	chnusfbk	Foreign branches of U.S. banks			

66-e	chfrb	Balances due from FRB/TA	2009Q1(15/10)	--- → ++	↑
			2010Q2(5)	--- → ++	↑
	chbalni	Total noninterest-bearing balances			
67	chbal	Cash & Balances due from depository institutions/Total deposit	1997Q1(15)	0	↓
			1995Q1(5)	0	↓
			2008Q4	--- → ++	↑
68-a	chcic	Cash items in process of collection /Total deposit	2000Q2	+ → ---	↑
68-b	chitem	Collection in domestic offices/Total deposit	2001Q2	0 → ---	↑↑
68-c	chcoin	Currency and coin in domestic offices/Total deposit	2000Q2	+ → ---	0
68-d	chus	Balances due from depository institutions in U.S. /Total deposit	2001Q2	--- → +	↓
68-e	chfrb	Balances due from FRB/Total deposit	2009Q1(15)	--- → ++	↑
			2010Q2(5)	+ → 0	0
69-a	chcic	Cash items in process of collection / cash due from depository	2000Q1	+ + → -- --	↑
69-b	chitem	Collection in domestic offices/ cash due from depository	2001Q2	+ + → -- --	↑↑
69-c	chcoin	Currency and coin in domestic offices/ cash due from depository	2000Q2	+ → --	↓
69-d	chus	Balances due from depository institutions in U.S. / cash due from depository	2001Q2	--- → +	↓
69-e	chfrb	Balances due from FRB/ cash due from depository	2008Q4(15)	--- → ++	↑
			2010Q2(5)	--- → 0	0

Appendix 7: Significant Explanatory Variables in Selected Studies

Explanatory variables	Hardy and Pazarbaşioğlu (1998)	Demirgüç-Kunt and Detragiache (1998)	Demirgüç-Kunt and Detragiache (1999)	Hutchinson and McDill (1999)	Eichengreen and Areta (2000)	Hutchinson (2002)	Beck, Demirgüç-Kunt, and Levine (2003)	Barth, Caprio, and Levine (2008)	European Central Bank (2005)
GDP growth	■	■	■	■		■	■		
Real interest rates	■	■	■				■		
Inflation	■	■	■			■		■	
Change in terms of trade		■							
M2/reserves		■	■		■				
Credit growth		■	■	■	■	■	■		
Domestic credit to the private sector/GDP	■	■							■
Capital inflows	■								
Real exchange rate	■								
Real exchange rate pressure						■			
Import growth	■								
'Northern' interest rates					■				
'Northern' output growth					■				
Budget surplus					■				
GDP/capita		■					■		
Deposits at banks/GDP	■								
Gross foreign liabilities/GDP		■							
Banking sector return on equity									■
Banking sector loans to nonbank deposits									■
Growth in GDP/capita									■
Residential property prices									■
Stock price index				■					
Region , country, or OECD dummy	■			■					
Industry concentration							■		
'Law and order' index		■							
Deposit insurance dummy		■		■					
Central bank independence				■					
Liberalisation				■	■	■			
Moral hazard index							■	■	
Diversification index								■	
Government						■			
Contract enforcement						■			
Accounting disclosure						■			
Capital regulations								■	
Bank entry and activity restrictions						■	■	■	
Ownership							■	■	
Economic freedom							■		
Banking freedom							■		
Institutional environment							■		

Appendix 8: Overview of the FSIs (IMF, 2013)

1. Financial Soundness Indicators: index of Summaries

Core FSIs

Deposit takers

Regulatory capital to risk-weighted assets
Regulatory Tier I capital to risk-weighted assets
Nonperforming loans net of provisions to capital
Nonperforming loans to total gross loans
Sectoral distribution of loans to total loans
Return on assets
Return on equity
Interest margin to gross income
Noninterest expenses to gross income
Liquid assets to total assets (liquid asset ratio)
Liquid assets to short-term liabilities
Net open position in foreign exchange to capital

Encouraged FSIs

Deposit takers

Capital to assets ratio
Large exposures to capital
Geographical distribution of loans to total loans
Gross asset and liability position in financial derivatives to capital
Trading income to total income
Personnel expenses to noninterest expenses
Spread between reference lending and deposit rates
Spread between highest and lowest interbank rate
Customer deposits to total (noninterbank) loans
Foreign-currency-denominated loans to total loans
Foreign-currency-denominated liabilities to total liabilities
Net open position in equities to capital

Other financial corporations

Assets to total financial system assets
Assets to GDP

Nonfinancial corporations

Total debt to equity
Return on equity
Earnings to interest and principal expenses
Net foreign exchange exposure to equity
Number of applications for protection from creditors

Households

Household debt to GDP
Household debt service and principal payments to income

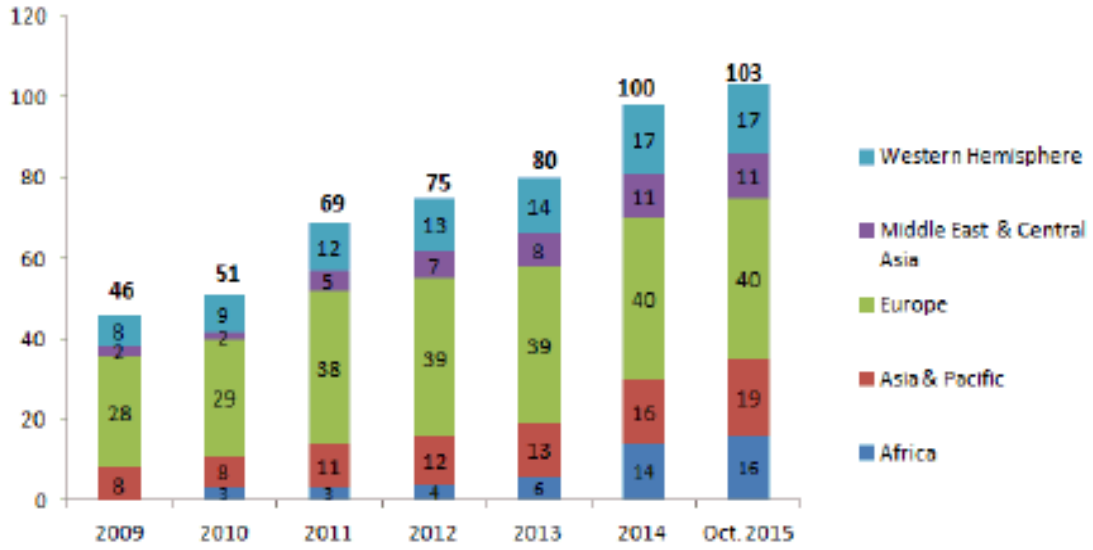
Market liquidity

Average bid-ask spread in the securities market
Average daily turnover ratio in the securities market

Real estate markets

Real estate prices
Residential real estate loans to total loans
Commercial real estate loans to total loans

2. Financial Soundness Indicators: Reporting Countries and Economies



Source: IMF's FSI website.

Appendix 9: Structural Break Tests for Large Banks

NO.	Short Name of Ratios	BREAKPOINT TEST				
		Maximum LR/WALD F-STATISTIC	QUANDT-ANDRES TEST	CHOW TEST	BAI_PERRON TEST	Zivot-Andrews TEST
1	intincy	2001Q1	2008Q4	N	2008Q1	2001Q4
2	intexpy	2001Q2	2001Q4	Y	1995Q2	2001Q2
3	nimy	2008Q1	2007Q1	Y	2004Q1	2008Q1
4	noniiy	2002Q3	2008Q1	Y	2008Q1	2002Q3
5	nonixy	1997Q3	1996Q1	Y	2008Q4	1997Q3
6	noijy	2010Q1	2007Q4	N	2007Q4	2004Q1
7	roa	1998Q4	2007Q4	Y	2007Q3	2004Q1
8	roaptx	2005Q2	2005Q2	Y	2005Q2	2005Q2
9	roe	2003Q2	2010Q1	Y	2003Q2	2003Q2
10	roeinjr	2010Q1	2009Q2	Y	2010Q1	2010Q1
11	ntlnlsr	2009Q2	1994Q4	N	2009Q2	2009Q2
12	elnantr	1994Q4	2007Q1	Y	1994Q4	1994Q4
13	iderncvr	2007Q1	2010Q1	Y	2007Q1	2007Q1
14	eeffr	2010Q1	2009Q3	Y	2010Q1	2010Q1
15	astempm	2008Q4	2009Q2	Y	2009Q3	2009Q3
16	iddivnir	2009Q2	2007Q4	Y	2009Q2	2009Q2
17	lnatresr	2007Q4	2007Q1	N	2007Q4	2007Q4
18	lnresncr	2006Q3	2006Q2	Y	2007Q4	2006Q3
19	nperfv	2006Q2	2006Q2	Y	2006Q2	2008Q2
20	nclnlsr	2007Q3	2007Q3	Y	2007Q3	2007Q3
21	lnlsdepr	2009Q3	2008Q4	N	1999Q1 2009Q3	2009Q3
22	idlncorr	2010Q1	2009Q2	N N	2009Q3 2009Q2	2009Q2
23	eqv	2009Q3	2009Q3	N	2008Q4	2008Q4
24	rbc1aaj	2009Q3	2009Q3	Y	2010Q1	2009Q3
25	rbc1rwaj	1997Q1	1994Q4	N	2010Q1	1994Q4
26	rbcrwaj	2009Q1	2009Q1	Y	2009Q1	2009Q1
11-b	ntlnlsr	2008Q3	2008Q3	Y	2008Q3	2008Q3
27	ntrer	2009Q2	2009Q2	Y	2009Q2	2008Q4
28	ntrecosr	2009Q2	2010Q1	N	2010Q1	2008Q3
29	ntrenrsr	1995Q3	2008Q4	Y	2010Q1	2008Q4
30	ntremulr	2008Q4	2008Q4	Y	2008Q4	2008Q4
30-b	ntreresr	2001Q3	2001Q3	N	2001Q3	2001Q3
31	ntrelocr	2008Q4	2008Q4	Y	2008Q4(15) 2009Q1(5/10) 2010Q1	2008Q4

Appendix 10 for Chapter 3: Three-stage Process of 2007/08 Financial Crisis

The 2007/08 financial crisis was characterized by non-bank FIs acting as one of the main triggers of the distress, the so-called "*the non-bank clue*" (FCIC, 2010), which is a novel property of the financial crash and is presented below as a three-stage process.

Stage 1 - Liquidity crisis of 2007

In the financial markets, the first casualties were subprime mortgage lenders, investment funds that focused on the subprime mortgage market, and ABCP programs with subprime exposure. Concerns spread to hedge funds and commercial paper programs during the summer, and in August global central banks took unprecedented steps to loosen monetary conditions and to provide liquidity to the CO markets.

By the end of 2007, most independent subprime mortgage lenders that relied on securitisation markets for their funding had failed or had been acquired. American Home Mortgage Corp., the 8th largest prime mortgage originator with a $3.3 billion ABCP program, announced it could not fund its obligations on July 31, 2007, and declared bankruptcy on August 6. In early 2007, two hedge funds run by Bear Stearns Asset Management began to experience rising client redemptions following weakening returns. Both these funds were heavily invested in subprime assets and declared bankruptcy by the end of July. By the summer of 2007, uncertainty in the value of MBS and CDOs began to have more severe effects on the commercial paper market and on the money market, in which financial institutions lend to each other.

Stage 2 - The run on Bear Stearns in early 2008

As mortgage default rates increased and asset-based securities lost value, financial guarantors faced mounting payment obligations. In November an December 2007, the three leading credit rating agencies issued credit outlook warnings or placed on negative watch the top financial ratings of several financial guarantors because of the companies' exposures to CDOs through credit default swaps. The collapse of the investment bank Bear Stearns was the next major crisis in the shadow banking system. It was unable to meet its obligations in March 2008. It arranged an emergency bridge loan from the Federal Reserve but after failing to secure additional capital, it was purchased by JP Morgan Chase, with government support, over that weekend.

Stage 3 - The panic of 2008

The collapse of Lehman Brothers in September 2008 was the final trigger that froze the shadow banking system. Its failure had repercussions for many components of shadow banking system and the traditional banking system. Most notably, withdrawals increased substantially at money funds, commercial paper markets came under pressure and certain hedge funds also suffered. In sum, the 2007 financial crisis was triggered mainly due to the process of the expansion of credit risks through securitisation. First, banks sold the mortgages through securitisation in the form of Mortgage-Backed Securities (MBS) to other market participants. MBS was then sold by financial institutions to the financial markets as Asset-backed securities (ABS), which can be classified into different tranches as the so-called Collateralized Debt Obligations (CDOs). Tranches of the CDOs constituted the underlying of Credit Default Swap (CDS), the transactions of which was increasingly active before the distress. Credit derivatives were popular before the crisis as they provided relatively high returns. However, once the bubble of the subprime mortgage market collapsed, every financial institution involved in the housing market and the relevant credit derivatives of MBS, ABS, CDO, CDS etc. got hit and eventually collapsed.

Appendix 11 for Chapter 4: Bank Z-Score, Natural Log of (Z-score)[56]

Observation date	Z-score	LN(Z-score)
29/12/1992	19.87	2.989211057
31/12/1993	20.01	2.996232149
31/12/1994	20.79	3.034472102
31/12/1995	20.69	3.029650492
31/12/1996	20.62	3.026261479
31/12/1997	21.06	3.047375507
31/12/1998	21.50	3.067983165
31/12/1999	20.63	3.026940201
31/12/2000	21.90	3.086372475
31/12/2001	22.52	3.114181754
31/12/2002	22.47	3.112069821
31/12/2003	24.29	3.190126495
31/12/2004	24.23	3.187385158
31/12/2005	24.31	3.190908356
31/12/2006	23.32	3.149418561
31/12/2007	19.19	2.954389316
31/12/2008	23.41	3.153077844
31/12/2009	25.36	3.232995669
31/12/2010	25.64	3.244173133
31/12/2011	25.81	3.250820129

[56] Annual, not seasonally adjusted; in our model, we used quarterly data

Appendix 12 for Chapter 4: The Basic Model and the Extended Model

The estimated function is shown as below:

$$RISK_{it} = Lasset_{it} + Interbankloanratio_{it} + Depositratios_{it} + \text{Nonperformingloansratio}_{it} + Equityratio_{it} + Interbankrate_t + c + \varepsilon$$

The preliminary results in terms of this function is shown as below:

$$LLP_{it} = SIZE_{it} + SIZE_{it}^2 + ILA_{it} + DP_{it} + NPLL_{it} + EA_{it} + I_t + c + \varepsilon$$

And the extended model using interaction variables is shown below:

$$Zscore_{it} = \begin{cases} \alpha_1 SIZE_{it} + \alpha_2 IL_{it} + \alpha_3 LD_{it} + \alpha_4 NPLL_{it} + \alpha_5 EA_{it} + \alpha_6 I_t + \alpha_7 GDP_t + \\ \sum_{\mu=1}^{7} \sigma_\mu \, Interaction\_Vari_\mu + c(SIZE \geq \tau) \\ \lambda_1 SIZE_{it} + \lambda_2 IL_{it} + \lambda_2 LD_{it} + \lambda_4 NPLL_{it} + \lambda_5 EA_{it} + \lambda_6 I_t + \lambda_7 GDP_t + \\ \sum_{\mu=1}^{7} \sigma_\mu \, Interaction\_Vari_\mu + c(SIZE < \tau) \end{cases}$$

Where,

Risk is measured by Z-score

SIZE, Lasset is bank size and is the log-transformation of bank total assets.

IL, Interbank asset ratio is defined as the ratio of interbank assets to total bank assets.

LD, Deposit ratio is defined as bank loans to total deposits.

NPLL, Nonperforming loans ratio is defined as the ratio of nonperforming loans to total gross loans.

EA, Equity ratio is defined as total equity to total bank assets.

I, Interbank rate is 3-month interbank rate.

C is a constant.

μ is the number of independent banking variables, and μ =1,…7.

$Interaction\_Vari_\mu$ takes value of one for the period from the 4th quarter of 2007 up to 3rd quarter of 2009 (Subprime mortgage crisis period), and zero otherwise.

i is the number of banks, and i=1,2....1397.

t is time period, t=1,2,...77 (here we set 1992Q4 is base quarter, equal to 1; then 2011Q4 =77).

τ is a threshold variable in terms of bank size.

Appendix 13 for Chapter 5: Bank Characteristics by Liquidity Hoarding Groups

Variable (Mean)	Before Interbank Market Crunch	During Interbank Market Crunch
Panel A: Liquidity Non-Hoarder		
Total Assets (in $ Million)	1405.16	1618.72
Tier1 Capital ratio	0.163	0.151
Loan Growth(% quarter)	2.144	1.764
Liquid Asset / Assets	0.307	0.267
Illquid Asset / Assets	0.679	0.738
Unused Commitments ratio	0.098	0.091
Unrealized Security Loss ratio	0.661	-0.166
Loan Loss Allowance ratio	1.290	1.361
Total Deposit growth(% quarter)	1.197	1.154
Core Deposit growth(% quarter)	0.749	1.089
Net Charge-offs / Assets	0.111	0.353
Panel B: Liquidity Hoarder		
Total Assets (in $ Million)	1814.91	2387.86
Tier1 Capital ratio	0.165	0.168
Loan Growth (% quarter)	1.18	-0.075
Liquid Asset / Assets	0.303	0.357
Illquid Asset / Assets	0.684	0.670
Unused Commitments ratio	0.087	0.077
Unrealized Security Loss ratio	0.832	-0.228
Loan Loss Allowance ratio	1.406	1.535
Total Deposit growth(% quarter)	0.841	0.889
Core Deposit growth(% quarter)	0.457	0.843
Net Charge-offs / Assets	0.164	0.377
Panel C: All Banks		
Total Assets (in $ Million)	1469.47	1808.48
Tier1 Capital ratio	0.163	0.157

Loan Growth(% quarter)	2.012	1.401
Liquid Asset / Assets	0.295	0.289
Illquid Asset / Assets	0.697	0.714
Unused Commitments ratio	0.093	0.089
Unrealized Security Loss ratio	0.698	-0.178
Loan Loss Allowance ratio	1.355	1.407
Total Deposit growth(% quarter)	1.141	1.115
Core Deposit growth(% quarter)	0.699	0.979
Net Charge-offs / Assets	0.124	0.361

Appendix 14 for Chapter 5: Univariate tests of mean and median differences between Net Lenders and Net Borrowers

	Net Borrowers (1)	Net Lenders (2)	p-values (3)
Dependent variables			
Liquid Assets Growth	0.305 (-0.034)	1.341 (0.456)	0.000 *** (0.000) ***
Loan Growth	1.287 (0.694)	2.967 (0.821)	0.691 *** (0.000) ***
Total Interest Expense Rate	1.227 (1.068)	1.128 (0.951)	0.271 *** (0.000) ***
Bank-level covariates			
Net Interbank Loans	-2.794 (-1.699)	6.992 (5.335)	0.000 *** (0.000) ***
Deposit Growth	1.467 (1.266)	1.033 (0.460)	0.000 ** (0.000) **
Total Assets (in $ millions)	1239.9296 (1,238.19)	1132.0511 (1,118.47)	0.000 *** (0.00) ***
Tier1 Capital ratio	0.151 (0.150)	0.160 (0.158)	0.000 ** (0.000) **
Unused Commitments ratio	0.102 (0.010)	0.091 (0.009)	0.000 *** (0.000) ***
Unrealized Security Loss ratio	-0.350 (-0.346)	-0.417 (-0.245)	0.090 *** (0.000) ***
Loan Loss Allowance ratio	1.582 (1.267)	1.471 (1.316)	0.000 *** (0.000) ***
Net Charge-offs / Assets	0.216 (0.062)	0.185 (0.036)	0.000 *** (0.000) ***

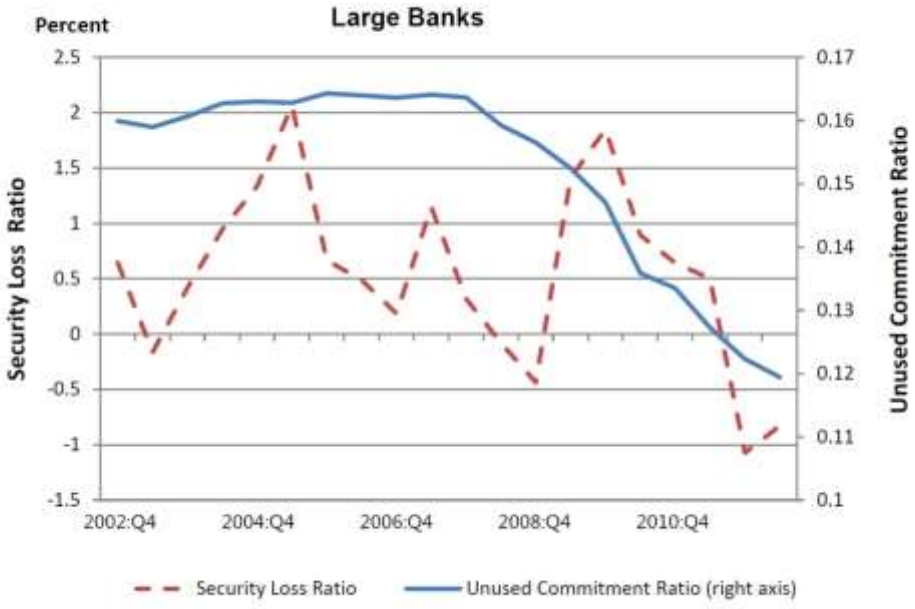
Note: This table reports the mean in the first row and the median in the second row (in brackets) for each variable. Column (1) is for Net Borrowers and column (2) is for Net Lenders. Net Borrowers (Net Lenders) are those with Net Interbank Loans less (greater) than its 30th (70th) percentile value in the previous quarter. In column (3), the first (second) row shows p-values of the significant tests for the mean (median) differences. Upper panel displays results for our dependent variables, and Lower panel for all bank-level covariates. *** and ** indicate the 1% and 5% significance levels respectively.

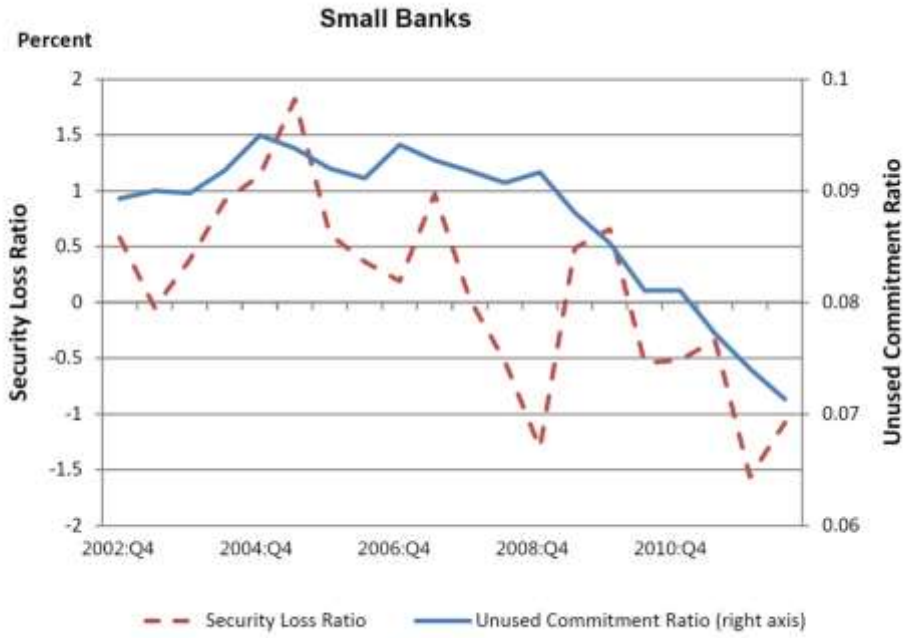
Appendix 15 for Chapter 5: Results of Fixed Effect Regressions by bank sizes

	Large Banks (Size ≥ 5.299027)		Small Banks(Size < 5.299027)	
	∆Liq.Asset)/ Assetst−1 (1)	∆Loans/ Assetst−1 (2)	∆Liq.Asset)/ Assetst−1 (3)	∆Loans/ Assetst−1 (4)
Size	-0.015*** (3.223)	0.003 (0.265)	-0.033*** (3.775)	-0.001** (1.873)
Size*ILC	0.176** (1.889)	0.079*** (2.778)	-0.284*** (3.875)	-0.025* (1.547)
Tier1 Cap ratio	-0.047* (1.322)	0.033 (0.189)	0.012 (0.154)	-0.014*** (2.975)
Tier1 Cap ratio *ILC	-0.493 (1.076)	1.579* (1.539)	-2.911*** (3.087)	1.233*** (2.895)
Core Deposit growth	0.008 (0.872)	0.002 (0.773)	-0.038*** (3.833)	0.005*** (2.767)
Core Deposit growth*ILC	-0.749 (0.632)	0.294 (0.762)	-1.135*** (3.967)	0.559*** (4.237)
Illiquid Asset/Assett−1	0.167*** (2.876)	-0.013* (1.276)	0.254*** (3.785)	0.003 (4.665)
Illiquid Asset/Assett−1*ILC	1.942 (0.843)	-1.220*** (4.653)	-0.588*** (3.764)	1.218*** (3.261)
Unused Commitment ratio	-0.057*** (3.764)	-0.067 (0.534)	-0.132*** (3.896)	-0.031*** (5.312)
Unused Commitment ratio*ILC	0.575 (1.145)	2.787*** (3.126)	1.974*** (4.764)	1.361*** (4.126)
Unrealized Security Loss ratio	-0.006 (0.829)	0.009 (1.546)	-0.016 (1.243)	0.039*** (3.131)
Unrealized Security Loss ratio*ILC	0.709 (1.134)	-0.136 (0.991)	-0.916** (1.793)	0.593*** (5.765)
Loan Loss Allowance ratio	-0.001 (0.996)	-0.001 (1.052)	-0.001 (0.868)	0.0004 (1.558)
Loan Loss Allowance ratio*ILC	0.018 (1.167)	0.021 (1.875)	-0.092** (1.762)	-0.038* (1.302)
Fed rate	-0.004 (0.458)	-0.003* (1.076)	-0.011 (0.552)	-0.725 (0.879)
Fed rate*ILC	-0.002** (2.096)	-0.852** (1.861)	-0.003*** (2.985)	-0.986* (1.526)
TED	-0.0113 (0.811)	-0.004*** (9.181)	-0.0004 (0.175)	-0.001*** (3.674)
TED*ILC	0.127** (1.921)	-0.767** (1.811)	0.013* (1.564)	-0.456*** (4.879)
Intercept	0.062 (0.536)	0.025 (0.281)	0.252*** (3.574)	0.015 (0.368)
Firm Dummies	Yes	Yes	Yes	Yes
Quart. Dummies	Yes	Yes	Yes	Yes
R^2	0.432	0.595	0.564	0.757
Observ.	291291	291291	784630	784630

Standard errors are in parentheses. *, **, *** denotes significance at 10%, 5% and 1% levels. Whole sample is split into in two groups according to a threshold value of log bank total assets (5.299027).

Appendix 16 for Chapter 5: Unused Commitments and Security Losses by Bank Size





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