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FINANCIAL STABILITY OF BANKING SYSTEM IN CHINA

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Abstract

This thesis aims at investigating the financial stability of China's banking system. Since the banking system is one of the most important financial intermediaries in the financial systems, the financial soundness of banks could secure the stability of the whole financial system. Two of the factors that may significantly increase imbalance of the banking system, and hence affect financial stability of an economy is the accumulated non-performing loans of banks and the macro-economic turbulences. This fact raises the questions of how macroeconomic condition, as a determinant of systemic distress, can be assessed more comprehensively and consistently, and what the implications are for modelling it within an integrated credit risk framework. The aim of this thesis is addressing these issues.

We develop a framework for macro stress-testing of China's banking system. Our estimates of the correlations between banks' stability indicators and macroeconomic factors establish significant relationships between the non-performing loan ratio and key macro-economic variables, such as GDP growth, the retail price index, the unemployment rate, total fixed investment, the money supply, interest rates and exchange rates. Further, results from the macro stress tests show that robustness, or otherwise, of the banking system is highly dependent on the source of the potential risk. Our value-at-risk tests suggest that (at a 99% confidence level) the Chinese banking system is robust with respect to interest rate shocks. However, GDP growth and exchange rate shocks exhibit a profound negative effect, indicating that significant losses become likely.

We also examine the determinants of non-performing loan ratio for regional China's banking system, using data from 2002 to 2011 for 31 regions in China. Our estimations suggest that the non-performing loan ratio worsens with decreasing economic growth, shrinking export and property market depression. Further, with the

help of a probit model, we identify the leading indicators of banking distress and estimate the banking distress probability for regional China. Moreover, this study provides an overview of banking system stability in the geographical distribution of these indicators. The findings show there are significant relationships between the regional banking distress indicator and key macroeconomic variables, such as GDP growth, the consumer price index, the unemployment rate, and house price. Based on the findings, we designed an early-warning system to monitor banking stability of regional China.

These results should prove informative for policymakers and regulators alike, regarding awareness of loss-limitation in China's banking system, the banking distress signals and macro-prudential perspectives to monitor the potential risk exposure of the banking system in China's regions.

Key words: financial stability; stress-testing; VAR model; non-performing loan; early warning system.

Declaration

I Bo Jiang, confirm that this work submitted for the degree of PhD in Economic and in area of risk management is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g. ideas, equations, figures, text, and tables) are properly acknowledged. A full list of the references used has been included.

Signed: Bo Jiang

Date: 2014

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Contents

List of Tables

List of Figures

CHAPTER 1

Introduction

1. 1. Background

There is no doubt that macro-economic stability is closely correlated with financial stability. Both economic theory and empirical practice from the financial crises in the last three decades clearly indicate that the volatility of the macro-economy is strongly associated with instability in the financial system. Such instability of financial system, which is always followed by crisis, can affect the economy through decreasing economic growth and increasing unemployment. Financial instability that originates from the outstanding debt of an economy has an adverse influence on the macro-economy through weakening the capabilities of the economy (Bean, 2004). Therefore, financial stability is increasingly proving to be a crucial factor in the health of the macro-economy.

The considerable costs of banking distress are well documented by an International Monetary Fund (IMF) survey of 53 industrial and developing countries in 1998. In this survey, 54 banking crises were documented between 1975 and 1997, which were always accompanied by downturns of macro-economic performance (Table 1.1).

The costs of reviving a failure in the banking sector after a crisis could be as large as half of a country's annual Gross Domestic Product (GDP) (World Bank, 2000). For instance, Laeven and Valencia (2011) use European Union (EU) data to illustrate that the output losses of previous banking crises in 2008 accounted for around 20–25% of GDP. Moreover, credit tightening following a banking crisis would affect the potential recovery of the crisis country. Therefore, the recent global financial crisis, underscored by numerous research initiatives and developments in policy, has highlighted the importance of understanding sources of vulnerability which may bring

about banking distress.

Table 1.1: Costs of Crises in Lost Output Relative to Trend 1975-1997

	Number of crises	Average recovery time(years)	Cumulative loss of output per crisis (%)	Crisis with output losses (%)	Cumulative loss of output per crisis with output loss (%)
Currency crises	158	1.6	4.3	61	7.1
Industrial	42	1.9	3.1	55	5.6
Emerging market	116	1.5	4.8	64	7.6
Currency crashes	55	2.0	7.1	71	10.1
Industrial	13	2.1	5.0	62	8.0
Emerging market	42	1.9	7.9	74	10.7
Banking crises	54	3.1	11.6	82	14.2
Industrial	12	4.1	10.2	67	15.0
Emerging market	42	2.8	12.1	86	14.0
Currency & Banking crises	32	3.2	14.4	78	18.5
Industrial	6	5.8	17.6	100	17.6
Emerging market	26	2.6	13.6	73	18.8

Source: International Monetary Fund, World Economic Outlook: May 1998

The relationship between macro-economic performance and banking stability, however, does not necessarily imply causation, because of the difficulties in identification of the direction of causation. Hence, it is crucial to identify the direction of causation, so that the supervisors and policymakers could adopt and implement the most appropriate public policies to strengthen financial stability.

There is an increasing trend in the economy of pressure to monitor financial stability within banks and other financial institutions along with the highly complex and globalised financial activities, the more sophisticated financial products, and the more comprehensive financial system. Financial crises in the past 30 years have brought a series of issues into the spotlight. Two of them are covered in this thesis – *macro stress-testing* and *early warning system* (EWS) –which fulfill the growing need for preventive risk management policy. The studying of financial stability and bank distress is an important issue. First of all, it would improve supervisors' and regulators' ability to forecast and manage underlying risks, which would enable them to manage,

coordinate and supervise more efficiently. Second, it would enable supervisors to efficiently distinguish between sound and unstable banking systems, and thus take the appropriate actions in a timely fashion in the case of problematic institutions. Third, it might save the fiscal cost of bail-out for a banking sector that may be suffering from adverse shocks. Fourth, the crisis in the banking sector may generate other crises and extend through other sectors, which might cause damage to the economy as a consequence.

While the form of crises may vary over time, the essence of a crisis remains the same, such as the cycle of affluent liquidity, fast credit growth, low-inflation environment, and asset-price bubble. The most recent global financial turmoil started in the mid-2000s while the United States (US) economy fell into an unbalanced macroeconomic position. Increasing defaults of sub-prime mortgage by 2007 resulted in an unstable domestic market, fiscal contagion dispersed all over the world, and global economic recession. Even worse, the recovery has been slow and turbulent, and many countries are still struggling in the aftermath of the crisis. The outbreak of the global financial crisis in 2008 has not only undermined financial institutions, but also brought in criticism to long-held beliefs and theories on risk regulation of the financial system, with renewed emphasis on macro-prudential supervision and reforming micro-prudential regulation.

In the case of China, although the country avoided the impact of the East Asian crisis in 1997 and the Global Financial crisis (GFC) in 2008 and has maintain a steady growth, severe structural problems remain, notably the banking systems' credit exposure of potential downturn of the macro-economy, the increasing concern about the real-estate bubble, and the threat from the shadow banking system. During the East Asian crisis, the non-performing loans (NPLs[1]) of the banking system skyrocketed to unprecedented levels: NPLs accounted for approximately 30% of GDP

[1]NPLs are loans which are classified as being in default or very likely to be in default. Generally, it refers to the loans that are more than three months overdue.

for Korea and Malaysia, and about 60% of GDP for Thailand (IMF, 1998). Heavy dependency on bank-based financial systems together with the high debt-equity ratios of corporations has exacerbated the economic distress in East Asian countries. This is a valuable lesson for China, as the financial system in China is also a bank-centred system and NPLs used to retain it at a high level because of the large share of state-owned enterprises (SOEs). Without in-depth financial reform, it is impossible to realise the goal of sustainable growth in a reasonable time with acceptable fiscal costs. Furthermore, the economies are likely to remain vulnerable to new external and internal shocks. To mitigate this, comprehensive risk management framework, adequate safety nets and appropriate policies are the prerequisites for stable and sustainable growth. It is also necessary for financial reform policies to involve two principal considerations: the first one is to minimise the likelihood of system distress with acceptable fiscal costs; and the second one is to maintain a healthy environment which is able to allocate asset effectively. This again highlights the necessity of enhancing financial stability, particularly for the banking sector, because systemic distress and considerable fiscal cost is usually caused by an unhealthy banking system. On the contrary, a healthy banking system is able to ensure the prudent credit support for businesses and households to maintain the growth of the real economy. For banking sector, due to that credit-related losses are often contributed by borrowers' failure to meet contractual loan obligations are the major risk source with potential to impair stability. Therefore, from a macro-prudential perspective, the modeling and projection of credit risk is a key element in the overall analytical framework used for conducting a forward-looking assessment.

The apparent economic problems in China have become an urgent cause for concern. The fast speed of growth is gradually slowing down, as comparative weaker consumer demand is unable to replace the export of labour-intensive production to become the new engine of growth. Extensive infrastructure projects and fiscal expansion seem no longer the panacea for growth due to the limitation of the

government's resources. Consumer prices have shown a steady decline, particularly in the case of real-estate prices (source: National Bureau of Statistics, China Statistic Yearbook). Meanwhile, the banking industry in China plays an important role in the development of both the economy as a whole and financial system. Since late 1990s, reforms have been carried out by government to create a competitive environment in the banking sector. Thus, increase in competition also result in greater risk-taking behavior of banks to chase profit. The vulnerability of the banking sector, which is mainly contributed to by the poor performance of state-owned enterprises, has grown more evident. In China, the priority is to advance financial reforms to prevent a further buildup of risks, foster a more efficient allocation of investment, and strengthen the management, transparency, and governance framework of local government finances. Key steps include deposit rate liberalization, strengthening regulation and supervision (including of shadow banks), and resolving the moral hazard problem rooted in the perception of widespread implicit guarantees with the introduction of deposit insurance and a formal resolution mechanism for failing institutions.

Based on the above overview, this thesis addresses factors that contribute to the securing of financial stability, particularly the banking system stability, in the economy. A better understanding of the resilience of a banking system to adverse macroeconomic shocks is of crucial importance for the proper evaluation of systemic risk and has a direct connection with the development of regulatory and prudential tools. Although financial stability plays a key role in the economy, there is currently no unique definition for financial stability. Some definitions emphasise the importance of outstanding debt on financial stability, because that outstanding debt would lead to a decrease of accessibility to money (Allen and Wood, 2006). This definition is also supported by Schwartz (1987), who suggests that the expectation on weakening accessibility to money would exacerbate financial crisis further through imposing financial pressure on the economic agents. Another strand of researcher focuses on the

importance of major financial institutions in financial stability. Researchers such as Crockett (1996) and Aspachs *et al.* (2007) argue that financial instability arises from both high probability of defaults (PDs) and low profitability of key financial institutions. Hence, outstanding loan, also known as non-performing loan, is chosen as a proxy to measure the stability of a banking system under economic imbalance. For a bank, which is one of the key financial institutions, the soundness arises from high returns on assets and equity capital and low returns volatility (De Nicolo, 2000). Hence, increase of distance-to-default of the bank would significantly secure financial stability. Thus, in this thesis, the level of financial stability is measured by non-performing loans of borrowers and financial soundness of banks.

1.2. Research Questions

Based on this background, the purpose of this study is to provide an integrated credit risk framework for estimating the determinants and indicators of the banking system's vulnerability in China. Regarding the theoretical precedent, the main research questions are

Q1. What elements of macroeconomic performance contribute to credit risk of the banking sector and how could these elements be integrated into a systematic stability framework?

Q2. In the light of relationship between the banking system's stability and macro-economic performance, does the banking system maintain enough resilience when confronting specific shocks?

Q3. How does an early warning system provide information for both banks and supervisory authorities about potential distress?

To answer the above questions, we develop the framework of an integrated credit risk model for assessing the stability of China's banking system. With the outcomes of this model, we apply the macro stress-testing to capture the robustness of the banking system in a situation of artificial shocks, and design an EWS to explore signals in

advance of shock occurrence. To achieve these research objectives, attention need to be paid to a number of issues from a conceptual perspective. To ensure the comprehensiveness of this framework, key risk factors from a wide range of classes, and from both within or outside the financial system must be involved. The framework should be adjustable so that scenario analysis can be applied. Moreover, the framework should be forward-looking; this is important to carry out stress-testing and the application of an EWS. Hence, when an upcoming shock is identified at an early stage, it would be beneficial for supervisors to take timely actions to prevent the crisis or mitigate the losses.

Generally, this thesis makes several contributions to the literature on the relationship between bank stability of Chinese banking and macro-economic performance and. First, this study includes the latest banking data from 2000 to 2012, which is the period of last round of banking reform in China that introduce the idea to macro-prudential management into risk management of banking system and relates to the recent crisis. Second, this study contributes to the existing literature by using various risk indicators including the non-perform loan ratio and the probability of occurrence of banking distress. Further, with regards to the econometric modeling framework, we use the VAR approach, which measures the feedback effect within macro stress-testing. Finally, the results of this study may provide some information for policymakers and supervisory authorities on how to monitor and deal with the potential reverse shocks, and hence enhance the soundness of the banking system in China. This study fills the gap of empirical study on both macro stress-testing practice and early warning system based on relationship between macro-economic performance and stability of banking system in China.

1.3. Thesis Structure

The rest of the thesis is structured as follows. Chapter 2 presents a literature review of

financial stability, as well as risk management for the banking sector in general, and China's banking system in particular. The methodology of the empirical study is discussed in Chapter 3. The discussion includes several topics such as the rationale of the methods and application of secondary data. Chapter 4 investigates financial stability through analysing the soundness of the banking system in China with macro stress-testing. In this chapter we develop a framework for macro stress-testing of China's banking system. Our estimates of the correlations between banks' stability indicators and macroeconomic factors establish significant relationships between the non-performing loan ratio and key macroeconomic variables, such as GDP growth, the retail price index (RPI), the unemployment rate, total fixed investment, the money supply, interest rates and exchange rates. This chapter also provides the results of a simulation of loan default rates of the banking system in China. We then examine the determinants of the non-performing loan ratio (NPLR) for regional China's banking system in Chapter 5. Further, we use a probit model to identify the leading indicators of banking distress and to estimate the banking distress probability for regional China. Finally, Chapter 6 summarises the thesis.

CHAPTER 2

Literature Review and Background

The author has undertaken an in-depth review of a large body of literatures on financial stability and risk management in the banking sector. Furthermore, significance of stress-testing for banks is discussed in detail in the chapter, and the history and characteristics of China's banking system are provided. The review that follows addresses the following.

• How can the banking sector identify and assess its underlying credit risk based on historical data?

• Is it possible to use stress-testing and the early warning system as standardised approaches based on the Basel Accord, to enhance financial stability?

2.1. Financial Stability

In this thesis I reflect on issues relating to stress-testing of the banking system in China, starting with the definition of 'financial stability'. In order to maintain a concrete basis for resources allocation through time, the most important target for an effective market economy is to ensure both monetary and financial stability. The absence of stability may lead to resource misallocation and may subsequently impede willingness to save and invest. In real terms, an unhealthy financial condition of the economic entities (for example, households and firms) would be likely to cause financial instability, which might even exacerbate the situation to become financial crisis. Bean (2004) in fact argues that the impact of financial instability could spread to the real sector of the economy as well.

For financial regulators like the central banks, the inherent functions of stabilising the price and setting out macro monetary policy offer a natural basis for the internal procedures for making forecasts and intermediate assessments. In other words,

monetary stability indicates a generally stable level of prices, which can be measured by inflation or deflation. In order to achieve a satisfactory inflation level, the central bank should set a clear 'bottom-line' and then design a structural analytic framework for the related factors. Unlike the crystal clear state of the inflation target, things are much more complex when central banks are assigned with the new responsibility of financial stability (see Table 2.1).

Table 2.1: Stress-Testing and Centre Bank

Element	**Price Stability**	**Financial Stability**
General definition	Clear	A range of definitions
Operational definition	Clear (variable and target)	Typically not specified
Scope of centre banks' responsibility	Full responsibility	Partial/shared responsibility
Research	Well developed	Developing

To begin with, what is the generally accepted definition of financial stability? In the first place, classical economics focuses most of its attention on the equilibrium among markets but not on the factor, or factors, which can lead to disequilibrium. For instance, Minsky (1977, 1982) believes that periodic financial turmoil is the extreme case of aberrant behaviour of the market. In the 1990s, due to the integration of financial markets all over the world, an increasing body of literature emerged to explain the phenomenon of financial instability. Crockett (1996) carried out a survey focusing on financial stability. Although he provided a simple definition for financial stability which refers to the smooth-functioning financial system, this survey actually focused on the absence of financial instability as the achievement of financial stability. In this survey, financial instability was defined as when the fluctuations in the price of financial assets undermine the economic performance, or the financial intermediaries fail to meet their contractual obligations. Houben *et al.* (2004) suggested that, due to the fact that the study of financial stability was still in its early stages, there was, as

yet, no widely accepted definition or analytical framework for assessing financial stability. Compared to the inflation target, which is able to select inflation rate or price index as the target variable, it is difficult to find a single target variable for accessing financial stability, particularly when the major issue of financial stability focuses on the banking system. This is because the banking industry is undergoing its integration process of global finance cooperation and has already engaged in increasingly complex and diverse international financial activities. Due to these reasons, the interactions and imbalances between the banking sector and other financial sectors, domestic country and international markets, would all have impacts on financial stability even if the banking sector remains robust. However, monetary stability and financial stability are interdependent; stability in one of them ensures the stability in the other.

The difficulties in identifying financial stability can be reflected in several aspects:

(1) Financial stability is a relatively ambiguous concept at the current time. On one hand, it is partly because it covers the different finance subjects such as financial institutions (bank, security company, and insurance company), and markets (money market and capital market). On the other hand, it is partly because it covers the different participants like government, private participant, and public participant. In addition, there are also other related issues that need to be considered including the legal system and financial regulation. Accordingly, Truman (2003) suggests that the financial system which encompasses both the monetary system and financial activities assessed from a systematic perspective. Owing to the comprehensive relationships that exist between those financial stability components, if any individual part has a problem, it would probably undermine overall financial stability.

(2) Financial stability requires that the financial system is not only able to minimise the probability of financial crises, but is also able to absorb and deal with the shocks in the early stages by itself.

(3) Financial stability implies the absence of contagion and the high likelihood of systemic effects. In other words, a single disturbance at individual financial institutions would not be possible against a backdrop of overall financial stability.

(4) Financial stability does not require that every single part of the financial system operates at peak performance all the time. This is because uncertainty is a natural characteristic of financial activities and the financial system encompasses many interlinked components such as infrastructure, institutions, and markets. Thus it is reasonable that the financial system operates stably at one point in time and might be less stable at some other time.

2.1.1. Definition of financial stability

As we discussed above, defining the price stability is a comparatively easy task in that the concept maintains a set of target variables for measurement. In contrast, there is no existing set of target variables for accessing the financial stability. Accordingly, we can only identify the absence of financial instability as financial stability. This point was first supported by Davis (2001) in an internet discussion. According to his proposal, financial stability is the absence of an adverse impact on the real economy. Nevertheless, there are several aspects of this definition that merit comment. Given that financial instability is the *ex ante* risk for potential disruption, it is not the same as crisis which has already led to actual damage. Early literature usually regards the cyclical excess as the reason for financial instability (Kindleberger, 1978). Economists and scholars believe that the rises in financial assets prices encourage speculators to finance additional purchases on margin, because of the motivation of greed. Hence, when these assets are significantly overvalued, the prices may suddenly drop which results in damage to the financial system. At the same time, Schwartz (1987) observed the phenomenon of financial instability from the viewpoint monetary policy and argued that a mistake in monetary policy generates financial distress, particularly disruption of money supply. Both of these viewpoints can explain the instability to a

certain extent. However, these opinions either are challenged by micro-economic behaviour theory, or they overlook the nonmonetary causes. Afterwards, the development of game theory introduced a new perspective for explaining the kind of agent behaviour that would produce instability in a financial system (Greenwald and Stiglitz, 1992). In recent years, there are two main strands to the definition of financial stability. Some researchers define financial stability in terms of robustness of the financial system to external shocks (Allen and Wood, 2006; Padoa-Schioppa, 2003), while others define financial stability in terms of the vulnerability of financial system to shocks originating within the financial system (Borio and Drehman, 2009; Schinasi, 2005).

2.1.2. Determinants of financial system stability

The study of financial fragility can be traced back to 1933 when Fisher first suggested that macroeconomic fundamentals, particularly debt liquidation, have a close relationship with financial fragility. When indebtedness of an economic entity goes beyond the equilibrium position, the attempt to liquidate debt would trigger increases in bankruptcies and unemployment and decreases in output and market confidence.

From the perspective of a theoretical study, business cycle models offer a good background for modelling NPL because these models emphasise the counter-cyclicality of credit risk (Williamson, 1987). Later, the financial accelerator theory became the most prominent theoretical framework for thinking about linkages between macro-economic performance and financial system (Bernanke and Gilchrist, 1999). These theories explain the cyclical nature of bank credit, NPL, and loan loss provisions. In the period of upturns, NPL ratios tend to be low. Meanwhile, optimism about the macro-economic outlook may persuade banks to loosen their lending standards, thus leading to a strong credit growth. These actions would sow the seeds of borrowers' and lenders' financial distress along with the profit growth. However, in the period of downturns, the over-expanding of credit would lead to rocketing NPL

ratios, coupled with the decline in the value of collaterals. Consequently, this leads to a tightening of credit extension, with adverse impacts on domestic demand.

These theories, however, are not in the position to provide a comprehensive understanding of the determinants of NPL, which are actually both institutional and macro-economic. The institutional indicators are linked to financial regulation and supervision. The differences of financial regulation and supervision among countries, which have direct impact on banks' behaviour and risk management practices, are better at explaining cross-country differences in NPL. The macro-economic performance affects banks' balance sheets and their debt-servicing capacity. The set of macroeconomic variables used varies across previous studies, but there are some broad macroeconomic indicators, like GDP growth, unemployment, and inflation that are generally included in the majority of the literature as the determinants of NPL.

The structure of the financial system is also recognised as a major factor of financial stability by a series of studies (Allen and Gale, 2004; Ibrahim, 2006). According to Ruiz-Porras (2009), a financial system could be a market-based system (financial markets play a key role in the financial system) or a bank-based system (the bank sector is the centre of the payment system). Ruiz-Porras (2009) uses the fixed-effect panel data to examine the relationship between financial structure and financial instability, and the financial determinant of financial instability. His findings suggest that the market-based financial system is more likely to improve financial stability. The first study about the relationship between financial structure and financial stability was carried out by Allen in 2001. Based on a theory of crisis, Allen (2001) describes the effects of the structure of the financial system, which might cause financial instability, and provides several possible solutions for preventing instability. Levine (2002) designs a ratio of the stock market activity (or size) to banking system loans to distinguish a market-based financial system from a bank-based financial system. Therefore, for this thesis, we choose stability of the banking sector to measure the financial system stability in that China's financial system is obviously a bank-

oriented one with an immature financial market. The banking sector is the centre of the whole financial system, not only in China, but also in other developing countries. Consequently, the indicators, which are able to imply the condition of bank's asset quality and solvency capability, are important to assess the stability of a financial system (De Nicolo, 2000; Uhde and Heimeshoff, 2009). Among these studies, Z-score is widely used to measure the financial soundness of banks; thus financial stability is defined as the distance-to-default for banks (e.g. Aspachs *et al*., 2007; Goodhart *et al*., 2006). Following this idea, improvement of profitability and asset quality could reinforce the soundness of a financial system. Moreover, Luintel *et al*. (2008) argue that the structure of the financial system could even have an influence on the macro economy.

Financial structure has also been an important aspect related to the study of economic performance. Luintel *et al*. (2008) used data of 14 developing countries over the period of 1978 to 2005 and, with country-by-country time-series analysis, revealed that financial structure significantly explains output levels in most countries. Beck and Levine (2004) also argued that stock market and bank development have a significant effect on economic growth.

The introduction of the VAR approach into empirical literature, when exploring the linkages between NPL and macroeconomic performance, has highlighted the feedback effect. In the study of the cyclical behaviour of default rates in Italian banks, the result suggests that default rates decrease during macroeconomic upturns and increase during macroeconomic downturns (Marcucci and Quagliariello, 2008). Marcucci and Quagliariello (2008) also point out that there is a feedback effect from the banking sector to the macro-economy through the bank capital channel.

2.1.3. Macro-prudential perspective

For policymakers, the financial crisis in 2008 has raised the requirements to expand the regulation boundary from a purely micro-based approach to macro-prudential

policy tools which enable the regulators and supervisors monitor the supply of credit more directly (Turner, 2010). According to the Deputy General Manager of the BIS, Herve Hannoun (2010), adding a macro-prudential approach can enhance the stability of a financial system both over time and at each time point. The origin of the idea of macro-prudential policy can be traced back to the mid-1980s, when Cross *et al*. (1986) firstly proposed that the macro-prudential perspective denotes a systemic or system-wide orientation of regulatory and supervisory frameworks and their link to the macro economy. However, the more precise definition did not emerge until the beginning of the twenty first century in order to derive specific implications for the architecture of prudential arrangements (Borio, 2009). Since then, the usage of the idea of macro-prudential perspective has gradually become more popular in the discourse on financial regulation. Subsequently, the term has gained further ground because of the financial crisis (BIS, 2008). As a consequence, the past two decades has seen an obvious increase in research on macro-prudential policy. Literally speaking, macro-prudential policy is the policy aiming at financial stability. However, given that there is no commonly shared definition of financial stability within the literature, in terms of the specific goals of macro-prudential policy, the Bank of England (2009) stated that the general view of macro-prudential policy aims at ensuring provision of financial intermediation services such as credit intermediation, payment services and insurance, thus preventing the volatile fluctuation of the credit and liquidity supply. In addition, Landau (2009) stated that macro-prudential policy should target avoiding bubbles and imbalances in general. In 2010, BIS provided a summative report about the evolution of themacro-prudential perspective, stating that this term has two distinguishing features (Clement, 2010). First, it focuses on the financial system as a whole, so as to control the macroeconomic costs brought by financial distress. Secondly, in contrast with an individual financial institution which treats aggregate risk as independent of their decisions, macro-prudential perspective treats aggregate risk as dependent on the collective behaviour of financial institutions (Clement, 2010).

As the result of growing consensus on the macro-prudential approach, the importance of monitoring and measuring financial stability has been recognised. Consequently, financial regulation authorities among countries have made considerable efforts to develop macro-prudential tools, including early warning indicators and macro stress tests (Borio and Drehmann, 2009).

2.2. Risk Management in the Banking Sector

Although the history of bank can be traced back to the fourteenth century in Italy and the concept of credit can be traced even further back to 5,000 years, the history of risk management for banks is much shorter. Harrington and Neihaus (2003) demonstrated that modern risk management began in 1955, and has since undergone considerable evolution including the introduction of self-insurance instruments, and the use of derivatives and statistical tools to manage bank risk (Dionne, 2013). (See Appendix B.1 for the evolution of the risk management.)

The studies on bankruptcy prediction emerged during the 1930s when Fitzpatrick (1932) first attempted to use comparative analysis to explore the signs of financial failure. Ratchford (1941), who followed Fisher's (1936) method, introduced the idea of discrimination to identify the quality of loans. However, due to the limitation of statistical methods at that time, this research cannot be used for predictive purposes without the help of financial ratio. Afterwards, univariate and multivariate discriminant models were applied to find the financial ratios which could be used for bankruptcy prediction (e.g. Altman, 1968; Beaver, 1966). These studies provided a solid base for future research in this field, while the multivariate discriminant model became one the most popular methods. In addition, Altman (1968) developed the Z-score model with five financial ratios, which could classify companies into three groups - healthy, bankrupted and other company. Altman kept improving the Z-score model and expanding it to different kinds of firms like larger companies, non-listed companies and non-manufacturing companies (Altman, 1977, 1993). As consequence,

in the 1970s, a series of research studies on bankruptcy prediction applied and developed the discriminant model (e.g. Deakin, 1972; Edmister, 1972; Libby, 1975; Wilcox, 1971).

The discriminant method, however, attracted criticism because of some assumptions it made, such as normal distribution of macro-economic data and financial ratio (Dimitras *et al.*, 1999; Joy and Tollefson, 1975; Ohlson, 1980). Therefore, the logit regression method was introduced to overcome some of the disadvantages of the discriminant method, thus providing higher prediction accuracy (Santomero and Vinso, 1977). Santomero and Vinso (1977) applied logit regression method to predict banking failure in the US. Some following studies expanded the application of the logit regression method to other sectors and introduced probit regression into the prediction of bankruptcy (Ohlson, 1980; Zmijewski, 1984).

The logit method, though, is still not a flawless methodology, suffering problematic assumptions which could not always hold in reality. Hence, a series of methods for bankruptcy prediction have been developed such as classification trees (Breiman *et al.*, 1983), neural networks (Zhang *et al.*, 1999), hazard models (Hillegeist *et al.*, 2004), and generalised additive models (Berg, 2007).

Over the past decade, the ongoing financial crisis has driven commercial banks and bank regulators to devote many resources to developing risk management in general and credit risk analysis in particular for the purpose of better quantifying the underlying risks. Within this trend, credit risk is the major source of risk for banks and regulators (BIS, 2001). In 1997, the Basel Accord formally published market risk models for regulatory capital calculations with the value-at-risk (VaR) method, which is defined as the maximum loss over a target horizon such that there is a low, pre-specified probability that the actual loss will be higher (Jorion, 2009). Besides, other organisations and financial institutions have also released some credit risk models, like J.P. Morgan (1998) and Credit Suisse Financial Products (1997). Credit risk refers to the degree of value fluctuation in debt and derivatives which was caused by

changes in the underlying credit quality. Compared with the VaR method which is able to generate about 250 forecasts (daily) per year for market risk, the credit risk method can only generate one forecast (yearly) or four forecasts (quarterly) per year because of longer horizons. Moreover, the limited historical data about credit loss also affects the validation of credit risk models. The demand of more comprehensive risk management technique encourages the invention of the stress-testing approach.

The common purpose of these risk management models is predicting the probability distribution function of losses, which is usually generated from a bank's portfolio. Therefore, the idea of an early warning system (EWS) arises as an important complementary technique for risk management. Identification of the main factors connected with banks' failure is the prerequisite for EWS and a series of studies contributed to this issue (e.g. Graham and Horner, 1988; Martin, 1977; Thomson, 1991). According to previous studies, several factors are found to contribute significantly to bank distress like managerial inefficiency (Barr *et al.*, 1993; DeYoung, 2003; Pantalone and Platt, 1987), and capital adequacy (Myers, 1977; Oshinsky and Olin, 2006; Santos, 2001). Insufficient capital adequacy may encourage the pursuit of high-return and high-risk portfolios, thus leading to moral hazard. According to the study of Torna (2010), there are five banking activities that have contributed to banking distress during the recent global financial crisis; these are investment banking, insurance, venture capital investments, securitisation and derivatives trading. The importance of the asset portfolio of banks and the quality of assets in risk management is also highlighted by studies, because real-estate construction is usually the major potential shock source during recent crises (Barrell *et al.*, 2010; Cole and White, 2012). Moreover, the provisions taken against losses and non-performing loans are playing an important role in risk management (Barth and Landsman, 2010; Betz *et al.*, 2014; Jin *et al.*, 2011; Ng and Roychowdhury, 2012). Along the same lines lie the studies of Arena (2008) and Jin *et al.* (2011), who suggest that the credit expansion in the period before the crisis may contain predictive information. In such a period,

banks may be more willing to allocate assets to risky assets (Wagner, 2007). A number of researchers have investigated the structure of banking systems, and find that the likelihood of failure is lower in concentrated banking systems (Cipollini and Fiordelisi, 2009; Matutes and Vives, 2000; Uhde and Heimeshoff, 2009). These studies explain that the incentive of concentrated banking systems to pursue excessive risks is weak, due to their high profits and robust capital reserves. However, some researchers argue that a concentrated banking system might increase bank fragility, because of higher interest margins and higher levels of default among borrowers (e.g. Boyd *et al.*, 2007; Schaeck *et al.*, 2009). Another direction of studies taken by Gonzalez-Hermosillo (1999), Porath (2006), Daley *et al.* (2008), De Graeve *et al.* (2008), and Aubuchon and Wheelock (2010), who focus on the relevance of macroeconomic performance, including GDP growth, inflation, money growth and interest rates, finds that macroeconomic indicators could significantly improve the predictive ability of the models used.

2.3. Regulations for the Banking Sector

It is commonly believed that a healthy banking system needs to operate under comprehensive supervision and regulation which entails complying with the rules. While the global liberalisation of the financial markets brings in many new opportunities, it also comes with a series of new risks and challenges for banks. Consequently, these new risks require new regulation methods and even new regulators to guarantee that the bank system functions well. Learning from the supervision practice in the past twenty years, the trend of liberalisation has forced the implementation of a prudential supervision perspective. In this way, the regulator should not only examine the activities of banks, but also be aware of the external financial conditions and other financial institutions with a close relationship with the bank sector.

Not surprisingly, like the disease promoting the progress of medical science, the economic crises between the 1970s and the 1980s pushed the central bank governors of the G-10 countries to take proactive measures to safeguard the banking sector from economic crisis. The Basel Committee on Banking Supervision (BCBS) which provides a platform for regular cooperation on banking supervisory matters was established at the end of 1974 by the central banks of the G-10 nations. It is widely believed that the BCBS was created to develop common guidelines about supervisory standards, thus promoting the quality of banking supervision worldwide (Singer, 2007; Tarullo, 2008). The Committee's members come from Argentina, Australia, Belgium, Brazil, Canada, China, France, Germany, Hong Kong SAR, India, Indonesia, Italy, Japan, Korea, Luxemburg, Mexico, the Netherlands, Russia, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The aim of the Committee is monitoring and driving the progress of the evolution of key supervisory issues, and strengthening the quality of banking supervision worldwide. Information exchange among members about supervisory issues, approaches, and techniques is beneficial to promote common understanding of the Committee's objectives. Therefore, this common understanding could be used to provide guidelines and supervisory standards in areas where they are considered desirable. In this regard, there are three major common understandings which are widely accepted and applied by the member countries; these are the International Standards on Capital Adequacy, the Core Principles for Effective Banking Supervision, and the Concordat on cross-border banking supervision (BIS, 2013).

In 1988, the Committee came out with its first capital measurement system which is also commonly known as the Basel Capital Accord I. Inspired by the bank failures (saving and loan crisis) during the 1980s, Basel I originally focused on credit risk, and set guidelines on capital adequacy. Afterwards, the Committee supplemented the Accord with requirements for exposures to market risk. There were two major objectives of Basel I, which were to strengthen the financial stability and to ensure a

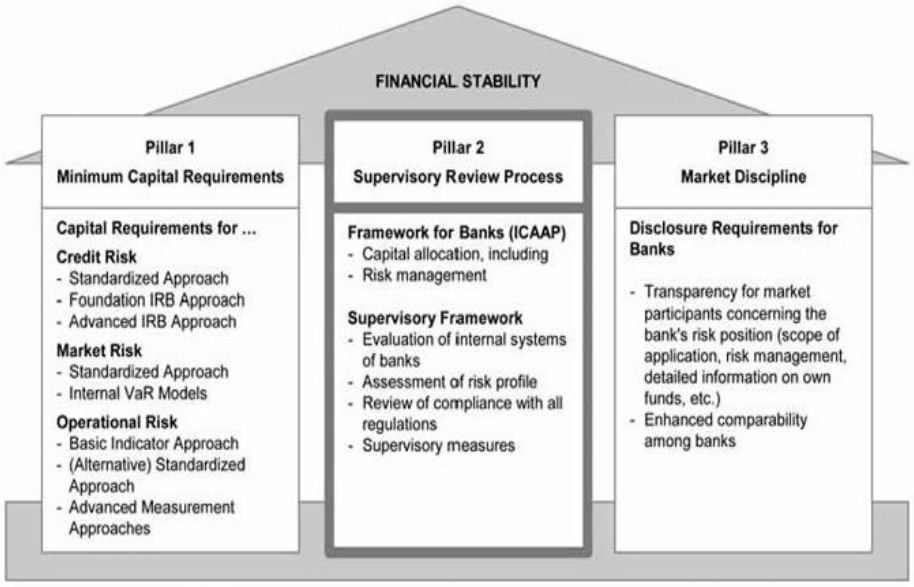
high degree of consistency among international banks (BCBS, 1988). The most important regulatory requirement in Basel I is a minimum capital level of 8% of risk-weighted assets spent on loans using the single matrix system for international active banks (Jackson *et al.,* 1999). In real terms, the bank should set aside eight million in reserves, when it provides a one-hundred-million loan to an entity. Otherwise, Basel I defines capital based on two tiers—Tier 1 (core capital) and Tier 2 (supplementary capital) (BCBS, 2001). However, Basel I has drawn criticism as it is narrow in its scope to ensure adequate financial stability to some extent, because it only covers credit risk and only targets G-10 countries (Balin, 2008). Moreover, Balin (2008) also pointed out that Basel I may have misaligned incentives to banks, as the absoluteness of the risk weightings of this Accord might not be suitable for all banks.

Due to these criticisms and the increasing concerns of vulnerability of financial systems brought by economic integration and globalisation, the Basel Committee issued a new Capital Adequacy Framework in 1999, which is also known as the Basel Accord II. The Basel II agreement introduced a set of measures and standards for capital adequacy which banking regulators of the member countries are now working with to improve their risk management and regulatory capital requirements. Additionally, the Basel II promotes the forward-looking approach in implementation of capital regulation which focuses on identification of potential risks and enhancing the capacity to deal with these risks in advance. The aims of Basel II are to improve the stability of the banking system based on three pillars as follow (BCBS, 2004, see Figure 2.1):

- Pillar 1: minimum capital requirements -where the Basel Accord I just monitors some of the risks in a simple way, the Basel accord II take all three major risks - credit risk, market risk and operational risk - into account for setting the capital requirements;
- Pillar 2: supervisory review - provides a framework and a set of tools to deal with the potential risks; and

- Pillar 3: market discipline - improves the quality of information disclosures of banks which helps the market and the stakeholders to get a more comprehensive knowledge of the overall risk position of the bank.

Figure 2.1: Three Pillars of Basel Accord II



Since the global financial crisis spread in 2008, however, some criticisms were raised against Basel Accord II, because the capital adequacy regime had led to an insufficient level of quality capital of major international banks and amplified the global credit cycle (Brunnermeier *et al*., 2009). Given the weaknesses of Basel Accord II which surfaced during the crisis, which are related with the bank's internal credit risk model and pro-cyclicality, the enhancement based on the Basel II framework is referred to as Basel III. The Basel Committee enhanced the previous Accords by introducing a more comprehensive set of reform measures to improve the regulation, supervision and risk management of the banking sector. The key objectives of Basel III are to

1. help the banking sector to strengthen its capacity to absorb losses brought by financial and economic shocks;
2. improve the quality of risk management; and

3. further reinforce transparency and disclosures of bank information.

On one hand, the reform targets bank-level (or micro-prudential) regulation. It aims at helping individual banking institutions to reduce their vulnerability when shocks take place. On the other hand, the reform also focuses on system-level, or macro-prudential regulation, which emphasises systematic risks that can accumulate within the banking sector as well as the pro-cyclical amplification of these risks over time.

2.4. China's Banking System

In the last three decades, China has maintained a surprisingly speedy and stable growth which also indicates the sustained development of the banking system. Along with China's comprehensive economic reform from 1978, which aims to transfer the planned economy into a market economy, the substantial progress of banking reforms have been the centre of overall effort, including independence of monetary policy for the centre bank, the autonomy of state-owned banks, the open market for the foreign banks, and bank regulation. Accordingly, a closer examination of the financial stability of the banking system in China is valuable for a number of reasons. First of all, the banking sector is the major financial intermediary in China because the bond markets and equity markets are not yet well developed. Secondly, China's banking sector successfully avoided the Asian financial crises in 1997 and the global sub-prime crisis in 2008 and its economic growth continued. Thirdly, the banking sector as the fiscal agents following the credit plan is suffering from large non-performing loans (NPLs). In addition, the legacy of banks being managed by government agencies, which has created inefficiency and weak risk management, is a formidable challenge for banks.

2.4.1. Banking reform in China

In this section, we review the main issues of reform of China's banking system so as to better understand the characteristics of the system in China.

a) Mono-banking System (1948-1984). The current banking system in China can be traced back to 1948 when the establishment of the People's Bank of China (PBC) set the foundation for China's banking system. At that time, the PBC was the only bank in the finance market which was responsible for providing all kinds of financial services as a state-owned and controlled bank under the Treasury Department, controlling about 93% of the total financial assets of the country. However, as there was no real sense of commercial banking market, the major functions of the PBC were accounting and cashier and the only client was the government. Under the highly centralised planning economy system, the bank played a supplementary role in assisting the Treasury to allocate funding.

b) Two-tiered banking system (1984-1994). Since 1978, China started the transformation from a planning economy to a market economy and the reform of the banking sector became the most important component of the transformation. The mono-bank system was not able to fulfill the growing requirements of financial service when the growth of the economy was on the fast track. In 1979, the general designer of China's 'Reform and Open', Xiaoping Deng, directly proposed that the existing banking system should be transformed into a real modern banking system. To fulfill the requirements of reform and opening-up, the first and the foremost important step was the establishment in 1979 of three specialised state-owned commercial banks - the Bank of China (BOC), the China Construction Bank (CCB), and the Agriculture Bank of China (ABC) - whose obligations can be easily distinguished by their names. The Bank of China specialises in transactions related to foreign trade and investment; the Construction Bank of China focuses on the fixed investment (in manufacturing) appropriation; and the primary business of the Agriculture Bank of China is agriculture loans. However, with a vague central bank system, the PBC exercised the dual functions of centre bank function and specialised commercial bank function simultaneously. In other words, the PBC was competing with other specialised commercial banks as an athlete, while it was also playing the role of referee.

Obviously, this kind of central bank system easily leads to the non-objective supervision. This situation was not improved until 17 September 1983, when the State Council issued 'the Decision of People Bank of China specializing in the central bank function'. Meanwhile, the Industrial and Commercial Bank of China (ICBC) which was separate from the PBC has carried on with the industrial and commercial loans and the saving business. Thus, the PBC was free to serve as a central bank and the two-tiered banking system was finally entrenched. During the initial stage, the reform focused on changing the mono-bank structure and encouraging those four commercial banks to become more active in the economic development process. In this way, these four specialised state-owned banks broke up the mono-bank system and took over the PBC to provide the finance service, mainly to the state-owned enterprises. At that time, there was a strict division of business for these four banks - for example, the ABC provided more than 95% of agriculture loans in 1985 (Qin and Ou, 2011) - but these four state-owned commercial banks were still part of an administrative hierarchy with limited autonomy of management, because the operations of the banks still followed the central economic plan and serviced specific economic sectors. During this period, the way in which capital was allocated did not undergo fundamental change. This is due to the fact that China's economic reform started from the micro-level; thus the government still retained the catching-up strategy inherited from the planning economy stage at the start of the process of change Since 1985, the allocation of the national income leaned to the private sector, which has resulted in the fact that because the fiscal revenue of central government has seen a decreasing share of national income, it had been increasingly difficult to meet the investment requirement of the state sector. Zhang (1998) suggested that the central government raises the money supply through the over-lending from the banking system to satisfy the investment requirement. Furthermore, the government controls the social deposit by controlling the SOBCs to make profit. However, because there was a limit to the monetisation, the PBC had to apply the quota management for the credit funding not

only on commercial banks, but also on regions. Against this background, the SOCBs, operating both policy business and commercial business, focused on extending credit scales and branch networks, but ignored the importance of risk management. When the benefit from the fast expansion of credit scale shrinks and the obvious inflation pressure expands, the SOBCs have to take on increasing costs and non-performing loans. Considering this situation, the authorities pushed banking reform to the next stage.

In order to give more autonomy to those specialised banks, three policy banks - the State Development Bank of China (SDBC), the Agricultural Development Bank of China (ADBC), and the Export-Import Bank of China (EIBC) - were established to take over the policy business related to lending in underdeveloped areas, export and import, and rural areas in 1994; thus the four SOBCs were able to expand their scope of business. It also was the burgeoning period for the joint-equity commercial banks (JCBs) and city commercial banks, which are smaller JCBs and have restricted geographical operations. Meanwhile, the commercial banks have shown impressive improvements in several aspects such as asset/liability management committees, credit committees, information system, and staff training. However, compared to the JCBs, the SOBCs had tremendous advantages in negotiating with the PBC on the credit quota and refinance issues. Besides, because of the lack of capital and branch network of the three policy banks, the policy banks cannot take over all the policy-based lending from the SOBCs. Hence, the SOBCs had to carry on with policy-based lending because of the pressure from the government Overall, the banking system of China was dominated by PBC and four SOBCs until the mid- 1990s (Wong, 2001). Wong (2001) also pointed out that the concentration ratio of total asset, total loan, and total deposit of the four SOBCs was 84%、84%, and 88%, respectively, in 1998.

Along with the progress of ‘Reform and Open’, there were three forces pushing the banking sector to change significantly by decreasing the degree of monopoly. The

first one was that the divisions of business between the big four specialised banks were blurred, which allowed these banks to become commercial banks. The second one is that the barriers of entry for banking sector were broken down; thus the up-coming commercial banks and financial institutions pushed the competition forward. The third one is that the SOCBs began to develop their risk management strategies and management of assets and liability ratio under the PBC's rules. Consequently, a united and ordered commercial banking market was established, accompanied by the rapid expansion of scale of money and the degree of monetisation. After this round of reforms, the amount of loans of commercial banks became based on their savings, so that some of the market share of the SOCBs was taken by the JCBs and other financial institutions. In addition, the SOCBs maintain more motivation for pursuing profit. Even though the SOCBs cannot completely abandon the policy business, the increasing share of commercial business has led to them holding some functions of a modern commercial bank. This means that the SOCBs should allocate their funding based on the perspectives of risk management and profitability. Therefore, the motivation of blind expansion of credit scale drops. At the same time, the SOCBs, as the legal person, improved their capacity in funding allocation among their branches, which means that the funds are more likely to flow into the more developed regions.

c) The modern banking system (1995- now). The year 1995 is known as the milestone moment for financial lawmaking in China. In this year, the enactment of Central Bank Law and Commercial Bank Law represented the first step in establishing a competitive, modern banking system. The Central Bank Law officially announced that the PBC was transformed from a mono-bank which provided all sorts of financial service to the central bank of the country with the responsibilities of making monetary policy, supervising the financial system and regulating the payments system. Despite this, the banking system is still under the control of the government to a great extent. This control was mainly over the ownership of banks and non-bank financial institutions by the PBC, the State Planning Commission, and the provincial and

municipal governments. Meanwhile, the Commercial Bank Law reclassified the big four state-owned banks as commercial banks, while provided the new supervision rules for commercial banks. Although, there were three policy banks which respond to the finance need of policy lending, the commercial banks had to continue their policy lending to support the state-owned enterprises (SOE) and infrastructure. This meant that the government still had a great impact on the operations of banks. According to Cho (1998), in this stage, the big four state-owned banks (ICBC, CCB, BOC, and ABC) dominated the Chinese banking sector, together accounting for more than 70%of the total banking system assets and more than 30%of the financial system assets.

Afterwards, since the competitive commercial bank market was settled, the institutional reform, as the initial step of banking reform, drew to a close and the reform moved its attention to bank restructuring, through the cleaning up of NPLs and recapitalisation. The bank restructuring, which began in the late 1990s, became the second important step of banking reform since poor asset quality and low capitalisation have been the pressing obstacles for the development of the banking industry and financial stability. The SOCBs were the major targets of the bank restructuring activities, since the policy lending for development had generated a large amount of non-performing loan. In 1997, the Asian financial crisis erupted. Even though China's banking industry had not suffered much from this turmoil, the lesson from this crisis accelerated the progress of banking reform of China in order to enhance its financial stability.

Generally, the restructuring consisted of four major steps:

a) Financial restructuring. The PBC injected the funding into banking sector, and then Centre Huijin Investments cancelled after verification of the equity capital of the Treasury Department and transferred some of the assets to Asset Management Companies (AMCs);
b) Shareholding system reform. Under the assistance of Centre Huijin

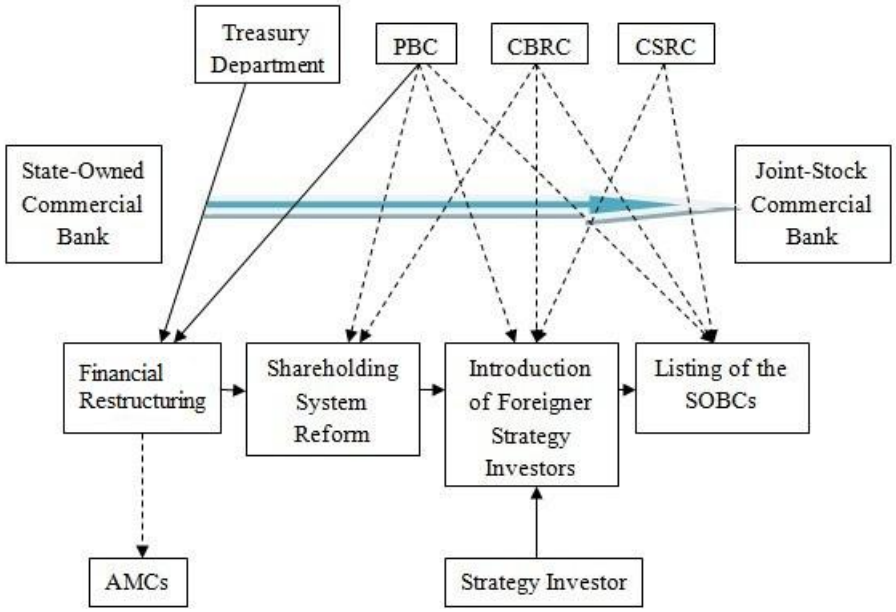
Investments, the SOBCs were transformed into joint-stock banks (JSBs);

c) Introduction of foreigner strategy investors;

d) Listing of the SOBCs.

Through these four steps, four organisations were involved - the Treasury Department, the People's Bank of China, the China Banking Regulatory Commission, and the China Securities Regulatory Commission (see Figure 2.2).

Figure 2.2: Banking Restructuring Process



Three rounds of restructuring can be clearly identified from the figure above. The restructuring started in 1998 when the government injected a tremendous amount of 270 billion (RMB) in the form of special national debt into the four SOCBs to reinforce the capital adequate rate (CAR) of SOCBs to above 4% in accordance with the rule of CAR set by the PBC (source: Almanac of China's Finance and Banking). This action provided sufficient liquidity for the SOCBs to satisfy the regulation requirements. Although the CAR increased to a satisfying level after the capital injection, this is not a radical treatment for the inherited problem of credit practice. It is because that capital injection is the temporary expedient which may lead to the

misallocation of resources. Moreover, the one-time capital injection cannot substantially improve the asset quality of these SOBCs. To avoid this potential problem, a comprehensive operation followed in 1999, when the assets of RMB 1.4 trillion (including non-performing loan of RMB 980 billion) were transferred from the four SOCBs to four corresponding Asset Management Companies (AMCs) - Cinda Asset Management Corporation, Great Wall Asset Management Corporation, Orient Asset Management Corporation, and Huarong Asset Management Corporation - by the authorities to rehabilitate the quality of the banks' assets (see Table 2.2).

Table 2.2: Asset Management Company

AMC	Cinda	Huarong	Greatwall	Orient	Total
Time of establishment	April, 1999	October, 1999	October, 1999	October, 1999	
Related SOCBs	CCB	ICBC	ABC	BOC	
NPLs stripping	3,730	4,077	3,458	2,674	13,939
Capital	100	100	100	100	400
Central Bank Lending	0	947	3,450	1,074	5,479
Financial Bonds	3,730	3,130	0	1,600	8,460

Unit: RMB 1,000 million;
Source:The People's Bank of China.

The second move started in 2003 with another capital injection into the CCB and the BOC when these two SOBCs were selected as the pilot banks for initial public offering (IPO). Along with the non-performing loan strip, the government authority, Central Huijin Investment, used foreign exchange reserve of USD 45 billion as further injection to improve the asset quality of the CCB and BOC. At the same time, these two banks issued subordinated debt to enhance their Tier II capital. Due to all these efforts, the NPL ratios of the CCB and BOC had fallen to 5.69% and 3.75%, respectively, while the CAR rose to 8% and 11.24% at the end of 2004, which was approaching the average level of the same financial indicators of foreign commercial banks. In the following year, the CCB signed the agreements about strategy

investment and corporation with the Bank of American and Temasek Holding, successively. In the same year, the BOC invited the Royal Bank of Scotland, Temasek Holding and the United Bank of Switzerland to become its strategic investors. The introduction of strategic investors diversifies the ownership structure and improves management quality. Finally, the CCB listed part of its shares in Hong Kong in 2005 and listed in the Shanghai stock market in 2007. Meanwhile, the BOC listed in both Hong Kong and Shanghai stock markets in 2006.

After the successful restructuring of the CCB and the BOC, the third round moved on to the IPO process of the ICBC and the ABC, with the injections of USD15 billion into the ICBC in 2005 and USD19 billion into the ABC. Because the ICBC was the biggest SOBC with the highest amount of non-performing loan, USD15 billion is not enough to cover the write-off. To redress this situation, on the one side, the Central Huijin Investment replenished the capital fund with the amount of RMB 124 billion. On the other hand, the second time of stripping of NPL was operated by AMC. Following the cases of the BOC and the CCB, the ICBC invited the Goldman Sachs Group as the major strategy investor via several rounds of tough negotiation. The Goldman Sachs Group's acquisition of an 8.89% stake of the ICBC (amounting to USD 37.8 billion) was the biggest single investment from foreign investors. Finally, the ICBC listed in both Hong Kong and Shanghai stock markets in 2006. The restructuring was proved successful by the significant promotion of CAR, NPL ratio, and provision coverage ratio of these three banks, which fulfilled the requirements of the CSRC for the listed company. By June 2008，the CARs of ICBC, BOC, and CCB were 12.46%, 13.7%, and 12. 06%, respectively，while the NPL ratios were 2.41%, 2.58%, and 2.21% respectively (Almanac of China's Finance and Banking). Unlike these three SOCBs, the ABC did not introduce foreign strategy investors instead of some financial investors, because of the unsatisfied condition of the capital market both at home and abroad at that moment. With the listing of the ABC in 2010, the

banking restructuring finally drew to a close. The process of restructuring the Chinese banking system cost the equivalent of between 20% and 24% of the 2004 GDP; this was injected into the banking system in the form of capital or substitute of NPL (Garc á-Herrero *et al*., 2006).

As of 2012, China's banking system comprised two policy banks, five large state-owned commercial banks; 12 shareholding commercial banks, 144 city commercial banks, 212 rural commercial banks, 190 rural cooperative commercial banks, 2265 rural credit cooperatives, a postal saving banking, four asset management corporations, 40 foreign financial institutions, 66 trust institutions, 18 financial leasing companies, 14 automotive finance companies, and four consumer finance companies. This large finance network consists of 3,800 body institution and 3.19 million practitioners in total.

2.4.2. The features of China's banking system

2.4.2.1. Centralisation

China's banking system is a considerable size not only in relative terms but also in absolute terms (see Table 2.3). By 2013, the ICBC had moved from third to first place on the back of a 15% increase in capital in The Banker's Top 1000 World Banks ranking (by Tier 1 capital) for the first time ever. In addition, there are 96 China banks listed in the World Top 1000 Banks ranking and four of them hold places in the Top 10 (the ICBC, CCB, BOC and ABC), while China's banks dominate the top of the table for the largest profits. Due to the growth of the economy, and the rapid increase in personal income, it is not surprising that total bank deposits from individuals have been growing very fast over the last 20 years, from RMB 11,066 billion in 2003 to RMB 34,740 billion in 2011.

Moreover, the bank credit has maintained a steady high-speed growth for over one decade, since the economic boom took off (see Table 2.4). However, the unprecedented level of credit expansion in China makes a severe banking crisis a very

real possibility. Once the growth of the credit-driven economy slows down, the tightening of liquidity could prove very dangerous in such a highly leveraged economy.

Table 2.3: Total Asset of Banking Financial Institution

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Banking Financial Institution Total	26,749	30,726	36,454	42,891	52,144	61,208	77,254	93,125	110,680
Policy Bank	2,125	2,412	2,928	3,473	4,278	5,645	6,946	7,652	9,313
Large-scale Commercial Bank	16,051	17,982	21,005	24,236	28,500	31,836	40,089	46,804	53,634
Joint-stock Commercial Bank	2,960	3,648	4,466	5,445	7,274	8,809	11,785	14,904	18,379
City Commercial Bank	1,462	1,706	2,037	2,594	3,341	4,132	5,680	7,853	9,985
Rural Commercial Bank	39	57	303	504	610	929	1,866	2,767	4,253
Rural Corporative Bank	n/a	n/a	275	465	646	1,003	1,279	1,500	1,403
Urban Credit Cooperative	147	179	203	183	131	80	27	2	3
Rural Credit Cooperative	2,651	3,077	3,143	3,450	4,343	5,211	5,493	6,391	7,205
Foreign Bank	416	582	716	928	1,253	1,345	1,349	1,742	2,154
New Rural Financial Institution and Postal Saving Bank	898	1,085	1,379	1,612	1,769	2,216	2,741	3,510	4,354

Unit: RMB one billion;
Source: the CBRC.

Table 2.4: Deposit and Lending of Banking Finance Institution

	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total Deposit	220,364	253,188	300,209	348,016	401,051	478,444	612,006	733,382	826,701
Including: saving deposit	110,695	126,196	147,054	166,616	176,213	221,503	264,761	307,166	347,401
Total Lending	169,771	188,566	206,839	238,280	277,747	320,129	425,597	509,226	581,893
Including: short-term loan	87,398	90,808	91,158	101,698	118,898	128,609	151,353	171,237	217,480
long-term loan	67,252	81,010	92,941	113,010	138,581	164,195	235,579	305,128	333,747
billing finance	9,234	11,618	16,319	17,333	12,884	19,314	23,879	14,845	15,154

Unit: RMB 100 million;
Source: the CBRC.

The rapid growth in asset and credit however does not imply a well-developed banking system because the diversity of banking products is insufficient, when over

70% of the profit is contributed by interest margin. Take the year 2010 for example: 16 listed commercial banks have gained RMB 1,400 billion of net interest income, while the total operating revenue was RMB 1,700 billion. In the same time, although the non-interest income had achieved a growth of 37.8%, to RMB 552 billion, the share of total operating revenue was still less than 20%. Moreover, almost all of the policies tend to benefit the state-owned enterprises (SOEs), while there is limited credit allowance left for small-and medium-sized enterprises (SMEs) and households. Take the year 2004 for example: the loans provided to SMEs and households accounted for just 15% and 11% of the total loans respectively (Garcá-Herrero *et al*., 2006).

Like many transition economies, the banking system in China has been dominated by the big four SOCBs— the ICBC, CCB, BOC, and ABC - which were established as the specialised banks in the 1980s to take charge of appropriation to key industries In 1985, the SOCBs held 93.12% of total deposit, and 94.12% of total loans. Even though the specialised banks had transformed into commercial banks in the 1990s, they still controlled the business of deposit and lending, with weak competition from other financial institutions. The remaining banks are relatively small, no matter what in terms of asset size, range of business, or branch coverage. This might offer an explanation for the high degree of concentration of Chinese banking system when measured in terms of the share of assets of the four largest banks. In the 1990s, the four SOCBs maintained their dominant position, facing limited competition from other up-coming commercial banks whose total assets and total profit were less than the smallest SOBC. According to Qin and Ou (2001), in 1999, the CCB took up 16% of total assets, while the total assets of other new-coming commercial banks accounted for less than 10%of total assets of the whole banking sector. Even though the other commercial banks had achieved rapid growth by the end of the 1990s, the four SOBCs held about 80% of total deposit and retained the share of total capital, total profit and tax at a stable high level of 80%, 90%, and 79%, respectively. This

point is also supported by the study of Garc á-Herrero *et al*. (2006). They suggest that, compared with other industrial countries, the relatively high interest margin in China can be treated as evidence of lack of competition. In 2003, the figures were 1.79% for China's bank sector and 1.38 per cent for EU banks. Furthermore, the government held a massive 99.45% share of the 10 largest commercial banks in China in 1995; this had been 100% in 1970 (La Porta, Lopez and Shleifer, 2004). The concentration ratio seems have fallen sharply since 1997 with the entrance of a number of non-state-owned banks. Since then, the weight of SOCBs in the banking system fell to 48.5% by 2011, while the importance of other commercial banks kept increasing. For instance, the weights of the JSCBs and the City Commercial Banks climbed to 16.6% and 9% respectively. This rapid change was mainly contributed to by the considerable growth in the JSCBs' assets, which was 30% and three times the growth in SOCB's assets.

In one respect, the banking management authority did not provide enough support for new-coming commercial banks when the SOBCs had the support from preferential policy. On the other hand, during the opening-up of banking market, the SOBCs also improve their sense of competition and make full use of their own advantages. In these ways, the high level of concentration of the banking market would possibly last for a long period in the future. Given that the SOCBs took up a considerable proportion of total bank assets, transforming these giants into genuine commercial banks would not only enhance the capacity of profit and efficiency of these banks, but would also improve the soundness of the whole banking system.

2.4.2.2. Non-performing loan

The high centralisation of the industry in the past 30 years has led to a series of problems in terms of asset quality and efficiency, particularly in the light of number of NPLs. Furthermore, the big proportion of NPLs particularly is a formidable challenge for the big four state-owned banks when the lending practices were under the credit plan and administered interest rates. In 1998, Dai, the governor of the PBC,

announced that about 20% of the total loans of the banking sector are classified as non-performing loans, while about 5% of the total loans are actually loss for the first time. His statement reflects the worsening situation of loan quality around the end of the 1990s when some optimists argued that the NPL ratio could in fact, surprisingly, reach 40%. As the president of the PBC, Dai's statement also delivers a signal that the regulators had noticed the problem of asset quality and were determined to reduce the number of NPLs in order to improve the soundness of bank. When we analyse the NPL problem and possible solutions, the lack of comprehensive and objective data on NPLs becomes the major obstacle. As the PBC did not formally publish the NPL data until 2002, the data of NPLs before 2002 were based on the reports by the Governor of the PBC which are classified based on the four-category classification (see Table 2.5). It is believed that these data released on NPLs are likely to be underestimated for several reasons. According to the State-owned Assets Supervision and the Administration Commission of the State Council, Hubei Province was responsible for RMB 84.5 billion of bad loans at the end of 1997, which accounted for 43.69% of all bank loans. Pei and Shirai (2004) also pointed out that it is strange that the NPLs' figure of 10% in 1998 rocketed to more than 25% in other years. The study of Shi (2003) also supports this argument. The estimated NPL ratios of SOCBs given by Shi (2003) were 39% in 1999 and 29.2% in 2000 which are more reasonable in reflecting the stripping of RMB1.4 trillion from the NPLs. Moreover, the figures of estimated NPL ratio provided by foreign research institutions and credit rating agencies were even higher than the PBC's data. For instance, the NPL ratio of SOCBs carried out by Moody was in the range of 35%-70% in 1996, while the ratio given by Morgan Stanley in 1998 was 36%（Li, 2002）. Consistent with these estimated NPL ratios, some argue that the NPLs of China's SOCBs would lead to a negative net worth of SOCBs, if applying international standards on bad loans (Lardy, 1998).

Table 2.5: Non-performing Loan of Banking Sector

	NPL Ratio (%)	NPLs (RMB 100 Million)
1997	25.00	12864
1998	10.00	6247
1999	25.00	16454
2000	25.00	16301
2001	25.30	17644
2002	25.30	20331
2003	17.80	24406
2004	13.21	17176
2005	8.61	13133
2006	7.09	12549
2007	6.17	12684
2008	2.42	5602
2009	1.58	4973
2010	1.14	4293
2011	1.00	4279
2012	0.95	4929
2013	1.00	5921

Source: the CBRC

Next, the PBC unveiled a series of regulations such as setting up core capital ratios and adjusting provisions. In this way, the NPL problem was partly relieved and banks made initial progress on improving the transparency and asset quality management. However, these actions did not bring the expected results because the major source of NPLs - the state-owned enterprise (SOE) - was also in the restructuring phase which created a tremendous amount of bad loans that increased from RMB30 billion in 1997 to RMB70 billion in 2000, while the amount of loans made to the private sector and joint ventures was much less. According to Gregory *et al*. (2000), loans made to the private sector from the whole of the banking sector was less than 1% of total loans made in 1998, with half of these loans from state-owned banks. The debt-to-asset ratio of the SOEs rose from 60% to more than an astonishing 80% where it remained until the end of 1990s (Wei and Wang, 1997). This kind of poor performance of SOEs directly impacts the asset quality of the banking sector as the state-owned banks

generously contribute more than 80% of the loans to SOEs (Li, 1995). Since the SOEs are the main source of NPLs, the reform of SOEs needs to be done in advance of the reform of commercial banks.

In addition, after the four trillion fiscal stimulus plans, there was less room for fiscal stimulus than there was before. Looking at government financing vehicles, even though central government debt was still low at around 20% of GDP, the increasing local government debt has accumulated to around 50% of GDP. According to the 2011 IMF report, if the future losses related to NPLs and unfunded pension liabilities are taken into account, the general government debt would rise to 85% of GDP.

Besides these external causes, there are two main underlying reasons for the NPL problem. The first one is the soft-budget constraints, which requires the banks to provide credit support to SOEs. The other is the deficient loan management of banks due to lack of motivation and instructions from regulators. In most practices, the overdue loans could be rolled over rather than disposed of as bad debts because the interest can be recorded as income. Aligning with the internal constraints, unlike the modern commercial banks' operation practices, the hierarchical organisation structure, inefficient information channel, and lack of risk management can be put down as the key reasons for poor performance. As Luo (2003) stated, besides the poor capital base and asset quality, China's bank sector suffers from poor corporate governance and internal controls and a lack of adequate risk management skills. The organisation structure together with the intervention from the local government weakens the control held by headquarters over their branches, particularly in the decision-making of loans. In the central and western regions and the northeast region where there are many key construction projects, local government and branches of SOBCs have more negotiation power with the PBC for more credit quota. The governors of the branches have to trade-off between the goals of maximising profit and maintaining good relationships with local government.

2.4.3. Banking regulation in China

In initial stage, since China's banking sector was part of the country's bureaucracy, the banking regulation and supervision in China has traditionally been framed within principles of economic regulation. This is due to the fact that state-controlled credit plans and politically determined interest rates played the key roles in the economic plan. Initial progress was made in 1995 when the Central Bank Law was enacted which imposed the obligation for regulation to be implemented and undertaken in a more prudential fashion: (1) classifying the loan into four categories based on the length of maturity; (2) setting the reserve for the loan loss; (3) defining the new information disclosure requirements; and (4) requiring the commercial banks to establish their own internal audit department. To prevent further accumulation of the NPLs, the PBC introduced the five-category classification for loans (normal, special attention, substandard, doubtful, and loss) based on the international practice of risk management. Although the PBC was appointed as the supervisor of China's banking sector, the obligation was actually shared by branches of the PBC and local governments. In order to strengthen its autonomy of supervision and internal management, the central bank introduced an experimental structure reform taking its example from the US Federal Reserve System in 1998. In this reform, nine cross-region headquarters were established which are responsible for the regulation of financial system, monetary policy, and internal management. Thus, following the restructure, the original provincial branches only take charge of organising financial services within their jurisdiction. Given that the provincial branches will report to the cross-region headquarters directly, the restructure aims to improve the regulatory power of local governments over on local PBC branches. However, in the three years following experimental reform, numerous management problems were identified, due to the increase of management process and cost. Consequently, the restructure, which was criticised by most of the scholars, industry insiders, local governments, and even the staff of the PBC, was terminated in 2001.

After entry into the World Trade Organization (WTO) in 2001, China's bank sector has gradually opened up to foreign banks and financial institutions. These newcomers bring more intense competition as well as new requirements for an updated international banking supervisory regulation. With deeper involvement in the global financial market, China's banking system cannot avoid facing the shocks of global financial crises. Douglas and Gaddie (2002) examined the financial crisis in the 1990s and found that the regional shocks are able to sweep through the whole international financial market in a short time; for instance, the Asian crises, the Russian crisis, the Argentine crisis and the Brazilian crisis. These shocks push the development of banking regulation frameworks at the domestic, regional and international levels. According to Deng (2009), there are four stages to the development of the international commercial banking regulation - administrative order approach, standard approach, internal model-based approach, and pre-commitment approach. These reflect the increasing complexity of financial markets.

Along with the integration into the global financial regulation, regulation authorities began to address prudential regulation as a new approach (Brehm, 2007). The year 2003 was another milestone year of banking regulation when the China Banking Regulatory Commission (CBRC) was established. The main functions of the CBRC are as follows: it (1) establishes regulation rules for the banking sector; (2) administrates the establishment, changes, termination and business scope of the banks; (3) conducts qualification management on the senior managerial personnel of the banks; (4) formulates the prudential operation rules for banks; (5) publishes statistics and reports of the overall banking system; (6) carries out on-site and off-site supervision, and deals with rule-breaking behaviours; (7) takes over or enforces the restructuring of banks with severe potential credit risk; and (8) oversees the supervisory boards of the major state-owned banks; along with other functions delegated by the State Council. Today, supervisory responsibilities are shared between the CBRC and the PBC. Following the international risk management practice,

financial institutions in China are required to measure and control credit risk, market risk, operational risk and liquidity risk (Santomero, 1997). However, economic regulation has not been completely replaced by prudential regulation, as economic regulation enables central and local authorities to guide economic development.

Due to the global financial crisis of 2008, a number of emerging countries have been under the global regulatory standard setting, such as the Basel Committee on Banking Supervision (BCBS) and the FSB, for the first time. China, as a major emerging economy, has become increasingly pivotal in radical changes of financial regulation. According to the study on the attitudes of Chinese officialdom towards the Basel Committee by Walter (2010), driven by the Asian crisis of the late 1990s and the global crisis in 2008, China's government increasingly emphasised the importance of China's steady adoption of Basel agreements in policy terms. This is all because the Basel Accord is, arguably, an important tool which would be useful for further banking reform. According to Bergsten (2008), China's authorities treat the engaging with international institutions and cooperation as a helpful action to overcome domestic resistance to reform. However, China's authorities did not fully join the BCBS until 2009, when they generally accepted the norms and standards of the Basel Accord. Look back to the mid-1990s, China was no exception to showing interest in adopting the Basel Accord, even though it did so relatively later than other Asian countries. Given that the Basel Accord I was originally designed for international banks from advanced countries, it is problematic for banks from developing countries to participate in international financial markets. For China, during that period, the banking system which was dominated by state-owned commercial banks was not able to either internationalise or open itself up to foreign competition. For instance, the law of the People's Bank of China (1995) firstly adopted the minimum capital adequacy ratio (CAR) of 8% of risk-weighted assets, but it was not enforced (Brehm and Macht, 2004). Along with the banking restructuring that took place from 2003, the PBC paid more attention to applying the minimum capital adequacy ratio rule, because the

SOCBs had adopted modern management practices and recapitalised. Among the latter, the rule on loan classification, new accounting and loan loss provisioning were introduced in 1998, 2001 and 2002, respectively. Furthermore, the China Banking Regulatory Commission (CBRC) established in 2003 pushed the progress of implementation of the Basel Accord forward greatly. The introduction of the International Advisory Board by the CBRC is another clear signal of the intentions to adopt essentially western standards of banking regulation and supervision.

China has achieved quite impressive progress on launching and localising the Basel Accord in recent years. Over 2003 to 2007, the big four SOCBs adopted the advanced International Financial Reporting Standards (IFRS) system before they went public. During this period, the figure of proportion of banks' assets which has satisfied the Basel Accord I increased sharply from only 0.6% in 2003 to over 80% in 2008 (CBRC, 2007). This means that even though there is no complete consensus on the full implementation of the Basel Accord, progress is gradual and substantial nonetheless (Davies, 2010). Owing to the success of banking restructuring, it has significantly accelerated the process of implementation of Basel Accord II and the improvement of risk management. Furthermore, the SOCBs which have involved in international financial markets introduced the Internal Ratings Based (IRB) approach into their internal risk management, following 'Guidelines on the Implementation of the New Capital Accord for China Banking Industry' issued by the CBRC in 2007. For other banks, although there is no mandatory requirement for them to adopt the IRB approach, the authorities encouraged them to draw up a plan for implementation no later than 2013. Later, in June 2012, 'Rules for Asset Management of Commercial Bank' issued by the CBRC as the localised Basel Accords II and III, drew up a final plan for the banking regulation reform. This rule has set the end of 2018 as the deadline for all kinds of banks to fulfill the Basel Accord requirements. This deadline is reasonable because, to date, only a few major banks have implemented the Basel II. This means that other medium-sized commercial banks, city commercial banks and

rural commercial banks should adopt both Basel Accords II and III concurrently. Given that the Basel Accord III redefines the rules related to capital and qualified capital tools, banks are asked to pay more attention to the key element of capital. Although banks sector is able to follow the new capital rules to some extent, the banks mainly depend on core capital reserve of common stock and dividend control to satisfy the requirements of regulation, because the capital tools available on the financial market are limited (more details of CBRC's supervision practice of banking sector see table 2.6).

Table 2.6: CBRC's supervision of banking sector in China

Indicator	Definition	Requirement
Non-performing loan ratio	Non-performing loans to loan outstandings	< 5%
Provision coverage ratio	Loan-loss reserves to non-performing loans	>150%
Loan loss provision ratio	Loan-loss reserves to loan outstandings	>2.5%
Loan to deposit ratio	Loans to deposits	<75%
Current ratio	Current assets to current liabilities	>25%
Liquidity coverage ratio	Stock of high quality liquid assets to net cash outflows over a 30-day time period	>100%
Capital adequacy ratio (CAR)	Net capital to risk weighted assets	>8%
Tier 1 (core) CAR	Tier 1 capital to risk weighted assets	>6%
Core Tier 1 CAR	Common equity to risk weighted assets	>5%,
Leverage ratio	Tier 1 capital to the adjusted on-and off-balance sheet assets of the relevant bank	>4%

Source: CBRC website

Another major change in Basel III is the stricter supervision of the global systemically important financial institutions (G-SIFI), because the increasing connection among international financial institutions makes the failure of just one of these institutions very dangerous to the whole global financial system. Currently, in China, there is just one G-SIFI, the Bank of China. The supervisors intend to impose

the stricter regulations (such as 1% of extra CAR) not only on the Bank of China, but also on other large commercial banks which can be treated as the systemically important financial institutions.

The recent global crisis, however, attracted increasing criticism of the Basel Accord (Davies and Green, 2008). China's regulators and supervisors also think back over the lessons to be learned from the Wall Street crash, and take the criticism of the Basel Accord seriously. Otherwise, because the authorities still have control power over the SOCBs to some extent, the banks pay more attention to political priorities rather than to developing risk management and competition capacity (Brehm, 2008).

In conclusion, the implementation of the Basel Accord has been a part of China's banking reform and the country has made impressive progress in order to strengthen the stability and profitability of the banking system. This tendency is motivated by the lessons learned from financial crises which are applied to enhance financial stability. Although there is a certain amount of criticism of the Basel Accord, the authorities hold an interest in applying the Basel Accord as a benchmark for banking reform. Due to the gradual adaptation of the Basel Accord, China's banking industry has improved its stability and profitability, particularly in the case of the SOCBs.

Overall, the Chinese banking system is the major element of the Chinese financial system, within which risks exhibited by commercial banks contribute most of the threat to the financial stability. The impact of macro-economic performance on stability of banking system is thus a basic issue to which should be paid great attention when conducting the macro-prudential management under Basel framework. However, unlike most of advanced economies, banking system in China maintains a series of unique characteristics as we discussed above. Therefore, we need to adjust the existed method to measure the issues related to financial stability of banking system in China.

CHAPTER 3

Research Design and Methodology

After highlighting the relevant theories and empirical studies, we discuss the methods applied in this thesis in details. The key objective of this chapter is to develop the research methodology to identify the research methods most appropriate for this study. We examine, in depth, the ontological and epistemological position of this research and establish whether the most valid method for this study is quantitative or qualitative. Moreover, the statistical approaches employed are discussed and these are then applied in empirical analysis in order to look for the possibility of a correlation between the variables of stability of the banking system and macro-economic performance.

3.1. Research Philosophy

The research philosophy adopted plays a fundamental role in research. There are some crucial procedures to rationally conduct a valid research. Every process involves different options: thus the choice of each option needs to be rationally selected according to the objectives and characteristics of the study (Saunders *et al*., 2009). Hence, this section provides a discussion of the nature and development of knowledge in order to apply the appropriate research philosophy.

Research can be defined as (e.g. Ryan *et al*., 2002; Saunders *et al.*, 2009) an activity in which persons are engaged to learn more about our environment by collecting data relative to the phenomenon under study, and analysing the results in a systematic way. Therefore, research of sufficient quality should cover several factors. It should have a clearly defined purpose, follow a logical process and apply well-planned research design. Appropriate analysis should be undertaken, and conclusions justified. Ethical standards should be adhered to, and limitations of the study should be stated (Boris *et al.*, 2005). Due to the fundamental role of research philosophy, it is

critical to start a research from identifying the underpinning philosophy and the specific method relevant to this study (Bryman and Bell, 2007). In general, ontology and epistemology are the two major issues for the research philosophy, which are widely accepted in economic research and logically related to two key research approaches: quantitative and qualitative research.

3.1.1. Ontological considerations

According to the definition by Bryman (2012, p.32), Ontology means "…claims and assumptions that are made about the nature of social reality, what exists, what it looks like, what units make it up and how these units interact with each other. In short, ontological assumptions are concerned with what we believe constitutes social reality". In other words, the ontology is concerned about the nature of the reality and how the reality can be identified by a vocabulary of terms and the relations between them, which is supported by the studies of Gruber (1993) and Gómez-Pérez and Benjamins (1999), among others. Therefore, to conduct research, it is necessary to clarify the ontological positions at the start stage, which is dependent on the researcher's philosophical thinking. Ontology usually involves two opposing positions: objectivism and subjectivism.

According to Saunders *et al.* (2009), objectivism refers to how social entities exist in reality external to and independent of social actors. Hence, objective researchers treat social phenomena as external facts that could not be affected and are constructed of real and factual features. Therefore, during the process of research, the entities, or phenomenon can be identified by their nature and relationships. Then the entities will be received by all humans, while the human mind could do nothing about the reality throughout the process.

On the other hand, subjectivism refers to where social entities are not only produced through social interaction, but are in a constant state of revision, which is in contrast to the objective stance (Bryman, 2012). Subjectivism emphasises the key role

of the human's mind in the interpretation to the world, because Vrasidas (2000) and Cronje (2006) among other researchers, argue that the world is created in the mind by interaction with the world and the interpretive process relies highly on the human's experiences and understanding.

The purpose of this thesis is to examine the determination of financial stability for the banking system in China, based on an objectivist view. According to the above arguments relating to ontological position, the reasons for this are presented below.

First, both financial stability and macro-economic performance are established facts which exist, and which can be classified by their properties and relations. Second, the relationship between the banking system's stability and the macro economy, which is the major aim of this thesis, exists external to social actors in reality as it only reflects the objective reality. The role of the author is to show this potential existing objective reality to others instead of creating something that did not previously exist. Therefore, objectivism is the appropriate ontological position for this thesis.

3.1.2. Epistemological considerations

Epistemology refers to what is regarded as appropriate knowledge about the social world; the nature, method, and grounds of knowledge. Moreover, the central issue in this context is whether a social world could be studied according to the same principles, procedures, and ethos as the natural sciences (e.g. Blaikie, 2007; Bryman and Bell, 2007). Complementary to ontological considerations, which focus on the human's opinion on the nature of the world, the epistemological position emphasises the human's opinion on the technical term for the theory of knowledge (Marsh and Stoker, 2010). Usually, research philosophy has two epistemological positions; these are positivism and interpretivism (or anti-positivism).

According to Remenyi *et al.* (1998, p33), positivism refers to "…working with an observable social reality and that the end product of such research can be law-like generalisations similar to those produced by the physical and natural scientists…".

Therefore, objective of research is to build testable hypotheses and then test and develop theories. In other words, the positivist study aims to identify a hypothesis and then make causal inferences regarding social phenomena (Lin, 1998). Moreover, in a positive research study, the researcher employs the existing theory as the foundation on which to develop a hypothesis and then to collect the credible data, following which the hypothesis is tested and confirmed (Saunders *et al.*, 2009). Consistently, positivism is epistemologically considered to be the fundamental concept of mainstream economic studies, where observers are not influenced by, and do not influence, the observed social phenomenon.

Meanwhile, interpretive is described as follow:

> the methods of research adopt the position that our knowledge of reality is a social construction by human actors…value-free data cannot be obtained, since the enquirer uses his or her preconceptions in order to guide the process of enquiry, and furthermore the researcher interacts with the human subjects of the enquiry, changing the perceptions of both parties (Walsham, 1995, p376).

Accordingly, researchers are not independent of the research, particularly in the case where the interview is used as a data collection tool, where the personal feelings and views of the researcher may influence the participants' response.

As stated, this thesis employs a positivistic approach, which is the mainstream econometric research approach (Hopper and Powell, 1985; Chua, 1986; Boland, 1991; Ryan *et al*., 2002), because this thesis is built on the foundation of existing theories. It takes an objective view of society, regards individual behaviour as deterministic, and uses empirical observation and a positive research methodology. Based on these theories, hypotheses would be extracted from relevant literature and tested with the help of collected data. Furthermore, in the data collection process, the personal feelings of the researcher would not be involved, because the data are only collected from highly credible databases, websites and annual reports.

3.2. Research Methods

As an objective and positive research, this thesis applies a hypothetic-deductive methodology which is considered relevant. This methodology begins with examination of the causal relationships between specific variables under a theoretical explanation. Afterwards, the required data are collected and analysed. The findings of the data analysis are then used to test and develop the chosen theory. It is important to choose the research methods - qualitative or quantitative - in the next step.

The qualitative method is described as a situated activity that locates the observer in the world, which consists of a set of interpretive, material practices that make the world visible. These practices turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self (Denzin and Lincoln, 2011). Hence, major qualitative research methods include the case study, oral history, focus groups, participant observation, holistic research, community discussion forums, and reflective journal log sources (Kumar, 2011).

On the other hand, as Hammersley (1993) suggests, the quantitative method usually refers to the application of the natural science experiment for scientific research. Consequently, the crucial features of the quantitative method are statistical measurement of the phenomena studied and systematic control of the theoretical variables influencing those phenomena. Moreover, some researchers argue that the quantitative method, the process of which consists of data collection using standardised approaches on a range of variables, examination of causal relationships between these variables, and test of given theory, is logically based on the positivism assumption (Desai and Porter, 2006; Henn *et al.*, 2005). Hence, positivism generally tends to adopt quantitative research approaches, while interpretivism inclines to the use of qualitative methods (Marsh and Stoker, 2010). The application of a quantitative research approach will fulfill the requirement of the positivist epistemological position, because the researcher remains separate from the data. Accordingly, this thesis use a quantitative method as it is more relevant to this type of research and to the

researcher's philosophical way of thinking.

In conclusion, this thesis follows both objectivism and positivism, thus defined as empirical research. According to the philosophical and methodological positions, a quantitative research approach is deemed to the most appropriate.

3.3. Empirical Models

This study adopts two main models to explore the relationship between the macro economy and banking system stability, and the determinants of banking distress in China. In the first empirical chapter, we begin by adopting the framework proposed by Wilson (1997a, 1997b), Boss (2002) and Virolainen (2004), i.e. estimating the relationship between credit risk and macro-economic dynamics. Next, we employ the Monte Carlo simulation approach to examine the distribution of possible default rates for the scenario under investigation.

The vector autoregression (VAR) is usually employed for forecasting models with interrelated time series and the dynamic impact of random disturbances within the model could be analyzed as well. The VAR approach treats each variable in the model as a function of the lagged values of all of the endogenous variables, which sidesteps the need for structural modeling. Because that only lagged values of the endogenous variables appear on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates. Moreover, even though the innovations may be contemporaneously correlated, OLS is efficient and equivalent to GLS since all equations have identical regressors.

Therefore, the first VAR model is designed as below:

$$y_t = \alpha + A_1 x_{t-1} \cdots + A_n x_{t-n} + B_1 y_{t-1} \cdots + B_n y_{t-n} + \mathrm{v}_t \quad (1)$$

Dependent Variables: Non-performing Loan Ratio.

Independent Variables: GDP (Nominal Gross Domestic Product Growth Rate), RPI (Retail Price Index), UNE (Unemployment Rate), HPI (House Price Index), FIX

(Total Fixed Investment), M2 (Money Supply), INT (Interest Rate), and EX (Exchange rate, Chinese Yuan to US Dollar).

where y_t is a vector of endogenous variables and x_t is a vector of exogenous variables. In this equation α is the vector of intercepts and $A_1 \cdots A_n$ are matrices of coefficients on the macro-economic variable lagged n times, and the matrices of coefficients $B_1 \cdots B_n$ are associated with the lags on the dependent variable, and the disturbance term is given by v_t, which may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

Subsequently, we employ Monte Carlo simulations to generate the distribution of possible credit losses under the macro-economic shock scenarios, which we can then compare with possible credit losses under the baseline scenario.

In the second empirical chapter, we adopt a general-to-specific approach aimed at identifying determinants of NPLR. We start with single-equation panel regressions including the whole list of possible explanatory factors of NPLR. The second model is:

$$NPLR_{i,t} = C + \alpha X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (2)$$

Dependent Variables: Non-performing Loan Ratio.

Independent Variables: GDP (Nominal Gross Domestic Product Growth Rate), GDPP (Gross domestic production per capita), CPI (Consumer price index), RPI (Retail Price Index), UNE (Unemployment Rate), HP (House Price), FIX (Total Fixed Investment), FDI (Foreign direct investment), and EXP (Annual change in regional export in percent).

Here $X_{i,t}$ represents the vector of endogenous and predetermined variables, including lags of the dependent variables; i=1,..., N is the cross-section indicator; t=1, ..., T is the time indicator; αexpresses a vector of coefficients of $X_{i,t}$; $\eta_i$is a time-invariant unobserved region-specific effect; $\varepsilon_{i,t}$is a vector of disturbances; and C is constant. Lags of the explanatory variable and NPLR itself are included to explore the effect of omitted explanatory variables and the persistence of NPLR.

In order to develop a EWS for the banking system in China, we apply the binary dependent variable model to study banking stability indicators. In this model, the dependent variable take on only two values, which is a dummy variable indicating the occurrence of an event, or a choice between two alternatives. Therefore the model could examine the relationship between the individual characteristics and the probability of event employed. Common models include probit (standard normal), logit (logistic), and gompit (extreme value) specification for the function. In Chapter 5, we apply the probit approach to explore the probability of occurrence of banking distress in China:

$$P_{i,t} = \alpha X_{i,t} + \varepsilon_{i,t} \quad (3)$$

where $P_{i,t}$ denotes a variable positively correlated with the likelihood of an occurrence of banking instability in region *i* at time *t*. Due to the fact that $-\infty<P_{i,t}<+\infty$ is not observable, we use the observable binary dependent variable $Y_{i,t}$, which takes on a value of 1 if banking distress actually occurs in region *i* at time *t* and 0 otherwise, using the following rule:

$$Y_{i,t} = \begin{cases} 1 \ \ if P_{i,t} > 0 \\ 0 \ \ otherwise \end{cases} \quad (4)$$

We follow the definition used by Demirgüc-Kunt and Detragiache (1998) for the dependent variable, in which the region is defined as an unstable region if at least one of the following two conditions is satisfied:

(1) The NPLR in the banking sector is larger than 10%.

(2) A systemic bank failure occurs or emergency measures are enacted for rescuing systemic banking problems.

3.4. Data Collection

Data are classified into primary or secondary data; these are distinguished by whether the information is gathered firsthand by the researcher for the specific purpose of the study, or from existing resources. The data type we employed for this study, secondary

data which are obtained from organisations' documents, published papers and electronic form, have some advantages and disadvantages. In terms of the advantages, the secondary data are generally believed to be of high quality and credible, because they have been identified and generated by experienced researchers and organisations. Furthermore, these researchers and organisations always have developed control procedures to control the quality of the emerging data (Bryman and Bell, 2007). Another advantage of utilising secondary data is that this approach can save time and cost as the data already exist. Accordingly, they can be immediately accessed and analysed for research. However, there are also three major limitations of secondary data. First, unlike primary data being gathered firsthand for specific research goals, secondary data might not completely satisfy the researcher's requirements. Second, there might be a problem when it is difficult to find the related data of variables of interest in a database. Third, potential bias, errors, or problems of data, which would surely affect internal or external validity, should not be ignored, due to the insufficient information offered by the of data (Frankfort-Nachmias *et al*., 1994).

The researcher has chosen secondary data as the data collection tool, which means the researcher would not be involved in a primary data collection process, as the data have already been gathered and recorded by someone else, such as government publication, financial newspaper, annual reports of public companies and commercial research organisations (Lancaster, 2007). Most of the data we employed in this thesis are extracted from the Thomson Reuters' Datastream database and the Ruisi Statistical database. In addition, other data sources we used include the Chinese Statistical Yearbook (NBS, various issues), Almanac of China's Finance and Banking 1999-2012, websites of the People's Bank of China and the China Banking Regulatory Commission. The sample in Chapter 4 covers quarterly updated data of NPLs and China's macro economy covers the period from 2000Q1-2012Q3. The sample in Chapter 5 is composed of annual data of NPLs and economic performance of 22 provinces, four direct-controlled municipalities and five autonomous regions in China

(totalling 31 regions) during the period 2000-2012. The time horizon of data sample of both empirical chapters is from 2000-2012 mainly because that the banking system has generally transformed from a closed two-tiered banking system to an opened modern banking system. Although the government still maintains certain controlling power through the state-owned commercial banks, as long as the lower entry threshold into banking sector, the public listing of state-owned commercial banks, and the opening of banking sector to foreign banks, the banking system in China has to face the financial shock from the international market and need to applied the risk management to ensure the stability of banking system. The NPL ratio data come from the website of the China Banking Regulatory Commission, which covers commercial banks, state-owned commercial banks, joint-stock commercial banks, city commercial banks, rural commercial banks and foreign banks. The time interval is constrained by the availability of long enough NPLR time series which have been published since 2003. As the quality of data in Chinese banking sector has been questioned, the data have been crosschecked from multiple sources to ensure consistency and to improve the reliability of the research findings. Besides, due to combining a number of datasets, it is important to note the differences in data collection methods, definitions of measures used in the data, and variations in general survey design. Thus, in this study we select the data carefully to prevent such problems occurring. In addition, the data sample is processed with Microsoft Excel and SPSS.

3.5. Procedures of Analysis

This study employs a range of statistical techniques to provide robust and reliable findings, and these statistical methods that are used in this thesis are discussed in this section. Due to the assumptions that were econometrically suggested, it might lead to some problems may emerge, particularly for employing panel data – namely, missing data, unbalanced data and outliers.

Beginning with missing data, this is caused by poor disclosure practices of some

variables and missing values of some variables at some point in time. The data sample used in this research maintains some missing values and we would not delete the observations that contain missing values as that removal strategy would affect the sample size. In order to overcome this problem, we turn to alternative data sources. Otherwise, the software this study applied (i.e. Eviews) would drop the missing value automatically if necessary. Furthermore, the problem of unbalanced data, which is also caused by missing data, can lead to other problems, which can be overcome by adopting appropriate estimation methods such as random-effect or fixed-effect regression.

Regression techniques not only provide the estimation of the relationship between a single dependent variable and a series of independent variables, but also offer summary statistics and significance of relationships. A group of summary statistics is generated during the application of regression models; the two major statistics are the adjusted R square and the Sig. F statistic. The former suggests the overall explanatory power of the model and the later confirms whether the regression coefficients are statistically significant. The three main alternative types of regression analysis adopted in this thesis are the VAR (vector autoregression) approach for time series data in Chapter 4, the fixed-effect regression approach and the binary logistic regression approach for panel data in Chapter 5. These approaches are applied based on their suitability in modelling specific relationships and exploring data.

The first empirical study adopts a framework to explain how macro-economic dynamics affect financial stability based on generalised impulse response functions with the help of a vector autoregression (VAR) model. The VAR which is popular in the literature allows estimating how NPLR changes in the time interval following adverse shocks. Furthermore, the VAR model also takes account of potential feedback effects from the banking distress to the macro economy. According to Sims (1980), in the studies of macro-economics and finance, the VAR model is widely applied to explain the interactions that exist between variables. Besides, the impacts of

unexpected shocks to specified variables on other variables in the model could be captured by the VAR model. The impulse response function is able to explain the effects of innovation shock on future values of the endogenous variables. Therefore, the VAR model is an appropriate tool for this thesis, because that we aim to find out the impact of macro-economic shocks on banking system stability. The second part of this chapter uses a stochastic simulation technique to implement stress-testing of the banking system. In this process, we firstly define some stress scenarios based on the estimating results of the VAR model, and then the future value of a specific variable is generated using Monte Carlo method under the given stress scenario. The strategy of designing artificial shocks of stress scenario is to combine the historical extreme events and the hypothetical shocks based on historical data of an economy.

The second empirical study employs the fixed-effect regression model over the 13-years period. Baum (2006) suggested that this methodology allows testing variations among cross-sectional units at the same time as for variations within individual units over time. The fixed effect model estimates the fixed effect on the dependent variables by controlling for the constant variations coming from the omitted variables and for unobserved heterogeneity between groups over time.

CHAPTER 4

Macro Stress Testing in the Banking System of China

4.1. Introduction

In recent years banks have engaged in increasingly complex and diverse international financial activities. The role of banks, as one of the most important financial intermediaries in an economy, and as a prerequisite for sustainable economic growth, reinforce the fact that instability in the banking system would be costly for the real economy. This is manifest by the myriad ways the current Global Financial Crisis (GFC) has impacted economies (e.g. Tagkalakis, 2013; Aboody *et al.*, 2014). In particular, the costs and losses, at the national level, associated with failures within the banking system, underscore the need for supervision with a macro-prudential perspective, particularly with regard to how banks measure and control their risk exposure.

From the macro-prudential perspective, the Basel III Accord emphasized the need for the development of a more robust stress-testing approaches compared to the Basel II.[2] The emphasis suggests that up-to-date risk management techniques — particularly, 'macro stress-testing' — have become effective tools in assessing stability of the banking system, and the financial system more broadly (see Sorge, 2004). This is especially so from the perspective of central banks, where stress tests are a prudent technique alongside the traditional regulation methods used to assess risk exposure in the financial system (Marcelo *et al.*, 2008).

In this study we focus on macro stress-testing in assessing financial stability in China, and we address two questions that naturally arise. First, how should we

[2]The notion of stress testing — which was originally developed in medicine (Missal, 1938)— has emerged as both an *ex ante* risk management tool for identifying vulnerability ahead an extreme shock, and a crisis management and resolution tool (Wong *et al.*, 2010; Visco, 2011).

measure the potential risks in the banking system? Secondly, how do we quantify the vulnerability of the banking system to potential risks? To achieve answers to these, we develop a framework for macro stress testing of credit exposures in the Chinese banking system. Our empirical analysis adopts a vector autoregression (VAR) approach, and investigates the relationship between the ratio of non-performing bank loans and key macro-economic factors, such as GDP growth, RPI, the unemployment rate, fixed investment, real estate price indexes, the money supply, interest rates, and the exchange rate. Macro stress testing assesses the credit risk of banks' overall loan portfolios and mortgage exposures by mapping multivariate scenarios against potential risks. The test introduces different types of macro-economic shocks into the scenarios, which are designed to replicate those that have occurred in past financial crises and stochastic simulations.

The present study is thus predicated on the following: first, stress-testing has become an integral part of banks' risk management assessments; second, in interpreting the results of stress tests, many banks create a link between market shocks and banks' responses. Interestingly, in China, which is an emergent global economy, stress testing is still at the embryonic stage. On this basis, we posit that the analyses contained herein are timely and important contributions to our understanding of this very important emerging market economy.

4.2. Literature Review

Many financial institutions have experienced large losses during the recent global financial crisis. These significant losses do not necessarily imply that these institutions and the supervisory departments failed as a result of traditional risk management processes, as it is apparent that most of these institutions had employed sophisticated risk management systems. For example, according to Stulz (2008), a considerable loss cannot only be attributed to a consequence of risk management failure as a significant loss might occur even with a perfect risk management system in place. In other words,

the common task of daily risk management is not able to control for extreme exposure under *certain* circumstances. That notwithstanding, the recent GFC has also highlighted serious deficiencies in traditional risk management models (e.g. Huang *et al*., 2009; Aizenman *et al*., 2012) and underscored the necessity for improvements in risk management systems, and the adoption of improved risk-management measures to better depict the possible risks. This is why stress tests and scenario analysis are apposite.

Moreover, regulators need to provide a clearer definition of financial stability and the framework to achieve this goal. Recently, regulators have charged banks with the responsibility of ensuring a sound, stable and efficient banking system as a whole, i.e. financial stability, rather than only assuring the soundness of their own bank (Borio, 2006). Financial stability depends, in essence, on the prudential regulation and effective supervision which was instituted in 1999 by the IMF and the World Bank via the Financial Sector Assessment Program (FSAP). Although there is no one generally accepted definition of financial stability, Marcelo *et al*. suggest that 'for a given economy, [financial stability] provides sufficient assurance that the efficiency of intermediation between the suppliers and demanders of funds (broadly speaking, between investors and savers) will not be significantly affected by adverse events (shocks)' (2008, p.65). Given the huge negative implications for the real economy in the event of financial instability, regulatory authorities should have a particular and well-justified interest in ensuring financial stability (as highlighted by the Basel III Accord).

As pointed out by Drehmann (2005), stress testing models differ in terms of complexity and the risks considered. Despite many significant contributions to stress testing (e.g. Elsinger *et al*., 2006; Jacobson *et al*., 2005; De Graeve *et al*., 2008; Pesaran *et al*.,2009; Aikman *et al*., 2009), there is no consensus on the set of tools, or the best approach, to use. As a consequence of this various approaches have been proposed, including Wilson (1997a, 1997b), Virolainen (2004), Sorge and Virolainen

(2006), Misina *et al*. (2006), and Jimenez and Mencia (2009). Differences notwithstanding, the underlying structures assume a linear relationship between macro-economic variables and the probability of default on the bank's loan portfolio.

4.2.1. Development of stress-testing

The idea of stress-testing originated in engineering. It is a kind of technique that aims to determine the stability of a given system or entity. To observe the results, it focuses on testing beyond normal operational capacity, often to a breaking point. In terms of economics and financial studies, 'stress' is always referred to as an extreme bad shock based on the historical economic and financial events such as a huge downward change in the GDP or stock market index. The Basel II framework brought significant progress in banking risk management, which encourages banks to develop their own models to decrease capital requirement (Mejstrik *et al.*, 2008). Initially, stress-testing was applied to portfolios or individual institutions, also known as micro stress tests. Meanwhile, there is also a wide range of research on the macro-economic perspective of banking system risk. With the development of techniques, more and more techniques have been invented to test the stability of financial institutions as a whole, which are also known as macro stress tests. Therefore, stress-testing as a set of tools of assessing and analysing the financial stability of the banking system should be treated as a way of focusing on the extreme banking risks that enhances the perception of them. It is a kind of accurate assessment on how those risks may be influenced by certain extreme shocks, both at the micro level (individual institutions) and the macro level.

According to Borio *et al*. (2012), both micro and macro stress tests have four elements; these are the risk exposures subjected to stress; the scenario defining the shocks; the model mapping the shocks onto an outcome, and the measure of the outcome. The aim of stress-testing is to measure the impact of severe shocks, which

are potentially able to harm to the financial stability. Hence, the results of stress-testing are threefold: to add value to the internal risk management practices implemented by banks, to provide a foundation for further development in prudential techniques, and to facilitate prevention and early warning and response tasks to deal with these adverse situations (Marcelo *et al*., 2008).

Up to two decades ago, stress-testing was initially raised by the International Organization of Securities Commission, and then accepted by the International Monetary Fund (IMF) as a key element of the Financial Sector Assessment Program (FSAP) -a joint effort by the IMF and the World Bank to assess vulnerabilities across institutions. Along with the growing integration of financial surveillance, the IMF started a trial about stress-testing as part of regular surveillance (IMF, 2006). This resulted in the rapid expansion of adoption of stress-testing among the regulation authorities of the member countries of the FSAP. As stated by Bunn *et al*. (2005), stress-testing soon became a key supplementary tool for broader macro-prudential analysis of potential threats to financial stability. Moreover, there is no doubt that the stress-testing application in the FSAP not only offers a tool to assess financial stability, but also has a lasting effect on encouraging policymakers of membership countries to develop a more specific financial stability assessment function (Jones *et al*., 2004). As the result of widespread implementation of the FSAP, many central banks and the IMF made extensive use of stress tests prior to the crisis. According to a report of the BIS (Fender *et al.*, 2001), 43 central banks undertook 293 stress test scenarios (stress tests based on a potential market event, such as a stock market crash) and 131 sensitivity stress tests (stress tests based on standardised moves in closely-linked market risk factors, such as a parallel yield curve shift).

During the follow-up crisis, the researchers developed the techniques with several broad varieties based on increasing numbers of stress-testing practices. On one dimension, it can be classified in the forms of sensitivity test and scenario test. According to Majnoni *et al*. (2001), the stress-testing models were not very

sophisticated but basic to some extent in the early period. Considering there are limited data and resources available, those models which examine the relationships between aggregate profits and losses and macroeconomic factors may be the only possible approach. As well as the work of Majnoni *et al.* (2001), the most common method applied in member countries of the FSAP is the sensitivity test. This method addresses the impact of a change in a single risk factor on the balance sheets of banks; but the sensitivity testis not able to estimate the interaction between macroeconomic variables. In 2006, Elsinger and colleagues made a milestone contribution. They developed a model covering market risk, credit risk, interest rate risk and counterparty credit risk to assess the impact on Austrian banking sector. The full coverage of risk exposure data of this model can thus achieve a very robust test of vulnerability based on on-balance sheet exposures. Furthermore, the idea of value-at-risk (VaR) which is used to access the volatility of portfolio was firstly introduced to measure loss distributions. As this model also makes use of the interbank exposures data, it is able to explore the path of the failures of one individual bank extending through the system, which is known as the contagion effect.

At the beginning, most of stress-testing practices were single-factor sensitivity analysis. However, this approach has evolved from being at the central position of the analysis to becoming a supplementary method. Meanwhile, the number of scenario analysis practices was increasing with varying degrees of complexity (Moretti and Swinburne, 2008). Unlike the sensitivity test, the scenario test focuses on scenarios in which multiple risk factors which are intended to be internally consistent change simultaneously. To achieve this objective, there are two approaches to designing the scenario. The first type is the historical approach which relies directly on historic data. The historical scenarios can be set in two ways. The first approach replicates a specific historical crisis, such as the global financial crisis of 2008, the stock market crash of 1987, and the Asian financial crisis of 1998. The second approach is to draw artificial shocks of specific risk exposure based on the tail part of the historical

distribution. This second type is a hypothetical approach which uses the experience and judgments of experts to identify the shocks that may possibly occur in the future and significantly affect the system. As we mentioned above, the work of Fender and Gibson (2001) sorted the 293 scenarios test into nine categories: the asset markets-related scenarios in which the shocks are linked with market rates or prices, such as equities market, interest rates market, credit spreads market, commodities market, and among others; the geographical areas scenarios in which the shocks are derived from market-wide stress within countries including Europe, Japan, North America, and the emerging market countries; and the "other" scenarios which covers a wide range of scenarios. Given these practices of scenario testing, macro stress test scenarios generally focus on severe macroeconomic situations, for example, a severe recession, a sharp drop in property prices, and a significant change of exchange rates.

On a second dimension, stress tests can be classified in the form of bottom-up and top-down. On one hand, the bottom-up approach refers to when the central bank or supervisor co-ordinates the macro stress tests by designing the scenarios; thus the institutions subsequently run with their internal models to measure the impact of the shocks on their performance. Then, the supervisory authority integrates the results from individual institutions. On the other hand, the top-down approach refers to when the central authority directly produces the stress test results with detailed position data.

On a third dimension, stress tests can be classified in the forms of the piecewise approach and the integrated approach. The piecewise approach runs on the portfolios of individual financial institutions to access the shocks from macroeconomic variables (such as economic growth, interest rates and unemployment). The latter embed the reduced-form equations into structural macro-econometric models, like the model of Norges Bank that has included financial stability variables in a macro-econometric model (Bardsen *et al*., 2006). On the contrary, the integrated approach focuses on the system level estimating a probability distribution of aggregate losses that could arise in a stress scenario based on an aggregate system-wide model. Several studies have

modelled default probabilities as non-linear functions of macro variables (Wilson, 1997).

Stress-testing in the FSAP covers a range of different risks, including credit risk, market risk, and liquidity risk:

- Credit risk is the major overall source of risk for the banking industry in many countries whose damages can be directly reflected in banks' balance sheets. To estimate credit risk, single factor sensitivity analysis is the fairly classic approach which consists of NPL migration analysis and loan reclassification analysis. Then, more approaches have been developed based on loan performance data and regressions. As the result of application of these advanced approaches, probabilities of default (PDs) and loss given default (LGD) have replaced NPL for measuring loan performance. According to Avesani *et al*. (2006), the credit risk model based on CreditRisk+, which was originally developed by Credit Suisse Financial Products (CSFP), has examined the relationship between macro financial factors and PDs and LGDs. Meanwhile, the implementation of scenario analysis for credit risk largely depends on data availability.
- Market risk consists of a range of different risks such as interest rate risk, exchange rate risk, real-estate price risk; credit spread risk, and commodity price risk. Because market risk shocks are usually built on the hypothetical or historical movements of related variables, the value-at-risk method is widely accepted to conduct such kind of stress-testing.

Because stress-testing is a relatively new topic, there is no consensus on the most effective set of tools, or the best approach to use. Moreover, Drehmann (2005) argued that stress-testing models are different in terms of complexity and the risks considered. As a result of this, some recent researchers have proposed various approaches to stress-testing, including Wilson (1997a, 1997b), Virolainen (2004), Sorge and Virolainen (2006), Misina *et al*. (2006), and Jimenez and Mencia (2009). However, they all share a similar structure rooted in the quantitative risk management

framework: the first one is that all papers employed forecasted macroeconomic variables to simulate the impact of shocks on the economy; and the second is that all these approaches required the translating of these macroeconomic variables into loss distributions. The most basic approach is assuming a linear relationship between the macroeconomic variables and the probability of default of the bank's loan portfolio.

It is generally accepted that carrying out any stress test normally involves the following stages:

1. to delimit the realm of application of the test;
2. to define, design and calibrate the shocks with which the target system is to be stressed;
3. to estimate the influence of the shocks selected and to quantify that impact in terms of variables demonstrating the financial condition of the system to be tested;
4. to identify the feasible considerations and policy measures emerging from the outcomes of applying point 3 above.

4.2.2. Feedback effect

Feedback effect illustrates the response of a financial system to the real economy when a risk factor relevant to macro-economic dynamics affects the financial system. Then, credit supply is expected to decrease along with the pressure on investment and consumption as a consequence. In their paper, Jacobson *et al*. (2005) pointed out that the feedback effect is another important issue of stress tests. Consequently, the aggregate vector autoregressive model (VAR), with the data of default frequency of companies, was proposed to measure financial stability including macro-economic feedback. The result of this model reveals a significant feedback effect from financial stability to the macro-economy by integrating defaults of company, balance sheet of bank, and macro-economy. After it was first practiced in Sweden，this methodology has become widely accepted. De Graeve *et al*. (2008) applied this method for banks in

Germany, and Pesaran *et al*. (2009) proposed a global VAR framework for modelling national and international macro-economic risk factors jointly. In 2009, the Bank of England (Aikman *et al*., 2009) provided a more comprehensive approach - RAMSI - which successfully explored the feedback mechanisms.

4.2.3. Contagion effect

Besides the feedback effect, there is another reason why the financial sector is often thought to be more likely to suffer from systematic instability. It is worth noting that interaction among financial institutions could not be explained by simply aggregating the behaviour of individual banks. Thus, this interaction might lead to systematic fragility at times. The contagion effect refers to when the failure of a bank may cause a further deterioration in the capital adequacy in other banks. Because of the contagion effect, the risks could be easily transferred from a single failure of an individual institution to the whole system through the interbank market, OTC derivatives transactions, and the payments and settlements system (Schoenmaker, 1996). The speed and the degree of contagion develop with the continued growth of international capital markets. Schoenmaker (1996) emphasised that contagions in the banking sector would spread more extensively, thereby resulting in larger losses, and causing serious damage to the economy at large. Otherwise, information asymmetry limits the public information for creditors to access the stability of their financial service provider. Even if there is a potential stress at other institutions, creditors may not realise that this vulnerability may directly affect their institutions. Because banks are the participants in the payment and settlement systems, the contagion effect could be amplified and pose a serious threat to financial stability (Corrigan, 1996).

4.2.4. Stress-testing in China

In China, the stress-testing is still in the early promotion period. The first Financial Stability Assessment Program (FSAP) of China was completed in July 2001 when the

CBRC organized some major commercial banks to conduct the stress-testing experiment with the mature risk management tools such as Risk Manager purchased from Risk Metrics. Then, at the end of 2003, the first formal stress test which assesses the credit risk, liquidity risk, exchange risk and interest rate risk was completed by the Industrial Commercial Bank of China (ICBC), the Agriculture Bank of China (ABC), the Bank of China (BOC), the China Construction Bank (CCB) and Guangdong Development Bank. Following the success of this attempt, two important regulatory documents were issued by the China Banking Regulation Commission in 2007 and 2008 respectively: 'The Notification of Conducting Stress Test on Real Estate Loan at Key Region' and 'Guidelines about Commercial Bank's Stress-Testing'. The IMF, however, stated that there are a series of obstacles facing full implementation of stress-testing in China, such as serious data gaps, weakness in the infrastructure and constraints on the FSAP team's access to confidential data (IMF, 2011).

In accordance with the implementation of stress-testing in China, the study about stress-testing is also in its early stages. Yang and Zhu (2004) provided a relatively comprehensive summary about the practices of stress-testing among supervision authorities of FSAP member countries. Based on Yang and Zhu's study, Ba and Zhu (2010) discussed the pros and cons of stress-testing, with a particular focus on how to carry out an effective stress test in developing countries with limited data. In addition, Ba and Zhu (2010) provided insightful views about further research on macro stress-testing and feasibility proposal of China's stress-testing practice.

On the dimension of empirical research, stress-testing was not used for bank's risk management at the beginning. Wang *et al.* (2002) suggested that China's export would not be seriously affected by the significant depreciation of the Yen with sensitivity analysis and stress scenario. Next, researchers turned their interest to assessing the vulnerability of banking system with the probit and logistic model. Chen and Wu (2004) carried out an empirical analysis of the vulnerability of China's banking system with data covering the period of 1978-2000 and found that macro-

economic dynamics, like financial deficit, inflation, growth of fixed asset investment, and interest spread, are the factors which could affect the bank's stability. Besides, they believed that financial variables are the major factors related to the vulnerability of the banking system. However, some researchers have argued that macro-economic variables have more significant correlation with the vulnerability of SOCBs, among which GDP growth, real interest rate, and inflation are the top three factors, while financial variable plays a supplementary role to the macro-economic variable (Fan, 2004; Ren and Sun, 2007). The growth of the non-performing loan was first introduced to the logistic model to estimate its relationship with financial stability (Li, 2006). Later, according to the FSAP, macro stress-testing became the most popular tool at the end of the 2000s. Xu and Liu (2008) explained how to use macro stress-testing to estimate the stability of a financial system by comparing several popular macro stress-testing approaches. The research by Xu (2008) conducted a linear macro stress-testing model to estimate the asset growth of China's banking sector under the extreme scenario when GDP growth and CPI deteriorated to various level in 2008 and 2009. The evidence from this study indicates that the asset of China's banking sector is able to maintain an increasing trend under the stress scenarios. Hua (2009) analysed the impact of macro-economic dynamics fluctuations on China's banking system and non-performing loan ratio by using the macro stress-testing scenarios method. Due to the uncertainty of the macro economy, credit risk stress-testing on the real-estate loan business has become the major element of risk management of commercial banks. Hence, such a credit risk stress test was carried out by Liu and Tian (2008), which analysed a series of risks for the real-estate loan business. For the real-estate loan business, the risks mainly depend on the repayment capacity of the real-estate company and mortgage borrowers. Some scholars suggest that the quality of the real-estate loan of commercial banks in China is relatively satisfactory. Nevertheless, if the real-estate price drops significantly, the NPL of the bank sector would likely double its size and badly undermine the profitability (Feng, 2009; Wang and Wang, 2009).

Moreover, Yu and Li (2010) noted that the default risk of mortgage would boost in the case that CPI increases sharply and GDP drops. However, these studies only borrow ideas from macro stress-testing, while still employing traditional methods to simulate the changes of macro-economic factors. Furthermore, this approach has some disadvantages that cannot effectively reflect the impact of macro changes on the banking system, and thus cannot show which macro-economic variables affect the credit risk of the finance system under the shock circumstances.

To conduct a more effective stress test for China's banking system, two main obstacles need to be overcome: (1) *The availability and quality of data*. For the People's Bank of China, the time horizon of basic public data for scenario design in the macroeconomic model is far from sufficient. Along with the varying statistical caliber and poor quality of data, these drawbacks lead to biases and errors in the stress-testing results. (2) *Macro-economic model*. In theory, the stress scenario is able to be designed based on the general macro-economic model, but there is no such widely accepted macroeconomic model which not only exactly reflects China's reality, but also passes the series of statistical tests. Alternatively, researchers have to apply the classic economic model or other countries' macro-economic models directly. However, during the transition period, the ubiquity of regional protectionism is the major characteristic of China's economy. Omitting this variable will definitely affect the effectiveness of stress-testing analysis.

4.3. Methodology

4.3.1. Empirical equations

In testing credit risk exposure in China's banking system, we will begin by adopting the framework proposed by Wilson (1997a, 1997b), Boss (2002) and Virolainen (2004), i.e. estimating the relationship between credit risk and macro-economic dynamics. Next, we employ the Monte Carlo simulation approach to examine the

distribution of possible default rates for the scenario under investigation. The Monte Carlo simulation generates a given year a number of losses by a random quantile of a severity distribution (McNeil *et al.*, 2010; Dutta and Perry, 2007).

We set $NPLR_t$ as the aggregate non-performing loan ratio of the whole banking system in China in period *t*. Since $0 \leq NPLR_t \leq 1$ we can employ its logit-transformed value (y_t) instead of $NPLR_t$ as the dependent variable. That is

$$y_t = ln\left\{\frac{1 - NPLR_t}{NPLR_t}\right\}$$

After this canonical processing for the credit risk index (note here that $-\infty < y_t < +\infty$), it follows that $NPLR_t$ is negatively related to y_t, which means a higher y_t indicates a better credit-risk status, and *vice versa*. Further, preliminary (augmented Dickey-Fuller) unit-root tests with the time trend and the intercept finds y_t (our dependent variable) to be stationary. More specifically, y_t dependents on its lags, and the *n* lagged values of the macro-economic variables:

$$y_t = \alpha + A_1 x_{t-1} \cdots + A_n x_{t-n} + B_1 y_{t-1} \cdots + B_n y_{t-n} + \mathrm{v}_t \qquad (4.1)$$

where y_t is a vector of endogenous variables and x_t is a vector of exogenous variables. In this equation α is the vector of intercepts and $A_1 \cdots A_n$ are matrices of coefficients on the macro-economic variable lagged n times, and the matrices of coefficients $B_1 \cdots B_n$ are associated with the lags on the dependent variable, and the disturbance term is given by v_t, which may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

This macro-economic framework examines the dynamics of the macro-economic variables as well. Based on Wilson's original specification, which every macro-economic variable follows an autoregressive (AR) process, we generalize a more realistic dynamic process by adopting by the following specification:

$$x_t = \beta + C_1 x_{t-1} \cdots + C_n x_{t-n} + D_1 y_{t-1} \cdots + D_n y_{t-n} + \varepsilon_t \qquad (4.2)$$

where β is the vector of intercepts; $C_1 \cdots C_n$ and $D_1 \cdots D_n$ are coefficient matrices; and

ε_t is an vector of disturbances. Following Wong *et al.* (2006) we recognize that macro-economic variables are mutually interdependent and equation (4.2) explicitly accounts for feedback effects of bank performances on the economy (the terms $D_1 y_{t-1} \cdots + D_n y_{t-n}$). Equation (4.1) and (4.2) together compose the framework to study the economic performance and the associated financial stability indicators.

In developing our model we aim to improve on the specification employed in Virolainen (2004) and Wilson (1997a, 1997b). First, we employ a lag-effect of the macro-economic variables to banks' credit risk. Second, by allowing x_t to depend on $y_{t-1},\ldots,y_{t-n}$ this implies previous bank performances can influence the present macro economy.

Subsequently, we employ Monte Carlo simulations to generate the distribution of possible credit losses under the macro-economic shock scenarios, which we can then compare with possible credit losses under the baseline scenario. Nevertheless, it is instructive to note that this approach has some limitations, such as the treatment of the contagion effect within the banking system. First, it is not unusual for central banks to use aggregate data when testing the change of credit risk in the regional banking system, based on the assumption that we move from top to bottom. However, the use of aggregate data when assessing credit risk in the whole banking system is equivalent to conducting micro stress-testing with the aggregate data, and ignoring the structural problems within the financial system. Second, the adaptive response of banking institutions may generate a feedback effect. It is commonplace that in a number of the macro stress testing practices the initial shock effect from the macro economy to the banking system is small in the first period, while the risk effect will be significantly increased when the period of stress testing is prolonged. In other words, the change of risk factors in the first round should not be treated as the ultimate outcome and underscores the need to continually reassess the response behavior of the banking system to a (macro-economic) shock.

4.3.2. Variables description and data sources

Following the framework discussed above, we adopt a macro-economic credit risk model to estimate the relationship between macro-economic variables and the non-performing loan ratio (NPLR) of the banking system covering the period from 2000Q1 to 2012Q3. Due to the importance of selecting the appropriate variables, Table 4.1 presents a brief summary of the variables considered in previous research, which then informs our choice of variables for China. Based on the aims of this research (and the reliability and availability of data), we will focus on eight major explanatory variables for China (see Table 4.2).

Table 4.1: Summary of Macro-economic Variables Employed in Previous Research

Author(s)	Geographical Location	Macro variables
Wong *et al.* (2006)	Hong Kong	Real GDP growth; Real GDP growth of Mainland China; Real interest rates (HIBOR); Real property prices.
Bardsen *et al.* (2006)	Norway	Real GPD; Real household consumption; Unemployment; Consumer prices; Interest rate; House prices.
Bunn *et al.* (2005)	United Kingdom	Interest rate; GDP; Output gap; Unemployment rate; Real exchange rate; Inflation rate; House price inflation rate.
Misina *et al.* (2006)	Canada	GDP growth rate; Unemployment rate; Interest rate; Credit/GDP ratio.
Virolainen (2004)	Finland	Nominal GDP growth; Interest rate; Exchange rate; M2; International balance of payment; Asset price.

We identify three popular dependent variables typically considered in previous research, namely: the firm's probabilities of default (PD) (see for example, Pesaran *et al.,* 2006); corporate expected default frequencies (EDF) (see for example, Alves, 2005); and, the balance sheet information of the bank (such as NPLR, capital adequacy ratios and liquidity). Compared to PD and EDFs, balance sheet information is a traditional measurement, but it is limited because balance sheet information is only available on a relatively low-frequency basis (quarterly and yearly). In contrast, the PD and EDF are available at a higher frequency, and they can be forward-looking. Due to the nature of China's commercial banks, and the availability of relevant data,

we employ NPLR as the measurable dependent variable pertaining to the balance sheet. According to the Loan Quality Assessment Guidelines (China Bank Regulatory Commission, 2005), the NPLR is classified as the total of sub-loans, doubtful-loans and loss-loans divided by total loans. In other words, a higher NPLR implies a higher level of credit exposure.

Table 4.2: Variable List

Variable	Description
NPLR	Non-performing Loan Ratio
GDP	Nominal Gross Domestic Product Growth Rate
RPI	Retail Price Index
UNE	Unemployment Rate
HPI	House Price Index
FIX	Total Fixed Investment, nominal (%YOY)
M2	Money Supply, M2 (%YOY)
INT	Interest Rate
EX	Exchange rate, Chinese Yuan to US Dollar

The eight explanatory macro-economic variables (Table 4.2), including the GDP growth rate, the retail price index, the unemployment rate, a house price index, the money supply (M2), the interest rate, exchange rate, and total fixed investment, can be placed into four categories to capture different kinds of potential shocks:

1. The business cycle is measured by GDP growth, retail price index (for inflation), and the unemployment rate, as the stability of the macro-economy is the premise of a healthy financial system. A growing economy is likely to be associated with rising incomes and reduced financial distress. Therefore, GDP growth is negatively associated with NPLR and unemployment is positively related with NPLR. After maintaining high-growth for a number of years, the growth of China's economy has slowed down somewhat, while inflation remains above the Government's target. Thus, the policy-makers in China have been concerned with how to implement a successful "soft-landing", whilst dealing with inflation.
2. Credit risk is measured by the interest rate, money supply (M2), and total

fixed investment. Banks are still the major source of corporate and fixed investment in China, and the interest rate and credit quota have a direct impact on the credit exposure of the banks' balance sheets. Otherwise, unlike their counterparts in developed countries, income from loans surprisingly makes more than 80 percent of the total profit of commercial banks in China. A hike in interest rates weakens borrows' debt servicing capacity, thus, NPLR is expected to be positively related with interest rate.

3. Property-value bubbles, which are measured by house price indexes, have triggered several financial crises, such as the Florida property bubble in late 1920s (White, 2009), the depression of Japan since 1991 (Posen, 2003), and the subprime lending crisis since March 2008. In China, the loans to the real estate sector have grown to RMB 11.74 trillion in September 2012, an increase of approximately 12.1% since the end of 2011 (Source: China Banking Regulatory Commission). Should this indicate a bubble this may create problems since real estate is a major item of collateral, and banks would be unwilling to service the debt should the value of real estate declines.
4. Exchange rate risk is measured by the exchange rate (Chinese Yuan to US Dollar), which reflects the global macro-economic environment. The fluctuation of the exchange rate might significantly affect the stability of the whole economy and output. An appreciation of the exchange rate can have mixed implications. On the one hand, it could weaken the competitiveness of export-oriented firms and adversely affect their ability to service their debt. On the other, it can improve the debt-servicing capacity of borrowers who borrow in foreign currency. The sign of the relationship between NEER and NPL is indeterminate.

These variables are initially chosen as macro-economic factors by the R-squared values of the regressions. We have also tried some other macro-economic variables like the consumer price index, producer price index, and stock market index, but find

no additional explanatory power.

We source the NPLR data from the China Banking Regulatory Commission website and the Ruisi Statistical database. Other data used in this study are sourced from DataStream, the National Bureau of Statistics of China, and The People's Bank of China. The summary descriptive statistics of data are presented in Table 4.3.

Table 4.3: Summary Statistics, 2000Q1-2012Q3

	NPLR	**GDP**	**RPI**	**UNE**	**HPI**	**FIX**	**M2**	**INT**	**EX**
Mean	11.22	9.77	1.51	4.02	4.93	19.58	12.08	6.37	7.59
Median	7.53	9.60	1.20	4.10	4.30	21.15	12.15	6.21	8.02
Maximum	29.18	14.80	7.56	4.30	12.19	37.40	19.54	7.83	8.28
Minimum	0.90	6.60	-2.03	3.10	-1.10	5.39	7.07	5.76	6.29
Std. Dev.	9.76	2.05	2.61	0.32	3.70	6.99	2.84	0.61	0.75
Observations	51	51	51	51	51	51	51	51	51

Prior to 2000 annual data was only available for some variables. The trend in the NPLR of the banking system in China had climbed to a peak in 1999, thereafter exhibiting a steady decline. In part this turning point may be explained by the establishment of asset management corporations between 1999 and 2004, which were responsible for managing the bad assets of the four major state-owned commercial banks. Since these "big four" state-owned commercial banks retained in excess of 60% of the total assets in the whole banking system, the concurrent injection by the Central Bank of a large amount of capital funds into these "big four", together with the purchase of non-performing loans by asset management corporations from these "big four", led to the overall NPLR dropping significantly.

Results of our preliminary tests using the augmented Dickey-Fuller (ADF) method (with trends and intercepts, testing the time series properties for all these variables) suggest that three of the macro-economic series — specifically RPI, HPI, and M2— are stationary $I(0)$. The other five variables — i.e. GDP, INT, EX, UNE and FIX — are first order stationary $I(1)$. Because of this we use their first differences, DGDP, DINT, DEX, DUNE and DFIX in the regression (see Appendix C, Figure C.1).

Table 4.4: ADF unit root tests

Variable	t-Statistic	Unit root test result
GDP	-1.88*	GDP~*I*(1), DGDP
RPI	-3.67	RPI ~*I*(0)
UNE	-2.75*	UNE ~*I*(1), DUNE
HPI	-3.48	HPI ~*I*(0)
FIX	-0.89*	FIX ~*I*(1), DFIX
M2	-7.31	M2~*I*(0)
INT	-2.69*	INT ~*I*(1), DINT
EX	-2.12*	EX ~*I*(1), DEX

* Non-rejection of the null of non-stationarity at 10%

Following Lutkepohl (1993) we focus on the Akaike (AIC), Hannan-Quinn (HQ) and Schwarz (SC) criteria for the selection of the lag lengths in our VAR model. Given the sample size, and the nature of the quarterly data, the results of the Akaike information criterion, Schwarz information criterion, and Hannan-Quinn information criterion all suggest a 4 period lag length. (see Appendix C, Table C.1).

4.4. Empirical Results and Discussion

4.4.1. Discussion of results

In this section we adopt a VAR framework that links the credit risk measurement of the banking system to the macro-economic variables (outlined in Table 4.2) which reflect the situation of the macro economy. In our VAR framework we assume that vulnerability in the banking system can be affected by the general economic conditions, and there is a potential feedback effect which allows stress in the banking system to impact the macro economy. Unlike simple linear regression, the order of variables in VAR should be arranged according to the speed of reaction to a particular shock. Therefore, our variable ordering is such that the variables related to the business cycle — such as GDP, RPI and unemployment rate — were located after NPLR, because the business cycleaffects the banking system after a lag. Consequently, interest rates and the exchange rate were ordered at the bottom of the VAR.

As the VAR results show in Table 4.5, most of the signs of the coefficients of the

variables are as expected and consistent with other studies (see Wong *et al.*, 2006 and Shen and Feng, 2010). Thus y_t is positively related to the lag effects on GDP growth and the unemployment rate due to the fact that when the economy enjoys steady growth with a low unemployment rate, the banking system can share the benefit as the financial intermediary. Meanwhile, y_t is negatively related to the lag of RPI and the money supply, albeit via comparatively weak correlations which are below expectation.

Between 2003 and 2007 China's economy experienced a significant cyclical upswing, with vigorous financing demand leading to a tremendous influx of funding into production. The onset of the GFC around 2008Q2 adversely impacted international trade. On the one hand, banks provided more loans to firms to avoid their potential default. On the other hand, the government employed easy monetary policy to ensure smooth growth. As a consequence, default rates remained stable, while the inflation rate and money supply increased significantly.

Table 4.5: Vector Autoregression Estimates

	$\mathbf{y_t}$	DGDP	RPI	DUNE	HPI	DFIX	M2	DINT	DEX
y_t (-1)	0.96*** (-0.27)	-4.70* (-2.64)	-2.75 (-2.25)	0.16 (-0.12)	-5.63** (-2.49)	0.08 (-9.81)	3.11 (-4.18)	-0.70 (-0.54)	0.01 (-0.18)
y_t (-2)	0.39 (-0.35)	2.51 (-3.44)	-2.90 (-2.93)	0.11 (-0.16)	3.14 (-3.24)	-0.77 (-12.81)	1.35 (-5.46)	0.34 (-0.70)	0.12 (-0.23)
y_t (-3)	-0.66** (-0.32)	5.31* (-3.12)	3.67 (-2.66)	-0.18 (-0.15)	4.86 (-2.94)	2.81 (-11.62)	-8.02 (-4.95)	1.34** (-0.64)	-0.11 (-0.21)
y_t (-4)	0.27 (-0.30)	-3.21 (-2.95)	1.75 (-2.51)	-0.03 (-0.14)	-3.28 (-2.78)	-0.74 (-10.96)	4.39 (-4.67)	-0.97 (-0.60)	-0.04 (-0.20)
DGDP(-1)	0.10** (-0.04)	-0.76* (-0.44)	0.11 (-0.37)	-0.04* (-0.02)	0.52 (-0.41)	-3.26** (-1.62)	0.24 (-0.69)	-0.07 (-0.09)	0.03 (-0.03)
DGDP(-2)	0.10* (-0.06)	-0.44 (-0.58)	0.37 (-0.49)	-0.05* (-0.03)	0.78 (-0.54)	-4.41** (-2.14)	-0.04 (-0.91)	-0.12 (-0.12)	0.03 (-0.04)
DGDP(-3)	0.02 (-0.05)	-0.44 (-0.53)	0.74 (-0.45)	-0.05* (-0.03)	0.85 (-0.50)	-3.40* (-1.98)	-0.35 (-0.85)	-0.04 (-0.11)	0.00 (-0.04)
DGDP(-4)	0.06 (-0.06	-0.17 (-0.63)	0.35 (-0.54)	-0.05 (-0.03)	-0.29 (-0.59)	-3.17 (-2.34)	0.49 (-1.00)	-0.19 (-0.13)	0.01 (-0.04)
RPI(-1)	-0.02 (-0.04	-0.35 (-0.44)	0.33 (-0.37)	-0.03 (-0.02)	0.19 (-0.41)	1.06 (-1.63)	-0.52 (-0.69)	0.11 (-0.09)	0.04 (-0.03)

	y_t	DGDP	RPI	DUNE	HPI	DFIX	M2	DINT	DEX
RPI(-2)	0.09 (-0.06)	-0.49 (-0.63)	0.22 (-0.53)	-0.05 (-0.03)	-0.13 (-0.59)	-3.42 (-2.33)	-0.07 (-0.99)	-0.19 (-0.13)	0.01 (-0.04)
RPI(-3)	0.06 (-0.04	-0.39 (-0.40)	0.20 (-0.34)	0.01 (-0.02)	-0.42 (-0.38)	-2.89* (-1.49)	0.13 (-0.64)	-0.06 (-0.08)	0.03 (-0.03)
RPI(-4)	-0.07* (-0.04)	0.41 (-0.39)	0.14 (-0.33)	0.02 (-0.02)	0.65* (-0.37)	0.07 (-1.45)	-0.20 (-0.62)	-0.01 (-0.08)	-0.04 (-0.03)
DUNE(-1)	1.12** (-0.55)	-10.48* (-5.42)	1.89 (-4.62)	-0.34 (-0.25)	-3.86 (-5.11)	-19.03 (-20.16)	-3.61 (-8.59)	-2.08* (-1.10)	0.11 (-0.36)
DUNE(-2)	0.83* (-0.48)	-10.30** (-4.69)	3.18 (-3.99)	-0.11 (-0.22)	-0.53 (-4.41)	-19.79 (-17.42)	-0.43 (-7.43)	-2.03** (-0.95)	-0.09 (-0.31)
DUNE(-3)	0.82* (-0.44)	-7.65* (-4.34)	1.57 (-3.69)	-0.13 (-0.20)	-3.65 (-4.09)	-19.70 (-16.14)	-1.93 (-6.88)	-1.59* (-0.88)	0.04 (-0.29)
DUNE(-4)	0.95** (-0.37)	-2.21 (-3.61)	2.76 (-3.08)	0.58*** (-0.17)	8.00** (-3.40)	-9.10 (-13.43)	-3.83 (-5.73)	-1.40* (-0.74)	-0.02 (-0.24)
HPI(-1)	-0.03 (-0.03)	0.02 (-0.30)	0.10 (-0.25)	0.03* (-0.01)	0.90*** (-0.28)	0.89 (-1.11)	-0.13 (-0.47)	0.00 (-0.06)	-0.02 (-0.02)
HPI(-2)	0.03 (-0.03)	-0.04 (-0.30)	-0.08 (-0.26)	-0.01 (-0.01)	-0.12 (-0.28)	0.04 (-1.12)	0.19 (-0.48)	0.00 (-0.06)	0.00 (-0.02)
HPI(-3)	-0.01 (-0.03)	-0.03 (-0.26)	-0.07 (-0.22)	0.01 (-0.01)	0.05 (-0.24)	-0.45 (-0.96)	0.00 (-0.41)	0.00 (-0.05)	0.00 (-0.02)
HPI(-4)	0.02 (-0.02)	0.01 (-0.17)	0.13 (-0.15)	-0.02** (-0.01)	-0.15 (-0.16)	0.69 (-0.65)	-0.13 (-0.28)	0.01 (-0.04)	0.00 (-0.01)
DFIX(-1)	-0.02* (-0.01)	0.07 (-0.12)	0.17 (-0.10)	0.01 (-0.01)	0.12 (-0.12)	-0.64 (-0.46)	0.08 (-0.19)	0.01 (-0.02)	-0.01 (-0.01)
DFIX(-2)	-0.03** (-0.02)	0.16 (-0.16)	0.04 (-0.13)	0.01* (-0.01)	0.00 (-0.15)	-0.31 (-0.58)	-0.04 (-0.25)	0.02 (-0.03)	-0.01 (-0.01)
DFIX(-3)	0.01 (-0.02)	0.08 (-0.15)	-0.11 (-0.13)	0.02** (-0.01)	-0.12 (-0.14)	-0.06 (-0.56)	0.30 (-0.24)	-0.03 (-0.03)	0.00 (-0.01)
DFIX(-4)	-0.03 (-0.02)	0.15 (-0.19)	-0.06 (-0.16)	0.01 (-0.01)	0.22 (-0.18)	0.51 (-0.72)	-0.10 (-0.31)	0.07* (-0.04)	-0.01 (-0.01)
M2(-1)	0.00 (-0.02	-0.26 (-0.18	0.08 (-0.15)	-0.01 (-0.01)	-0.02 (-0.17)	-0.06 (-0.67)	0.05 (-0.28)	0.01 (-0.04)	0.00 (-0.01)
M2(-2)	0.02 (-0.02)	0.06 (-0.19)	0.22 (-0.16)	-0.01 (-0.01)	0.14 (-0.18)	-0.78 (-0.71)	0.55* (-0.30)	-0.05 (-0.04)	0.01 (-0.01)
M2(-3)	0.02 (-0.02)	0.21 (-0.18)	0.24 (-0.16)	0.00 (-0.01)	0.33* (-0.17)	-0.32 (-0.68)	0.36 (-0.29)	-0.02 (-0.04)	-0.01 (-0.01)
M2(-4)	-0.04** (-0.02)	0.20 (-0.17)	0.09 (-0.15)	0.01 (-0.01)	0.13 (-0.16)	0.16 (-0.64)	-0.43 (-0.27)	0.06* (-0.04)	-0.01 (-0.01)
DINT(-1)	-0.10 (-0.22)	-2.26 (-2.17)	-0.54 (-1.84)	0.15 (-0.10)	-1.71 (-2.04)	9.72 (-8.05)	-0.54 (-3.43)	0.19 (-0.44)	-0.16 (-0.15)
DINT(-2)	0.14 (-0.17)	-1.40 (-1.69)	-2.10 (-1.44)	0.17** (-0.08)	-2.80* (-1.59)	2.13 (-6.28)	2.47 (-2.68)	-0.58 (-0.34)	-0.04 (-0.11)
DINT(-3)	-0.29	1.88	-0.42	0.12	0.90	8.41	-3.96	0.78	-0.10

	y_t	DGDP	RPI	DUNE	HPI	DFIX	M2	DINT	DEX
	(-0.22)	(-2.16)	(-1.84)	(-0.10)	(-2.04)	(-8.04)	(-3.43)	(-0.44)	(-0.14)
DINT(-4)	-0.26* (-0.12	-0.79 (-1.22)	-0.65 (-1.04)	0.11* (-0.06)	-0.83 (-1.15)	0.39 (-4.55)	1.15 (-1.94)	0.10 (-0.25)	-0.04 (-0.08)
DEX(-1)	-1.18* (-0.65)	3.82 (-6.35)	-4.21 (-5.41)	0.16 (-0.30)	-4.08 (-5.99)	-6.49 (-23.63)	-8.58 (-10.07)	1.35 (-1.29)	-0.26 (-0.43)
DEX(-2)	-1.19* (-0.69)	-2.02 (-6.75)	-0.83 (-5.75)	0.23 (-0.32)	8.79 (-6.36)	-0.27 (-25.10)	-4.27 (-10.70)	0.85 (-1.37)	-0.22 (-0.45)
DEX(-3)	0.18 (-0.78)	-2.65 (-7.67)	-2.49 (-6.53)	-0.21 (-0.36)	-7.53 (-7.23)	-35.22 (-28.53)	10.37 (-12.16)	-0.15 (-1.56)	0.57 (-0.51)
DEX(-4)	-0.01 (-0.84)	6.50 (-8.21)	5.43 (-6.99)	0.17 (-0.39)	2.49 (-7.74)	-27.69 (-30.54)	-9.97 (-13.02)	-0.52 (-1.67)	0.31 (-0.55)
C	-0.20 (-0.29)	0.60 (-2.83)	-6.33*** (-2.41)	-0.07 (-0.13)	-2.73 (-2.66)	8.35 (-10.52)	4.45 (-4.48)	0.27 (-0.58)	0.26 (-0.19)
R-squared	1.00	0.86	0.98	0.90	0.99	0.78	0.92	0.88	0.78
Adj. R-squared	0.99	0.29	0.88	0.48	0.93	-0.10	0.59	0.38	-0.09
Sum sq. resids	0.10	9.93	7.20	0.02	8.82	137.36	24.95	0.41	0.04
S.E. equation	0.11	1.05	0.89	0.05	0.99	3.91	1.67	0.21	0.07
F-statistic	175.12	1.52	9.88	2.14	17.05	0.89	2.77	1.76	0.90
Log likelihood	75.12	-30.02	-22.62	110.75	-27.27	-90.43	-51.20	43.21	94.30
Akaike AIC	-1.66	2.91	2.59	-3.21	2.79	5.54	3.83	-0.27	-2.49
Schwarz SC	-0.19	4.38	4.06	-1.74	4.27	7.01	5.31	1.20	-1.02
Mean dependent	2.81	-0.02	1.83	0.01	5.32	-0.14	11.93	0.01	-0.04
S.D. dependent	1.27	1.25	2.55	0.07	3.68	3.73	2.59	0.27	0.07

*, ** and *** indicate significance at the 10%, 5% and 1% level respectively;
standard errors in ( ).

Regarding interest rates, a rise in interest rates implies an increase in the financing cost of loans. In particular, small firms which needed money to survive the crisis could not afford the financing cost, and failed to return their earlier loans. In addition, exchange rates have a strong negative correlation with the default rate for particular types of firms. Thus, the depreciation of RMB had negative impacts on three types of industries: industries whose raw materials are imported; second, those industries which maintain a huge amount of foreign exchange liabilities; and, third, the tourism industry.

Interestingly, in our study we do not find a significant relationship between default rate and real estate price though, intuitively, one would expect this to be the case. The prolonged impacts on the default rate are captured by the lags i.e. DGDP(t-

1): (0.09), DGDP(t-2): (0.10), RPI(t-4): (-0.07), DUNE(t-1): (1.12), DUNE(t-2): (0.83), DUNE(t-3): (0.82), DUNE(t-4): (0.95), DFIX(t-1): (-0.02), DFIX(t-2): (-0.03), M2(t-4): (-0.04), DINT(t-4): (-0.26), DEX(t-1): (-1.18), and DEX(t-2): (-1.19). Moreover, the coefficient of the lagged default rate, y_t(t-1) :(0.96) and y_t(t-3) :(-0.66), are significant. This finding indicates that the expected default rate of banks in the past period would generate a prolonged impact on the NPLR in the current period. In other words, a one percentage point increase of the NPLR in the previous quarter will lead to a NPLR increase of 0.96 percentage points in the current quarter, which indicates that the impact of shocks are long-lasting. Because the signs of the coefficients of y_t(t-1) and y_t(t-3) are different, it implies that the response of the banking system towards shocks is slow, possibly due to the time needed for implementing risk solutions. Meanwhile, this finding suggests that it is necessary for the regulators to launch a risk early warning system toidentify the potential shocks, and the real shocks, at an early stage, because it is too late when the impact of the shock appears on the banks' balance sheet. The fact that negative autocorrelation of y_t (t-3) is different from the previous research (Shen and Feng, 2010) may be attributed to the differences in frequency of data. However, we posit that the quarterly data we employ is likely to be more informative. Given the autocorrelation of y_t, it is necessary to analyze the progress of the default rate over a time horizon that is longer than the duration of the designed shock in order to reflect the long-term impact of the shock.

In addition to the aforementioned analysis, we conduct impulse response analysis in order to simulate shocks to the macro economy, and estimate the feedback from these shocks to the NPLR. We are also able to estimate whether the changes in the NPLR have a further impact on macro-economic developments. In the VAR approach, because of the lag structure, a shock on one variable not only just has impact on the variable itself but also affect all of the other endogenous variables. Therefore, the impulse response function is used to explore the effect of a one-time shock to one of

the innovations on current and future values of the endogenous variables. Following the traditional VAR literature, the impulse response analysis is accomplished by means of the orthogonalised impulse responses with Cholesky decomposition. Our impulse response functions suggest that the default rate increases to 0.08 over three quarters, following unexpected shocks to the GDP, and reverts to a lower level in the fourth quarter. Unexpected shocks in the RPI result in a decrease in default rate, with an effect potentially lasting more than 25 quarters. The response to a positive shock on real estate prices is not obvious during the first four quarters, and the impulse response of y_t climbs to a peak of 0.25 from the fifth period to the twentieth. This can provide an explanation for why we failed to find a significant coefficient of real estate price in the credit risk model, because the impact of shocks to house prices can only be observed after four quarters, while the model estimates the lag value of the macro-economic dynamics for four periods. However, when there is an innovation shock of one standard error for the unemployment rate, fixed investment, money supply, interest rate and the exchange rate respectively, there are no significant changes in y_t. (see Appendix C, Figure C.2).

Correlation between variables does not necessarily imply causality in real world. Therefore, in VAR approach, Granger causality test is employed to test whether an endogenous variable can be treated as exogenous. In this Chapter, we carried out the Granger causality test to detect the causal direction between variables, and results shows that the default rate is Granger caused by a series of macro-economic variables, including GDP, fixed investment, money supply, and interest rate. (see Appendix C, Table C.2).

4.4.2. Scenario analyses

In the previous analysis we examined the relationships between the NPLR and key macro-economic variables. In this section we aim to examine the response of the expected default rate to macro-economic shocks, via simulations. To generate the

future path of the expected default rate, our scenario analysis conducts a stress test on the banking system in China, with historical and hypothetical scenario methods. The historical scenario method provides limited insight since China has maintained high growth for over two decades without suffering severe shocks. Given this, we seek to gain insight by mimicking the effects of the Asian Financial Crisis in 1998, and the Argentinean Financial Crisis (1999-2002), using the parameter estimates for the Chinese economy derived in the previous subsection (estimated coefficients of VAR approach). On the other hand, as uncertainty is the nature of hypothetical scenarios, we assume the macro risk factors follow the normal distribution and choose the 1/10, 1/25, and 1/100 quantiles as the shock values, reflecting the maximum loss incurred over 10 years, 25years, and 100 years respectively. These changes are modeled to occur separately from 2012Q4 to 2013Q2, from the moderate situation to the severe case, and there is no further artificial shock introduced for the subsequent quarters. We conduct the following out-of-sample forecast by step-by-step method. In every forecasting period, the model is re-calculated with the new available data of variables of scenarios and generates the forecasted value of financial stability indicator for the next period. Given the macro-economic variables we have selected, we design four scenarios as follows: (i) The benchmark scenario, in which there is no shock; (ii) shocks via the business cycle, in which China's GDP growth rate slides to 7%, 6%, and 5% respectively in each of the three consecutive quarters (starting from 2012Q4); (iii) a rise in the interest rate by 300, 400, and 500 basis points respectively in each of the three consecutive quarters starting from 2012Q4; (iv) rises in the exchange rate by 5%, 10%, and 15% respectively in each of the three consecutive quarters starting from 2012Q4.

Since stress testing focuses on extreme, but plausible shocks, we have designed the scenarios with a feasible probability such that these changes in the macro-economic variables can occur. Furthermore, these scenarios reflect extreme situations which can bring large losses to the banking system. In addition, we have designed a

worsening trend for shocks, as economic stimulus policies may not be effective immediately. Then we simulate 2000 future paths and compute the expected default rates in 2013Q4 to construct a frequency distribution. With this frequency distribution, we can examine whether the banking system is stable within a certain confidence level, because the tails of the distributions provide insight into the extreme losses.

Table 4.6: Stress-Testing Results for Scenarios

Period	Benchmark		GDP Shock		Interest Rate Shock		Exchange Rate Shock	
	y_t	NPLR (%)	y_t	NPLR (%)	y_t	NPLR (%)	y_t	NPLR (%)
2012 Q4	4.34	1.29	4.34	1.28	4.34	1.29	4.34	1.29
2013 Q1	4.14	1.57	4.09	1.63	4.14	1.57	3.04	4.54
2013 Q2	3.98	1.83	3.71	2.93	3.98	1.83	0.99	27.15
2013 Q3	4.20	1.48	3.62	2.58	4.34	1.28	0.46	38.76

The default rates in the following three periods after the shocks (2013Q1, 2013Q2, and 2013Q3) were computed with the macro-economic risk (VAR) model on a step-by-step basis. The results of this are outlined in Table 4.6. The following are noteworthy:

1. *The benchmark scenario*: As that there is no shock in this scenario, the default rates (y_t) are at stable level about 4.17. Consequently, the NPLR for the whole banking system peaks at 1.83%, indicating very stable conditions for the banking system.
2. *The GDP shock scenario*: Following the shock, the default rates in this scenario respond strongly to the change in GDP growth and the unemployment rate. The NPLR rises to 2.93% in 2013Q2, and falls down to 2.58% in 2013Q3. Accordingly, the influence of this business cycle shock on financial stability is profound, which would lead to an increase in provision for bad loans, and a concurrent decrease in capital adequacy. Even though China's growth has all the hallmarks of a successful soft-landing in the past three years, the banking system is still vulnerable in the face of such a GDP shock.

3. *The interest rate shock scenario*: In this scenario we found a limited response in the relationship between the default rate and changes in the interest rate with the NPLR being raised to 1.83% in 2013Q2. Subsequently the NPLR falls to 1.28% in 2013Q3. This result suggests that the major clients of banks (big corporations and state-owned-enterprises) are not sensitive to the financing cost of debt.
4. *The exchange rate shock scenario*. Recall that some industries — such as those whose raw materials are imported, those which maintain a huge amount of foreign exchange liabilities, and the tourism industry — can be profoundly affected by exchange rate shocks. It is of particular note that the strongest influence occurs in the exchange rate shock scenario, since the NPLR rockets to 27.15% in 2013Q2, and keeps rising to a more severe 38.76% in 2013Q3. This will likely lead to significant losses for banks and indicates that China's government should be cautious in exchange rate reform.

Building on this, we generate a conditional probability distribution of losses based on the concept of value-at-risk. Usually value-at-risk is expressed a cut-off point of the distribution beyond which the probability of the loss occurrence is less than the given quantile. This process is as follows: first, as reported in Table 4.7, we compute the response of the financial stability indicator with macro-economic credit risk model and the Monte Carlo simulation (computed 2000 times); secondly, corresponding simulated values of financial stability indicator are used to assess loss distributions.

Table 4.7: Loss Distribution Scenarios, A Quarterly Horizon

	Benchmark		GDP Shock		Interest Rate Shock		Exchange Rate Shock	
Confidence Level (%)	y_t	NPLR (%)	y_t	NPLR (%)	y_t	NPLR (%)	y_t	NPLR (%)
80	4.35	1.28	3.65	2.53	4.42	1.18	1.37	20.14
90	4.27	1.38	3.57	2.74	4.34	1.29	1.25	22.29
95	4.19	1.49	3.49	2.93	4.27	1.37	1.16	23.94
99	4.06	1.69	3.37	3.32	4.12	1.59	0.97	27.54

These loss distributions, again, include a benchmark scenario and three stressed scenarios. Generally, the value-at-risk results show that for the confidence level of

99%, the banking system in China is able to maintain the financial stability with an interest rate shock, with an acceptable NPLR of less than 2%. According to 'the Core Indicators for the Risk Management of Commercial Banks' (China Banking Regulatory Commission, 2005), this indicates that the current risk from interest rate changes is moderate for the banking system. However, for the GDP chock and exchange rate shock our results suggest that with an 80% confidence level the NPLR exceeds the 2% threshold in each case. Our study suggests that an exchange rate shock is likely to be profoundly damaging in terms of the NPLR, exceeding 20% at each confidence level tested. The results shown in Table 4.7 do not contradict the previous step-by-step forecasting methods, though there are some differences in magnitude which can be explained by the differences in the methodological approach used. Overall, however, we would assert that this triangulates our result.

4.5. Conclusion

This study has developed a framework for macro stress-testing of credit risk for the banking system in China. This framework was used to measure the financial stability of the banking system in response to shocks in different macro-economic variables. We utilized VAR models and analyzed eight macro-economic variables, with the macro-economic credit risk models successfully explaining the impact of severe macro-economic shocks on the balance sheet of banks. The analysis suggests that there are some significant relationships between the default rates and macro-economic factors, such as GDP growth, the unemployment rate, the interest rate, and the exchange rate, which are focal concerns for macro stress testing perspectives.

Macro stress-testing is used to assess the financial stability of the banking system. We combined the historical method and the hypothetical method to produce three stress scenarios with various artificial shocks including GDP growth shocks, interest rate shocks, and exchange rate shocks. Thereafter, the distribution of possible NPLRs, derived from the Monte Carlo method, was simulated, and the value-at-risk for credit

risk was calculated. The stress-testing results indicate that the banking system in China would be healthy in the case of interest rate shocks, but in the case of GDP growth and exchange rate shocks the NPLR of banks would climb beyond the limit of 2%. Overall, the Chinese banking sector is well prepared to absorb the credit losses associated with a set of distressed macroeconomic scenarios without threatening financial stability.

Although from a macro prudential perspective China emerged unscathed from the GFC, the Central Bank of China should learn the lessons of risk management from Western countries and encourage commercial banks to carry out both micro stress-testing and macro stress-testing under the framework of FSAP. For the policy makers, they should pay more attention to the stress testing results during the decision-making process, especially when formulating growth and exchange rate policies. In particular the ongoing foreign exchange rate system reform is something that needs to be considered carefully so that China can avoid severe exchange rate shocks, which our study suggests would be extremely costly. Our results also provide helpful suggestion to policymakers in China in monetary policy formulation. The empirical results indicate that the interest rate and money supply have significant effects on stability of banking system in China. Therefore, applying the interest rate and the reserve requirement ratio is useful for China to achieve financial stability. In practice, when the economy is down, the policymaker could decrease the interest rate and the reserve requirement ratio to stimulate the economy. When the economy is up, the policymaker could increase the interest rate and the reserve requirement ratio to suppress the economy and reserve certain capital buffer for potential shocks to banking sector.

CHAPTER 5

Non-performing Loan, Economic Performance and the Determinants of Banking Distress

5.1. Introduction

The costs of reviving a failure in the banking sector after a crisis could be as large as half of a country's annual GDP (World Bank, 2000). For instance, Laeven and Valencia (2011) use EU data to illustrate that the output losses of previous banking crises in 2008 reach around 20–25% of GDP. Moreover, credit tightening following a banking crisis would affect the potential growth of the crisis country. Therefore, the recent global financial crisis, underscored by numerous research and developments in policy has highlighted the importance of understanding sources of vulnerability which may bring about a banking distress. This focus is driven not only by the considerable cost of such crises, but also because they usually start from the failure of a single large institution then spread through the whole financial system, with associated macro-economic risks. As a result, assessing the financial system as a whole and treat aggregate risk as endogenous was defined as macro-prudential perspective, which is intent on minimizing system wide distress and preventing output costs associated with financial instability (Borio, 2009). Hence, central banks, tasked with maintaining financial stability, place much emphasis on developing macro-prudential regulation policy (Das *et al.*, 2004). Therefore, early identification of these risk sources is playing a major role because it provides valuable information for policy makers to decrease vulnerabilities and improve the ability of the financial system to absorb the impact of shocks. There is a common place for these costly economic and financial crises in both developing and developed countries, due to financial crises, a low quality of banks' loan portfolio is usually a major indicator of the banking system

distress. When we study about the determinants of banking system distress, the linkages between macro-economic shocks and the risk of banking distress have renewed its interest. The main aim of this study is to uncover the determinants of banking system distress and to establish the linkages between non-performing loans and macro-economic performance in regional China.

It is widely believed that the outburst of financial crisis could hardly be forecasted (e.g. Rose and Spiegel, 2011). Therefore, the Early Warning System is such a tool designed for financial system supervisor and policy makers to forecast whether and when the given economic entity would be impacted by adverse shocks. The idea of the EWS was raised in 1990s because of a series of financial crises, which are from European monetary system crisis in 1992 to the crisis of Asia in the middle of 1997. More specifically, Lindgren *et al.* (1996) summarise that three-quarters of IMF member countries have experienced banking distress over this period. The EWS including both macro- and micro-economic variables is able to offer an overview of financial system vulnerability. There is a wide range of literature on the EWS applying numerous approaches from panel logit model to signal extraction method to binary recursive trees. There is no doubt that false alarms would cause inappropriate policy action, highlighting the importance of accuracy of the EWS. However, the fundamental issue of the EWS is the choice of financial and macro-economic variables to evaluate. In other words, it is impossible to build a general economic model which is suitable for every country and can deal with all kinds of crises. Particularly for the emerging countries, the reliance on generic indicators is influenced by the dearth of data and banking crisis observations. As a result of the limitation of EWS, the implementation of EWS is required to distinguish the characteristic of a certain country and choose variables based on the nature of the banking system and lending behaviour.

China's economy expanded rapidly during 1978 and 2012 with an average real GDP growth of 9.8% (source: IMF), even though under a dire international context in

recent years, which no other country in the world has achieved such a long term rapid growth. As the OECD survey reports that, China has now overtaken the euro area and is on course to become the world's largest economy around 2016 (OECD, 2013). Along with the reform and opening policy first adopted in 1978, the explosive growth of foreign investment and export became the new engine of development, especially in coastal regions. Even though the inland regions have also been benefited by the reform and opening policy, the development speed was left behind, thus the following economic disparity among regions evolved into political and social problems. Since 2000, the inland regions have achieved their own rapid growth owing to development programs carried out by the government in the mid-1990s in order to rebalance regional development. Therefore, the economic disparity leads to the disparity of financial sector development and the differences in characteristic of financial stability among regions.

The banking sector of regional China is interesting for several reasons. The foremost reason is that the vast geographical disparities linking with the regional distribution of economic activity, living standards, resource base, and other determinants of stability of the banking sector. Pronounced inequalities in income and economic opportunities between the coastal and inland regions of China are well documented in the literature. During the transition process from a centre-planned economy to a market-based economy, China has experienced growing inter-provincial inequality. Indeed, there are considerable disparities in growth performances among provinces. The gap between the most dynamic regions in terms of GDP per capita, Shanghai, is RMB 75,108, and the least dynamic, Guizhou, is RMB 9,428 in 2008. The general regional classification of provinces reveals that coastal provinces have experienced much faster growth than inland provinces. It is widely believed that preferential policies from the central government for the coastal provinces generally drive the disparity. Besides the promotion from the preferential policies, the coastal economies naturally contain the geographical advantage in engaging in international

trade and hence are most competent to industrialize by relying on export-oriented processing industries. Additionally, coastal regions are able to profit from a higher percentage of arable land, better conditions for developing infrastructure, and easy access to the sea. These significant regional disparities in economic generate different demands for types of financial arrangements, which will result in differences in stability condition of regional banking system. In addition, in China, major banks usually operate across wide regions, thus, it is not easy to determine the regional financial stability. The aggregate data do not reflect regional stability of the banking system. Due to these special characteristics of such a transitional economy, it is inappropriate to simply adopt the model which has been applied to development countries or just focus on the national level.

These perspectives are reflected in this study, which examines regional China's banking system stability, using macro-economic indicators and panel data covering twenty two provinces, four direct-controlled municipalities and five autonomous regions. There are two major aims of this study. One is to provide an overview of banking system stability in the geographical distribution of these indicators by plotting them on maps. The other one is to identify appropriate early warning indicators of banking crises in regional China. In this way, this study could enable regulators to monitor the banking system vulnerability at an initial stage and carry out corrective actions to prevent potential adverse shocks.

The structure for the remainder of this chapter is as follows: Part 2 provides an overview of the literature. Part 3 depicts the data and method. Part 4 presents the estimation results. Part 5 offers some concluding remarks.

5.2. Literature Review

Risk management in the banking sector has been the focus of researches in the past several years, among which the credit risk management is particularly a popular topic. It is all due to that credit risk is the major source of risk in the banking system.

Moreover, credit risk has been the target of strict banking regulatory (BIS, 2001). Due to the increasing interactivities in the global economy, banking sector regulators and risk managers of is in front of a question like "How would it affect the vulnerability of a given bank (or banks) in a given region in the case of severe shocks to economy?" Consequently, the Bank for International Settlements (BIS) announces the reform of regulation of bank capital for credit risk, which is also known as Basel Accord II. Basel Accord II has caused a debate in the literature. Some argue about the effect of business cycles which focus on the effect of economic downturns on banks and value-at-risk (VaR) capital requirements (Carey, 2002; Allen and Saunders, 2003). But this debate does not take into account of the macro-economic factors at national and global levels or build up an explicit model.

Banking regulators have been increasingly interested in looking for formal models to support the financial stability monitor. In the recent researches, there are various approaches have been used. Goodhart *et al.* (2006) have attempted to model systemic risk in a general equilibrium framework. However, this approach is highly stylized and extremely difficult to perform. Therefore, there is a more common alternative approach which describes how the risk profiles, especially the default probabilities, of banks respond to changes in macro-economic conditions. The linkage between default probability and macro-economic factors and can be modelled in two ways. First one is the asset-pricing approach which relies on an option-pricing framework and extracts risk from observed security prices (Gray *et al.*, 2007; Frisell *et al.*, 2007). These approaches usually require high-frequency data, which is able to capture the market's perceptions of the risks of the system. The second one is to use balance-sheet information to estimate the performance of the bank's risk exposures. Many central banks apply this kind of approach as an input to their financial stability analysis (Foglia, 2009), because that these models offer a flexible and operational means of capturing a wide range of risks and transmission channels.

The literature on the determinants of NPL and the interactions between NPL and

macro-economic performance is grounded in theoretical models as well as empirical regularities. Following the financial accelerator theory, empirical literatures include the cyclical nature of bank credit, NPL, and loan loss provisions. In particular, in upturns, contemporaneous NPL ratios tend to be low. Also, competitive pressure and optimism about the macroeconomic outlook lead to a loosening of lending standards and strong credit growth, sowing the seeds of borrowers' and lenders' financial distress down the road. The loosening of lending standards in upturns depends on the existing regulatory and supervisory framework. In downturns, higher-than-expected NPL ratios, coupled with the decline in the value of collaterals, engenders greater caution among lenders and lead to a tightening of credit extension, with adverse impacts on domestic demand. Dash and Kabra (2010) provide a detailed review focused on explaining differences in NPL across banks within specific countries highlighting the role of macro-economic performance and the management quality and policy choices. Louzis *et al.* (2012) examine the relationship between management quality, macro-economic fundamentals and NPL with the data covering Greece's nine largest banks during 2003–2009, and find a positive relationship between NPL and real lending rates. Besides, the result also shows that they find that management inefficiency is positively associated with NPL. This result is in line with Espinosa and Prasad (2010). The financial crisis and recession that began in 2007 brought a sharp increase in the number of bank failures in the United States. Aubuchon and Wheelock (2010) investigated regional patterns in bank failure in the US and found that bank failures during 2007-2010 were concentrated in regions that experienced the most serious shocks from real estate markets and the sharp declines in economy performance. They also argue that banks are vulnerable to localized economic shocks.

There is another strand of the literature focus on predicting NPL at the macro-economic level. Rinaldi and Sanchis-Arellano (2006) model NPL from households' debt for a panel of seven euro area countries. Jappelli *et al.* (2013) model consumer

credit and mortgage debt with the sample covering eleven European countries. The results all indicate that a higher ratio of debt-to-income is related to a higher level of NPL in subsequent periods.

China, covering approximately 9.6 million square kilometers, is the world's third largest country, while it is the most populous country on earth with a population of over 1.35 billion. Given that China has experienced 30 years of rapid economic growth, the industrial structure has significantly changed (Wu and Yao, 2006). The dominated position of agriculture has been replaced by manufacturing and services. At the provincial level, the structural change is even more pronounced. Afterwards, it would be bias when study a topic related to this immense country solely from information at the national level. For instance, GDP per capita in current price of China in 2012 was 6,075.92 in US dollar. However, this indicator was much higher in coastal regions like Jiangsu province (USD10,827) and Zhejiang province (USD10,022), while it cannot provides accurate view of the situation in inland regions like Gansu province and Guizhou province where GDP per capita are USD3,482 and USD3,100 separately (Source: IMF). Due to this reason, there are numerous studies have been carried out with indicators from provinces, autonomous regions and direct-controlled municipalities (Li and Xu, 2008). Besides, the study should take into account not only regional economic disparity, but also regional development policy, because these policies may have an influence on the magnitude and direction of inequality in a country (Kanbur, 2000).

The reform and opening policy has led to China's remarkable double-digit growth for most of the past three decades (see Table 5.1 and Figure 5.1). Nominal GDP has dramatically increased from RMB1,871.8 billion in 1990 to RMB 9,800 billion in 2000 and RMB 51,932 billion in 2012. In the initial stage of the economic boost era, the open cities and special economic zones in coastal regions have been benefited by the policy priority firstly. This situation was caused by Deng Xiaoping's concept that we should let some regions to achieve prosperity firstly. Thus these

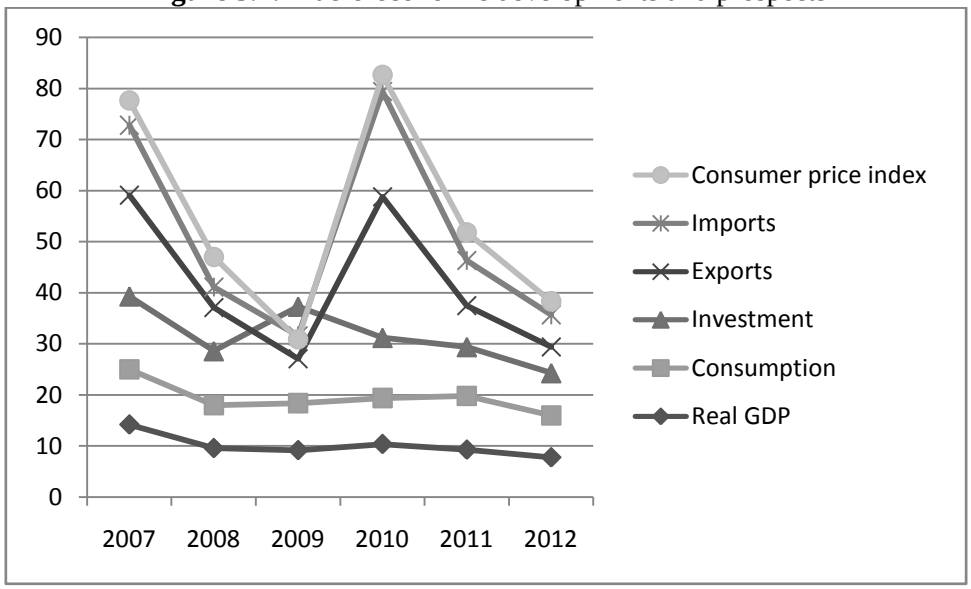
regions could become engines for economic development of the rest regions. Owe to this policy, the development of inland regions lagged further behind coastal regions, and expanding economic disparity among regions, which eventually became a political and social problem. Economic disparity didn't shrink until the mid-1990s, when China's development strategy shifted to the reduction of regional economic disparity, followed by a series of specific programs, such as the Great Western Development Strategy in 1999, the Northeast Area Revitalization Plan in 2002 and the Rise of Central China Plan in 2004. With the help of these programs, reorientation of infrastructure investment towards the less prosperous regions has contributed to reducing regional inequality. There are nine provinces/ direct-controlled municipalities/ autonomous regions out of top ten fastest growth provinces/ direct-controlled municipalities/ autonomous regions are located in inland region in 2012. For example, real GDP growth rate of Chongqing province, Guizhou province, and Yunnan province are 13.6%, 13.6%, and 13.0% separately, while some coastal regions have slowed down their growth below 10%. However, in terms of GDP volume, the coastal regions still keep ahead of inland regions, which nominal GDP of Guangdong province (USD904, 046 million) is about thirty times of Qinghai province (USD29,854 million). All these demonstrate the wide gap still exists.

Table 5.1: Macro-economic developments and prospects

	2007	2008	2009	2010	2011	2012
% change						
Real GDP	14.2	9.6	9.2	10.4	9.3	7.8
Consumption (households and government)	10.8	8.4	9.2	9.0	10.5	8.2
Investment (fixed capital and inventories)	14.3	10.6	18.9	11.8	9.6	8.3
Exports	19.8	8.5	-10.2	27.6	8.1	5.1
Imports	13.7	4.0	4.5	20.6	8.8	6.3
Consumer price index	4.8	5.9	-0.7	3.2	5.5	2.6

Source: National Bureau of Statistics, OECD Economic Outlook database.

Figure 5.1: Macro-economic developments and prospects



There is a series of literature discussed the relationship between financial intermediation development and regional disparity (e.g. Zhang, 2000; Park and Sehrt, 2001; Chen *et al.*, 2010). These studies suggest that the banking system plays an important role in amplifying regional development disparity, because that the urban bias of state-owned banks leads to the concentration of cheap loan in the developed area. Moreover, we can discover that the high growth rates achieved by inland regions in recent years are also driven by the enormous amounts of fixed asset investment introduced by the government. To achieve this high level of fixed investment, the regions concerned will need to raise funds through the financial systems of both their and other regions, especially through the banking system. Additionally, considering that a certain amount of fixed investment as the part of four trillion stimulus plan in recent years, which is mainly channeled into infrastructure construction and excess capacity industries, it will become the potential source of default risk for banking system in the following five to ten years.

According to Ozgulbas and Koyuncugil (2010), the early warning system (EWS) is a system applied to predict the probable unfavourable movement, thus reduce crisis risk of cases, affairs transactions, systems, phenomena, firms and people. More specifically, a financial EWS is a monitoring system which alerts the potential risks

and shocks before they influence the financial system soundness. This system mainly targets on financial risk, macro-economic shocks, and potential bankruptcies. Motivated by financial crises, the IMF has taken a lead in developing EWS models with an influential paper by Kaminsky *et al.* (1998). Then there is a large amount of literature dedicates to develop the statistical forecasting models (e.g. Frankel and Rose, 1996; Berg and Pattillo, 1999; Kamin *et al.*, 2001). In light of these researches, private sector has also implemented various models to predict financial system vulnerability (e.g. JP Morgan, 1998; Goldman Sachs, 1998; Deutsche Bank, 2000; Credit Suisse First Boston, 2001). These studies usually investigate both internal and external factors, as predictive variables. Given that the EWS tracks the historical information of financial crises in a country or region, the relative contribution to these crises of the external and domestic variables included in the EWS can be calculated as well. Due to that the EWS models contain substantial value for policy makers to assess underlying vulnerabilities and take pre-emptive steps, the performance of EWS models, especially that of out-of-sample forecast has become the major concern (Berg *et al.*, 2005).

There are two main approaches in the empirical literature of the EWS: the signal extraction approach and the econometric approach.

The signal extraction approach was firstly introduced by Kaminsky *et al.* (1998) into the EWS system. The Kaminsky-Lizondo-Reinhart (KLR) model, designed prior to the 1997 crisis, has achieved a fairly satisfactory prediction that most vulnerable countries have suffered the hit of the following crisis. They found three most useful indicators -such as real exchange rates, stock prices, and the ratio of public sector deficits to GDP -out of the 16 potential indicators, which measure the degree of financial liberalization, balance-of-payment conditions, and real and fiscal sector developments (Kaminsky and Reinhart, 1999). Later studies such as Goldstein *et al.* (2000) and Rojas-Suarez (2001) followed this method.

The multivariate logit/probit model is generally the most popular model for the

econometric approach. Demirgüc-Kunt and Detragiache (1998) examine the determinants of banking distress, using panel data covering 65 developed and developing economies for 1980–1994, with the help of the multivariate logit/probit model. The pooled logit model gradually accepted by most literature because that accounting for time- and country-specific effects leads to better in-sample fit (e.g. Davis and Karim, 2008; Duca and Peltonen, 2013; Sarlin and Peltonen, 2013). Within the following studies, a set of explanatory variables estimated including macro-economic, financial, institutional and past-distress variables (see Demirgüc-Kunt and Detragiache 2002, 2005; Domac and Martinez-Peria, 2003; Lestano *et al.*, 2003). Besides the most popular macro-economic and financial variables, there was an increased attention on studying institutional development. Kaufmann *et al.* (2010) developed a useful indicator, known as KKZ institutional index, which measures country-level differences in institutional development consists of six dimensions: voice accountability, political stability, government effectiveness, regulations quality, rule of law, and control of corruption.

As mentioned before, most studies have focused on the US and the EU banks. Until the late of 1990s, studies emerged to analyze banking failure in developing countries during the global financial crisis, such as Latin America (Gonzalez-Hermosillo, 1999), East Asia (Rahman *et al*., 2004), and the Gulf Cooperation Council countries (Maghyereh and Awartani, 2014). In China, the researchers didn't pay enough attention to the EWS until the Asian financial crisis burst in 1997. For early warning indicator system, the one designed by Liu (1999) consists with the performance of domestic financial institution and economic fundamental. Then, the indicator portfolio expands covering three main groups, such as micro-economic indicator (default rate of individual company, z-score of financial institution), macro-prudential indicator (e.g. GDP growth, inflation and money supply), and financial market indicator (e.g. securitization ratio and price earning ratio) (He, 2001; Dong, 2004; Chen, 2006; Pong and Li, 2009). For empirical study, the KRL signal extraction

approach and logit/probit econometric approach are broadly applied (Xin and Gao, 2004; Shi and Mou, 2005; Chen *et al.*, 2006). They found that GDP growth, inflation and export are significantly related to China's financial stability as macro-economic proxy, while some financial market indicator like domestic credit/GDP and private sector credit/GDP are closely correlated with the probability of occurrence of financial distress.

5.3. Data and Methods

In our analysis we adopt a general-to-specific approach aimed at identifying determinants of NPLR. We start with single-equation panel regressions including the whole list of possible explanatory factors of NPLR. We estimate

$$NPLR_{i,t} = C + \alpha X_{i,t} + \eta_i + \varepsilon_{i,t} \quad (1)$$

where $X_{i,t}$ represents the vector of endogenous and predetermined variables, including lags of the dependent variables; i=1,..., N is the cross-section indicator; t=1, ..., T is the time indicator; α expresses a vector of coefficients of $X_{i,t}$; η_i is a time-invariant unobserved region-specific effect; $\varepsilon_{i,t}$ is a vector of disturbances; and C is constant. Lags of the explanatory variable and NPLR itself are included to explore the effect of omitted explanatory variables and the persistence of NPLR.

There is wide range of statistical methods of the EWS such as linear regression, decision trees, neural networks and hazard models. In practice, logit/probit regression model is one of the most popular methods. In our application of the probit approach to study banking stability indicators for China can be described through the following equation:

$$P_{i,t} = \alpha X_{i,t} + \varepsilon_{i,t} \quad (2)$$

where $P_{i,t}$ denotes a variable positively correlated with the likelihood of an occurrence of banking instability in region i at time t. Due to the fact that $-\infty < P_{i,t} < +\infty$ is not observable, we use the observable binary dependent variable $Y_{i,t}$, which takes on a

value of 1 if banking distress actually occurs in region *i* at time *t* and 0 otherwise, using the following rule:

$$Y_{i,t} = \begin{cases} 1 & if P_{i,t} > 0 \\ 0 & otherwise \end{cases} \quad (3)$$

We follow the definition used by Demirgüc-Kunt and Detragiache (1998) for the dependent variable, in which the region is defined as an unstable region if at least one of the following two conditions is satisfied:

(1) The NPLR in the banking sector is larger than 10%.

(2) A systemic bank failure occurs or emergency measures are enacted for rescuing systemic banking problems.

Table 5.2: Variables' Description and Data Sources

Variables	Description	Main Source
NPLR	Ratio of non-performing loans to gross loans, in percent	China Banking Regulatory Commission (CBRC)
GDP	Gross domestic production index	National Bureau of Statistics of China (NBSC)
GDPP	Gross domestic production per capita	NBSC
UNE	Unemployment rate in percent	NBSC
CPI	Consumer price index	NBSC
RPI	Retail price index	NBSC
EXP	Annual change in regional export in percent	NBSC
FDI	Foreign direct investment	NBSC
FIX	Fixed asset investment	NBSC
HP	House price	NBSC

As shown in Table 5.2, we start by including the whole list of the independent variables following both the theoretical and empirical literature. GDP, unemployment rate, and the annual change in regional export are chosen as indicators of general macro-economic performance and economic cycle, because that the stability of economic fundamentals is the premise of a healthy financial system and weak economic fundamentals are more likely to amplify potential shocks to a systemic banking problem. Therefore, GDP growth and export are expected to be negatively related with NPLR, while the unemployment rate is positively related with NPLR.

Consumer price index (CPI), retail price index (RPI), and changes in the housing

price are included as additional indicators of the state of the macro-economic and financial environment that may influence loan quality. Real estate is been chosen for several reasons. First of all, real estate loan is one of the most critical components of bank assets. Moreover, commercial property has a widespread use as collateral for other kinds of loans. Consequently, Davis and Zhu (2009) pointed out that house prices are correlated with prices of commercial property, which has also been a source of major bank losses during financial crises. In China, loans for real estate sector have grown to RMB 11.74 trillion (September 2012 a growth of 12.1%), while housing mortgages reached RMB 2.2 trillion at the end of 2011 maintaining rapid growth (Source: China Banking Regulatory Commission). Despite the fact that the growth of the proportion of real estate loans in total banks' loans slowed down under regulation, the amount of real estate loans still increased by RMB 565.3 billion. As Allen and Gale (2000) suggest, asset price inflation, amplified by credit expansion, is a potential risk for banking stability. Additionally, owing to that real estate is the major item of collateral, banks would be less willing to service the debt in the case of the real estate value declines. Owing to that the bank is the major finance resource of fixed asset investment nowadays in China, the volume of fixed asset investment has a direct impact on the credit exposure on the bank's loans. In short, rising asset price is able to help banks against unexpected adverse shocks by boosting the value of the underlying assets used as collateral, thus, real estate price changes are assumed to be negatively related with NPLR.

The impact of inflation on bank's debt servicing capacity and loan quality could be positive or negative through diverse channels. High inflation level is typically associated with low unemployment as the Phillips' curve suggests. Additionally, high inflation reduces the real value of outstanding loans. Hence, it will enhance the debt service capacity of the bank system. However, the impact could be opposite through weakening the debt service capacity by reducing real income.

Regarding the fast growth of fixed asset investment which is mainly supported by

banking sector, it leads to more susceptible for debtors when they face adverse shocks. Therefore, it is possible to weaken debt servicing capacity of debtors. In economic upturns, the swift expansion of borrowers' indebtedness would indicate inadequate risk management or a softening of lending standards. Thus, it would be positively related with succeeding periods' NPLR.

GDP per capital is also selected as a proxy for institutional quality in the EWS model following previous studies (e.g. Demirgüc-Kunt and Detragiache, 1998; Rodrik, 2003). They found that institutional quality is positively correlated with GDP per capital and negatively correlated with the probability of banking instability, because a good institutional quality usually implies the existence of an effective banking regulation.

The dependent variable - non-performing loan ratio (NPLR) - is defined as the ratio of overdue loans to gross loans. According to the "Loan Quality Assessment Guidelines", non-performing loan ratio = (sub + doubtful + loss) / total loans. The use of NPLR in the remainder of the study refers to this definition.

For the logit/probit EWS model, we only employ lagged explanatory variables in order to emphasize the function of this model as a leading indicator. We set the maximum time lag of the explanatory variables to two years.

Table 5.3: Summary Statistics (2002-2011)

Variables	Mean	Median	Maximum	Minimum	Std. Dev.
NPLR	9.21	6.00	37.30	0.57	8.63
GDP	112.69	112.70	123.80	105.40	2.21
GDPP	23351.59	19074.00	85213.00	3701.00	16184.05
CPI	103.09	103.00	110.10	97.70	2.25
RPI	102.41	102.30	110.60	96.80	2.48
UNE	3.77	3.90	6.50	1.30	0.66
FIX	5085.84	3509.66	26749.68	133.96	4830.81
EXP	0.27	0.27	1.65	-0.69	0.28
FDI	634.87	232.00	5728.51	3.31	988.69
HP	3556.21	2797.58	17782.00	1210.00	2526.64

We employ an annual panel data from 2002 to 2011 for a sample of 22 provinces, four

direct-controlled municipalities and five autonomous regions in China (totaling 31 regions; see Appendix D, Table D.1). The NPLR ratio data comes from the website of China Banking Regulatory Commission, which covers the commercial banks, the state-owned commercial banks, the joint-stock commercial banks, the city commercial banks, the rural commercial banks and the foreign banks. The time interval is constrained by the availability of long enough NPLR time series which are published since 2003. Due to the unavailability of NPLR data, the sample is unbalanced. The use of panel data offers the benefit of increasing the sample size while having a cross-region perspective.

The list and description of variables used in the analysis are in the Table 5.3. The explanatory variable list covers GDP growth (GDP), GDP per capita (GDPP), unemployment (UNE), consumer price index (CPI), retail price index (RPI), change in export (EXP), foreign direct investment (FDI), fixed asset investment (FIX), and real-estate price (HP).

5.4. Empirical Results

Over the last decades, China's government has implemented a series of economic development plans to support the regional economy to reduce the gaps between provinces. However, different regions are in different paces of economic development, so that the problems they faced are different as well. The eastern region was characterized by an export-oriented economy with clustered foreign financial institutions. Consequently, the development was largely affected by quick international capital flow and active private financing which are highly risky issues. The growth of the central region has accelerated significantly by accepting industry transferred from the eastern region, while the industry structure has been improved simultaneously. Nonetheless, excess capacity in some traditional advantage industry becomes the new potential risk factors. The western region which was the less developed region maintained fast growth trend. With this trend, the assets of banking

sector expanded quickly, when the outdated risk management is not able to handle the potential risks in property credit and financing platform.

In 2011, the operating scale of the banking sector in all regions continued to expand. The total assets of the banking sector in eastern, central, western, and north-eastern regions reached RMB59.34 trillion, RMB15.50 trillion, RMB18.97 trillion, and RMB7.49 trillion, up 17.44%, 16.69%, 21.76% and 16.07% respectively. The share of the banking sector in eastern region dropped continually. However, it still takes down about 50% of the entire banking industry with a certain amount of headquarters of the large commercial banks and foreign-funded banks located here. The assets size of the banking sector in the western region maintains the fastest growth in the four regions and the share of the western region increased by 0.58 percentages. Among the 14 provinces whose assets size of the banking sector grew more than 20%, 10 provinces are located in the western region, including Tibet (29.27%), Chongqing (26.25%), and Xinjiang (26.03%).

Along with the expand trend of asset size, the overall asset quality also improved to some extent. Both the non-performing loan (NPL) and NPL ratio decreased continually. As the end of 2011, the outstanding NPLs in eastern, central, western, and north-eastern areas reached RMB376.94 billion, RMB248.23 billion, RMB198.97 billion, and RMB167.96 billion, and NPLRs are 1.2%, 3.03%, 1.89% and 4.22% respectively (see Appendix D, Figure D.1). Among all the four regions, the NPLs in western region dropped most by RMB68.79 billion while the NPL ratio declined by 1.41 percentage. Even with significant growth of banking sector in 2011, downside risks to the regional economy gradually emerged. Under such circumstances, underlying credit risk of loans extended to certain industries and areas is likely to surface. First, there is lending risk related to local government financing platform companies (FPC). Currently, debt of local government FPC was approaching centralized payment period, together with economic slowdown and decrease in revenue from selling lands, the short term solvency of local government may be

affected. Second, asset quality is possibly undermined by adjustments in the real estate sector. The house price may drops due to a series of national macro management policies. Considering the strong correlation between real estate and other sectors, the adjustment of the real estate sector would directly affect the loan quality of the real estate sector and its upstream/downstream industries, thus lead to higher default risk of mortgage loans.

Since the stochastic variables included in the long-run equation are mostly non-stationary, it is important to establish first the stationarity of the residuals of the cointegrating equation before proceeding to the second stage. Thus, residual tests were undertaken to ensure that the requisite statistical properties are satisfied. To inform model specification, we examine the level of integration of the variables. The results in Table 5.4 suggest that most series are stationary in levels and others are stationary in first-difference. We use tests proposed by Levin *et al.*, (2002) which assume common unit root processes, and the Fisher-ADF and Fisher-PP tests (Maddala and Wu, 1999), which assume individual unit root processes across regions included in the panel. The Fisher test based on the p-values of individual unit root tests, and assumes that all series are non-stationary under the null hypothesis against the alternative that at least one series in the panel is stationary. The results suggest that, all variables are stationary in levels.

Table 5.4: Panel Unit Root Tests

Variables		Assumes common unit root process	Assumes individual unit root processes	
		Levin, Lin & Chu t	ADF - Fisher	PP - Fisher
NPLR	Level	-15.41***	95.09***	157.79***
ln(GDP)	Level	-7.06***	67.96	124.43***
ln(GDPP)	Level	-8.04***	57.19	98.08***
UNE	Level	-10.20***	94.87***	147.47***
ln(CPI)	Level	-24.97***	192.33***	243.62***
ln(RPI)	Level	-19.19***	150.22***	250.15***
EXP	Level	-10.78***	120.06***	206.49***
ln(FDI)	Level	-11.77***	75.64	79.23*
ln(FIX)	Level	-5.41***	96.99***	116.41***
ln(HP)	Level	-8.64***	81.24*	105.22***

*, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively;
Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

We conduct models using several econometric specifications presented in Table 5.5,

including OLS, two-way fixed effects, and random effects. First, we fit an OLS model including lags of the dependent variable as explanatory variables. We follow up with a fixed effects model. The statistics of the Fisher and chi-square test suggest the country-specific fixed effect is appropriate in models.

Table 5.5: Determinants of Non-Performing Loans

Explanatory variables	OLS		Fix-Effect	
	(1)	(2)	(1)	(2)
C	471.36*** (95.48)	348.39*** (66.45)	489.97*** (114.37)	458.05*** (95.07)
NPLR_{t-1}	0.75*** (0.07)	0.76*** (0.07)	0.69*** (0.08)	0.68*** (0.08)
NPLR_{t-2}	0.03 (0.07)	0.03 (0.07)	0.01 (0.09)	0.07 (0.09)
$\ln(GDP)$	10.66 (10.56)		12.35 (13.36)	
$\ln(GDP)_{t-1}$	20.64* (11.60)		20.10 (12.57)	
$\ln(GDP)_{t-2}$	-35.56*** (9.73)		-32.02*** (12.26)	
$\ln(GDPP)$		-8.81* (5.02)		-1.28 (6.36)
$\ln(GDPP)_{t-1}$		17.27** (8.03)		15.58* (8.21)
$\ln(GDPP)_{t-2}$		-8.84* (5.05)		-5.66 (5.94)
$\ln(CPI)$	-38.65*** (8.72)		-41.97*** (11.02)	
$\ln(CPI)_{t-1}$	-36.19*** (8.34)		-38.33*** (0.07)	
$\ln(CPI)_{t-2}$	-21.21** (9.78)		-24.20* (12.34)	
$\ln(RPI)$		-24.63*** (8.86)		-37.93*** (10.66)
$\ln(RPI)_{t-1}$		-43.07*** (9.44)		-50.25*** (10.57)
$\ln(RPI)_{t-2}$		-6.07 (9.13)		-16.34 (11.37)
UNE	0.52 (0.70)	-0.19 (0.73)	0.27 (0.93)	-0.91 (0.95)
UNE_{t-1}	-1.08 (0.95)	-0.45 (1.01)	-1.72* (1.04)	-1.02 (1.08)
UNE_{t-2}	0.57 (0.70)	0.53 (0.73)	1.04 (0.84)	1.07 (0.86)
EXP	-0.42 (0.63)	-0.01 (0.68)	-0.34 (0.73)	-0.09 (0.78)
EXP_{t-1}	0.81 (0.66)	0.23 (0.71)	0.65 (0.77)	0.00 (0.82)
EXP_{t-2}	-1.83*** (0.63)	-2.12*** (0.65)	-2.12*** (0.77)	-1.95** (0.78)
$\ln(FDI)$	0.00 (0.64)	0.82 (0.64)	0.03 (0.81)	0.85 (0.78)

$\ln(FDI)_{t-1}$	-0.36 (0.89)	-1.32 (0.90)	-0.58 (0.95)	-0.94 (0.95)
$\ln(FDI)_{t-2}$	0.38 (0.60)	0.57 (0.63)	0.57 (0.75)	0.75 (0.76)
$\ln(FIX)$	-2.38 (2.31)	-1.58 (2.36)	-3.68 (2.69)	-4.88* (2.84)
$\ln(FIX)_{t-1}$	4.31 (3.98)	1.63 (4.10)	5.41 (4.27)	3.56 (4.33)
$\ln(FIX)_{t-2}$	-2.15 (2.43)	-0.09 (2.59)	-4.60 (2.91)	-5.05 (3.13)
$\ln(HP)$	-1.81 (1.51)	-1.36 (1.61)	-0.71 (1.99)	-2.27 (2.14)
$\ln(HP)_{t-1}$	-1.85 (1.81)	-3.18 (1.94)	-1.86 (1.93)	-3.66* (2.04)
$\ln(HP)_{t-2}$	3.21** (1.52)	4.31** (1.67)	4.85*** (1.79)	4.91** (1.89)
R-squared	0.93	0.92	0.96	0.93
Adjusted R-squared	0.92	0.91	0.94	0.91
Durbin-Watson stat	2.29	2.34	2.26	2.36
F-statistic	106.45	97.18	56.12	41.60

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively; standard errors in ( ).

The findings of the panel regressions presented in Table 5.5 are generally in line with stylized facts and expectations. First, the coefficients of the lags of NPLR are found to be significant and positive in all three models. This finding indicates that the deterioration of banks' loan quality in the preceding period would generate a prolonged impact on the NPLR in the current period, and this impact doesn't decrease in short-time horizon. It implies that NPLR would worsen relatively slowly when affected by a shock, implying it would be reasonable to anticipate long-term effect. Therefore, this finding suggests that an early warning system should be more reliable to identify the potential adverse shocks to loans in advance. Second, GDP_{t-1} and unemployment rate are found to be, respectively, positively and negatively related to NPLR, which is contrary against our expectation. It may be due to that, during China's banking reforms, the continuous operation of the central bank including stripping bad asset from banks' balance sheet and capital injection reduced the NPL ratio. However, the sign of the coefficient of GDP_{t-2} meets our expectation. Third, our results show a negative relationship between inflation, real estate price, fixed asset investment and the NPLR. Therefore, it confirms that deterioration in the macro-

economic environment is substantially associated with bank distress, and captured by rising NPLR. The results for inflation indicate that high inflation in China would reduce the real value of outstanding loans. Therefore, it will significantly enhance the debt service capacity of banks. Both the R-square and the Durbin-Watson statistics indicate that the model is able to adequately explain the relationship between banks' bad loan and macro-economic dynamics. Besides, the results of Hausman test, Hansen test, and Arellano-Bond test suggest, comparing with random-effect model and GMM model, OLS and fixed-effect model with sector dummy are more appropriate for our regression.

Table 5.6 to Table 5.9 report sub-sample region results based on OLS estimation and two-way fixed-effect estimation respectively, which divide the 31 province/direct-controlled municipalities/ autonomous regions into four geographical regions i.e., east region, central region, west region and north-east region. Similar to the findings from the above aggregate model, macro-economic variables contribute to the build-up in NPLs in the each regions. However, the regression of north-east region failed to provide satisfied results, most probably, because of the small sample size. The NPLRs of the previous period are found to have a significantly positive relationship with NPLRs of next period. The coefficients show that this variable of east region is more sensitive than other regions, which may be caused by increased exposure to guarantee chain risk in the east region, which has negative impact on asset quality of banking institution. Guarantee chain risk, characterized by high industry concentration, with common practices of cross guarantee within the industry, thus, may trigger wide credit risk. Meanwhile, financing entities are connected through guarantee chain which leads to contagion effect among regional banking system, forming a major risk exposure and affecting regional financial stability. Despite some insignificant differences, GDP growth, unemployment rate and inflation all exhibit a strong autocorrelation in all three regions, which are generally consistent with the aggregate model. As the result, a steady economic growth with low unemployment is the fundamental for banking

sector stability. World trade is found having significant correlation, but the signs of the current period and previous period are opposite. It demonstrates that the changes in export business have a lagging effect towards the asset quality of banking institutions. Therefore, some of the export business faces the situation of excess capacity and the uncertainty of appreciation of RMB, the risk would be accumulates during the economic upswing and shows its harm later. The negative correlations of fixed investment indicate that the strong investment demand, especially the infrastructure projects dominated by government, would improve the asset quality of banks. Nevertheless, evidence from east region illustrates the potential risk of overheating infrastructure projects which are supported by the local government financing platform. The pressure of repayment concentrating on the local government financing platform was high with lower growth rate of tax revenue, significant decrease of land leasing revenue and failure to realize expected profit for some projects. Property price is found negatively related with NPLR in central and west region. It may explain the concern about the impact of overheating real estate market towards the banking system. The results indicate that the non-rational increase property price in central and west region would encourage the speculative behaviour and push up financing cost for real-estate company, thus deteriorate banking stability.

Table 5.6: Determinants of Non-Performing Loans in East region

Variables	East Region			
	OLS(1)	FE(1)	OLS(2)	FE(2)
C	223.31*** (77.05)	253.26*** (79.56)	493.07*** (89.76)	441.44*** (79.21)
NPLR(-1)	0.76*** (0.04)	0.71*** (0.05)	0.77*** (0.04)	0.76*** (0.05)
$\ln(GDP)$	2.68 (9.59)	-6.39 (8.37)		
$\ln(GDP)_{t-1}$	-9.22 (10.48)	-10.37 (8.47)	11.08 (9.04)	3.04 (7.42)
$\ln(GDP)_{t-2}$			-15.27* (8.99)	-12.21** (5.92)
$\ln(CPI)$	-6.87 (9.78)	-5.36 (8.17)	-42.14*** (8.38)	-31.60*** (7.08)
$\ln(CPI)_{t-1}$	-34.96*** (12.13)	-31.11*** (9.90)	-31.80*** (8.36)	-29.15*** (6.21)
$\ln(CPI)_{t-2}$			-28.27*** (8.47)	-25.18*** (7.51)
UNE	-0.45 (0.66)	-0.49 (0.67)		
UNE_{t-1}	0.56 (0.62)	-0.69 (0.63)	0.22 (0.20)	-0.05 (0.63)
EXP	-2.89** (1.42)	-2.89** (1.25)		
EXP_{t-1}	1.47 (1.01)	1.69* (0.96)		
EXP_{t-2}			-2.16*** (0.78)	-1.74* (0.94)
$\ln(FDI)$	0.04 (0.58)	0.17 (0.83)		
$\ln(FDI)_{t-1}$	-0.45 (0.60)	-1.10 (0.83)		
$\ln(FIX)$	-3.15 (2.23)	-3.93** (1.95)	0.08 (0.18)	-0.77 (0.72)
$\ln(FIX)_{t-1}$	3.55 (2.15)	3.59* (1.92)		
$\ln(HP)$	0.36 (1.71)	1.60 (1.26)		
$\ln(HP)_{t-1}$	-0.27 (1.73)	-0.55 (1.31)	0.49 (1.64)	-1.26 (1.16)
$\ln(HP)_{t-2}$			-0.63 (1.61)	2.10 (1.26)
R-squared	0.96	0.98	0.95	0.98
Adjusted R-squared	0.95	0.96	0.94	0.97
Durbin-Watson stat	1.92	2.04	2.14	2.29
F-statistic	102.68	90.41	98.43	117.48

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively; standard errors in ( ).

Table 5.7: Determinants of Non-Performing Loans in Central region

Variables	Central Region			
	OLS(1)	FE(1)	OLS(2)	FE(2)
C	355.22** (142.91)	28.78 (188.76)	876.19*** (216.17)	863.27*** (239.19)
NPLR(-1)	0.79*** (0.08)	0.29* (0.51)	0.85*** (0.08)	0.32* (0.18)
$\ln(GDP)$	38.20* (19.22)	48.29** (20.61)		
$\ln(GDP)_{t-1}$	-3.49 (17.46)	26.57 (17.50)	16.48 (16.15)	42.44** (15.79)
$\ln(GDP)_{t-2}$			-58.82*** (18.70)	-38.24** (16.72)
$\ln(CPI)$	-27.51 (16.58)	3.83 (16.76)	-65.49*** (19.60)	-65.18*** (22.85)
$\ln(CPI)_{t-1}$	-85.97*** (17.56)	-68.89*** (15.15)	-41.39** (16.85)	-46.95*** (15.93)
$\ln(CPI)_{t-2}$			-37.89 (25.03)	-65.28** (30.14)
UNE	4.73*** (1.61)	2.96* (1.61)		
UNE_{t-1}	-3.69** (1.64)	-2.25 (1.57)	0.02 (0.69)	1.30 (1.52)
EXP	0.10 (1.60)	-1.26 (1.49)		
EXP_{t-1}	5.98*** (1.43)	5.11*** (1.47)		
EXP_{t-2}			-3.78** (1.50)	-1.67 (1.57)
$\ln(FDI)$	6.57* (3.25)	3.70 (3.52)		
$\ln(FDI)_{t-1}$	-8.84*** (3.02)	-8.50** (3.13)		
$\ln(FIX)$	0.98 (4.61)	-4.90 (4.09)	-0.54 (0.64)	-6.65*** (1.67)
$\ln(FIX)_{t-1}$	0.81 (4.46)	3.89 (3.31)		
$\ln(HP)$	6.67 (3.97)	4.50 (3.69)		
$\ln(HP)_{t-1}$	-7.18* (4.12)	-10.29** (4.32)	-3.46 (3.58)	-3.08 (3.04)
$\ln(HP)_{t-2}$			3.44 (3.96)	2.73 (3.41)
R-squared	0.97	0.99	0.96	0.98
Adjusted R-squared	0.96	0.97	0.95	0.97
Durbin-Watson stat	2.64	2.14	2.27	1.94
F-statistic	68.62	90.42	71.93	98.20

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively; standard errors in ( ).

Table 5.8: Determinants of Non-Performing Loans in West region

Variables	West Region			
	OLS(1)	FE(1)	OLS(2)	FE(2)
C	387.46*** (89.98)	481.86*** (95.07)	549.97*** (108.22)	751.44*** (84.56)
NPLR(-1)	0.59*** (0.06)	0.26** (0.09)	0.59*** (0.07)	0.15* (0.09)
$\ln(GDP)$	-22.48 (15.43)	-24.38* (12.84)		
$\ln(GDP)_{t-1}$	16.81 (15.23)	-1.77 (12.62)	31.77** (14.06)	-3.63 (8.94)
$\ln(GDP)_{t-2}$			-43.48*** (14.23)	-43.28*** (9.37)
$\ln(CPI)$	-27.37*** (10.10)	-25.94*** (7.40)	-39.70*** (9.53)	-28.08*** (6.51)
$\ln(CPI)_{t-1}$	-43.83*** (11.96)	-37.54*** (9.06)	-32.55*** (8.83)	-35.39*** (5.65)
$\ln(CPI)_{t-2}$			-29.39*** (10.78)	-37.19*** (8.16)
UNE	1.31 (1.35)	0.13 (1.51)		
UNE_{t-1}	-1.01 (1.33)	-0.72 (1.27)	0.04 (0.62)	0.72 (1.13)
EXP	-0.10 (0.79)	-1.21** (0.60)		
EXP_{t-1}	1.56** (0.76)	2.59*** (0.58)		
EXP_{t-2}			-0.69 (0.78)	-0.27 (0.66)
$\ln(FDI)$	0.37 (1.10)	0.76 (0.87)		
$\ln(FDI)_{t-1}$	-0.74 (1.05)	-0.67 (0.80)		
$\ln(FIX)$	-0.19 (3.46)	-1.21 (2.67)	-0.05 (0.23)	-3.73*** (1.02)
$\ln(FIX)_{t-1}$	0.62 (3.46)	-2.74 (2.59)		
$\ln(HP)$	-2.63 (2.08)	-1.47 (2.37)		
$\ln(HP)_{t-1}$	-1.50 (2.16)	-2.25 (2.33)	-3.68** (1.84)	-4.40** (1.75)
$\ln(HP)_{t-2}$			0.93 (1.84)	0.24 (1.74)
R-squared	0.89	0.95	0.89	0.97
Adjusted R-squared	0.88	0.93	0.87	0.95
Durbin-Watson stat	2.16	2.21	2.31	2.12
F-statistic	47.17	50.12	51.26	80.96

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively; standard errors in ( ).

Table 5.9: Determinants of Non-Performing Loans in North-east region

Variables	North-east Region			
	OLS(1)	FE(1)	OLS(2)	FE(2)
C	483.92 (1291.49)	-252.40 (1184.25)	2660.06** (935.82)	1871.35*** (739.43)
NPLR(-1)	0.66 (0.55)	0.25 (0.67)	0.09 (0.21)	-0.75** (0.23)
$\ln(GDP)$	66.34 (159.23)	150.84 (147.41)		
$\ln(GDP)_{t-1}$	-28.86 (210.39)	-14.86 (221.29)	138.95 (85.44)	-81.13 (104.64)
$\ln(GDP)_{t-2}$			-113.88 (137.58)	-28.62 (98.44)
$\ln(CPI)$	-18.14 (68.86)	25.40 (75.21)	-211.71*** (53.95)	2.74 (100.79)
$\ln(CPI)_{t-1}$	-99.89 (64,96)	-38.68 (69.36)	-64.63 (45.56)	-28.99 (41.94)
$\ln(CPI)_{t-2}$			-292.62*** (71.24)	-112.80 (94.82)
UNE	1.68 (5.69)	3.29 (5.21)		
UNE_{t-1}	-1.43 (5.26)	-2.89 (5.86)	-2.22** (0.97)	-6.53*** (1.31)
EXP	-3.16 (6.98)	-1.74 (6.68)		
EXP_{t-1}	3.64 (6.05)	-1.09 (6.50)		
EXP_{t-2}			8.35** (3.15)	2.05 (3.14)
$\ln(FDI)$	-0.75 (6.65)	0.25 (6.31)		
$\ln(FDI)_{t-1}$	2.37 (7.67)	0.97 (5.95)		
$\ln(FIX)$	-24.62 (24.37)	-35.27 (31.36)	-6.00 (5.92)	-7.95 (4.94)
$\ln(FIX)_{t-1}$	22.79 (29.04)	37.68 (36.77)		
$\ln(HP)$	-31.12 (35.08)	-31.49 (36.42)		
$\ln(HP)_{t-1}$	18.79 (41.76)	-10.73 (47.40)	-44.99** (17.68)	-77.02*** (15.65)
$\ln(HP)_{t-2}$			36.59** (13.93)	3.23 (12.27)
R-squared	0.97	0.99	0.97	0.99
Adjusted R-squared	0.93	0.95	0.95	0.98
Durbin-Watson stat	3.18	3.04	2.48	2.94
F-statistic	21.37	27.84	38.43	88.95

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively; standard errors in ( ).

The probit model results are presented in Table 5.10. The McFadden R-squared, also known as pseudo R-squared, suggests an acceptable goodness of fit value of 0.53. The LR statistics for both equations suggest that the explanatory variables chosen have a fairly strong effect and probability of decision on in the dummy dependent variable.

The output of Hosmer-Lemeshow test and Andrews test are presented in Table 5.10 as well, whose null hypothesis is that the fit is sufficient to the data. With the p-value, we cannot reject the null hypothesis, so it is reasonable to consider the goodness-of-fit is quite acceptable, and expect well-performed forecast ability.

The estimated coefficients of GDP and CPI are negative, while that of UNE is positive, with all being significant at 10% level. It indicates that banking instability is preceded by slowing economic growth, declining inflation and high unemployment rates. However, the findings of CPI are not completely consistent with the empirical findings by Demirgüc-Kunt and Detragiache (1998, 2000) and Wong *et al.* (2010), which indicate that high inflation may enhance the asset quality of banking sector by reducing the real value of outstanding loans. One possible explanation may be because inflation level in China appears to follow a steady growth trend along with the economic growth and has not show obvious fluctuations. Institutional quality, measured by GDPP, is positively related to banking distress and is statistically significant at the 10% level, which indicates regions with higher institutional quality are found to be more vulnerable to banking distress. Specifically, in China, the east region accumulates more potential banking risks than other regions, due to higher levels of active informal finance and speculative behaviour prevalent in this region. The estimated coefficient of HP is negatively and statistically significant at the 5% level, which is generally consistent with the theory (Allen and Gale, 2000 and Che *et al.*, 2011). Allen and Gale (2000) found that credit expansion is able to accelerate asset price increases, and lead to systemic banking distress. In China, Bank lending also plays one of the most crucial roles in pushing up property prices. Therefore, any bursting of the property price bubble would affect banking stability directly (Che *et al.*, 2011).

Table 5.10: Estimation Results of the Probit Model

Explanatory variables	Coefficients	Standard errors
C	197.36***	66.84
$\ln(GDP)_{t-1}$	11.49	7.59
$\ln(GDP)_{t-2}$	-14.96*	8.32
$\ln(GDPP)_{t-1}$	-1.69	1.06
$\ln(GDPP)_{t-2}$	1.98*	1.06
$\ln(CPI)_{t-1}$	-16.46**	7.45
$\ln(CPI)_{t-2}$	-17.59**	7.16
UNE_{t-1}	0.47*	0.25
EXP_{t-1}	0.51	0.55
$\ln(HP)_{t-1}$	-2.38**	0.98
$\ln(HP)_{t-2}$	-1.25	0.98
McFadden R-squared	0.54	
Log likelihood	-73.40	
LR statistic	169.89	
H-L Statistic	4.88	
Andrews Statistic	37.14	
Prob. Chi-Sq(8)	0.77	
Prob. Chi-Sq(10)	0.0001	
Number of observation	247	

Note: ***, **, and * denote significance at1 percent, 5 percent, and 10 percent, respectively.

The predictive power of the model is the crucial element of the early warning system for banking distress. Table 5.11 shows the effect of forecast of the estimated model, with the cutoff of 0.5, equaling to the threshold of the model. The observations are classified as having predicted probabilities that are above or below the cutoff value in the left-hand, while the observations are classified using the predicted probability given by the sample proportion of y=1 observations in the right-hand. "Correct" classifications are obtained when the predicted probability is less than or equal to the cutoff and the observed y=0, or when the predicted probability is greater than the cutoff and the observed y=1. In our predicted results above, 148 of the Dep=0 observations and 69 of the Dep=1 observations are correctly classified by the estimated model.

Specifically, the proportion of correct classification is 87.9% indicating that the model correctly predicts 87.85% of the observations (90.80% of the Dep=0 and 82.14% of

the Dep=1 observations).The gain in the number of correct predictions obtained in moving from the right table to the left table reflects the predictive ability of model. The gains are reported in both absolute percentage increases (Total Gain), and as a percentage of the incorrect classifications in the constant probability model (Percent Gain). This model predicts that all 163individuals will have Dep=0. This prediction is correct for the 163 y=0 observations, but is incorrect for the 84 y=1observations. The estimated model improves on the Dep=1 predictions by 82.14 percentage points, but does more poorly on the Dep=0 predictions (-9.20 percentage points). Overall, the estimated equation is 21.86 percentage points better at predicting responses than the constant probability model. This change represents a 64.29 percent improvement over the 65.63 percent correct prediction of the default model, which indicates good forecasting capability of our model and methods.

Table 5.11: Expectation-prediction Result

	Estimated Equation			Constant Probability		
	Dep=0	Dep=1	Total	Dep=0	Dep=1	Total
P(Dep=1)<=C	148	15	163	163	84	247
P(Dep=1)>C	15	69	84	0	0	0
Total	163	84	247	163	84	247
Correct	148	69	217	163	0	163
% Correct	90.80	82.14	87.85	100.00	0.00	65.99
% Incorrect	9.20	17.86	12.15	0.00	100.00	34.01
Total Gain*	-9.20	82.14	21.86			
Percent Gain**	NA	82.14	64.29			

*Change in "% Correct" from default (constant probability) specification
**Percent of incorrect (default) prediction corrected by equation

5.5. Conclusion

The global financial crisis in 2008 has emphasized the challenges posed by rising NPLR in advanced economies. Although China has been relatively unaffected, there are lessons that can be learnt from a comprehensive examination of the relationship between NPLR and macro-economic performance. Our analysis is the first to examine

NPLR from a sample that covers most regions in China and data related to the recent crisis.

Using the panel data from 2002 to 2011 for 31 regions in China, this study identifies the determinants of NPLs in regional China's banking sector and examines a set of leading indicators of banking instability. Furthermore, we develop an EWS model to estimate the probability of an occurrence of banking distress. Our empirical results support the view that macro-economic performance determines the level of non-performing loans. In particular, we found strong evidence of a significant relationship between inflation, real estate price, fixed asset investment and nonperforming loans. The study also showed that change in export and foreign direct investments have an effect on NPLs of banks. This implies that regulators and central banks in China have to be wary about increasing NPLs during periods of low growth and tight financing. The EWS model suggests that slowing economic growth, declining CPI, an increase in unemployment would deteriorate asset quality of banks. In addition, the asset price, which is generally pushed up by strong credit expansion, is useful leading indicators of banking distress.

The empirical findings of this chapter have both practical applicability and policy implications for banking regulation in regional China. The regressions' coefficients along with assumptions on macro-economic variables and asset prices are able to be used in a macro-stress testing to assess the stability of banking sector based on some indicative threshold. Moreover, our study highlights the central role of NPL. As that NPLR is still a permanent feature of banks' balance sheets, policies makers should pay attention to prevent excessive risk-taking during upturns. It also suggests that a stronger focus on macro-prudential regulation, particularly through capital and liquidity buffers, and countercyclical provisioning, could help mitigate the impact of macro-economic risks on the banking system. From a policy perspective, the EWS is substantial valuable to anticipate banking distress for supervisors if it is employed carefully and sensibly. Developing a reliable EWS, which is able to obtain clearer

signals to inform regulators to take action to prevent financial turmoil, could be one of the major targets for policy makers.

However, this analysis is subject to some drawbacks. First, the NPLR is a general measure of loan quality. Accordingly, the flow of debt classified as non-performing loan for the first time would be more informative. Second, the importance of banks in the overall credit allocated to the private sector differs across regions because of the involvement of non-bank financial institutions. Thus, it is difficult to assess the macro-financial stability only with NPL from the balance sheets of banks.

CHAPTER 6

Conclusion

This chapter is divided into 3 sections. The first section provides a brief summary of this study. The second section discusses the limitations of this research. The last section provides some directions for further research focusing on the subject matter for reducing the effect of the limitations.

6.1. Summary

The major purpose of risk management is to identify and control the potential risk in a logical and systematic way. Appling the appropriate credit risk management strategy would definitely offer the banking sector greater capacity to minimise losses when it confronts risks. Hence, the impact of risk management for the banking system could be significantly improved by the ability of those concerned to measure credit risk. In this way, both banks and the supervisors can construct the optimal plan to manage and monitor the credit risk in a portfolio with the help of the forecasted credit loss distribution: for example, actions on the loan loss reserves or selling loans to reduce risk.

Although there was a range of traditional credit risk method, the arrival on the scene of the Basel Accord I, II and III have made impressive progress in this field, including the detailed instruction of risk assessment for financial institutions, the 8% capital requirement of the total of operational capital, and - most important – the three pillars framework. The capital requirement is emphasised in the first pillar. The second pillar illustrates the supervisory review process with tool sets for risk measurement. The third pillar focuses on market discipline, which means that information disclosure is accessible for both the market and the stakeholders. Generally, the widespread implementation of the Basel Accord is beneficial for

banking systems to assess their risk exposure following a much clearer and easier process. With the clear identification of risk exposure, it is possible to achieve an effective risk management practice with lower cost, wider coverage of risks, and *ex ante* risk management action. Furthermore, the monetary policy maker and supervisor authority might be availed of a range of tools like stress-testing and the early warning system, with which to monitor the healthy financial environment of growth. Therefore, to reduce the vulnerability of a financial system, it is necessary to have a better understanding of characteristic of risk factors of the system and apply these methods which are discussed throughout this thesis.

This thesis studied financial stability in China (specially, in the Chinese banking system). Considering NPL as a factor that increases financial pressures on the macro economy and hence financial instability that the monetary authority or central bank should be aware of, Chapter 2 has provided a literature review of financial stability, risk management for the banking sector, and China's banking system in general. The philosophy and methodology issues of this thesis were discussed in detail in Chapter 3. Chapter 4 has developed a framework for macro stress-testing of credit risk for the banking system in China. This framework was used to measure the financial stability of the banking system in response to shocks in different macro-economic variables. We utilised VAR models and analysed eight macroeconomic variables, with the macroeconomic credit risk models successfully explaining the impact of severe macro-economic shocks on the balance sheet of banks. Macro stress-testing was used to assess the financial stability of the banking system. We combined the historical method and the hypothetical method to produce three stress scenarios with various artificial shocks including GDP growth shocks, interest rate shocks, and exchange rate shocks. Thereafter, the distribution of possible NPLRs, derived from the Monte Carlo method, was simulated, and the value-at-risk for credit risk was calculated.

Chapter 5 uses the panel data from 2002 to 2011 for 31 regions in China to identify the determinants of NPLs in regional China's banking sector and examines a

set of leading indicators of banking instability. Furthermore, we develop an EWS model to estimate the probability of an occurrence of banking distress throughout different regions.

Chapter 4 indicated two key points: first, there are some significant relationships between the default rates and macroeconomic factors, such as GDP growth, the unemployment rate, the interest rate, and the exchange rate, which are focal concerns for macro stress-testing perspectives; and second, the banking system in China would be healthy in the case of interest rate shocks, but in the case of GDP growth and exchange rate shocks the NPLR of banks would climb beyond the limit of 2%. Although from a macro prudential perspective China emerged unscathed from the GFC, the Central Bank of China should learn the lessons of risk management from Western countries and encourage commercial banks to carry out both micro stress-testing and macro stress-testing under the framework of the FSAP. In the case of the policymakers, they should pay more attention to the stress testing results during the decision-making process, particularly when formulating growth and exchange rate policies. The monetary authority should maintain a reasonable and abundant level of liquidity in the banking system and encourage the financial institutions to enhance credit support to the weak links in the real economy, while keep improve the risk-resistance capacity of banking system. Furthermore, the ongoing foreign exchange rate system reform is something that needs to be considered carefully so that China can avoid severe exchange rate shocks, which our study suggests would be extremely costly.

The empirical findings of Chapter 5 support the view that macroeconomic performance determines the level of non-performing loans. In particular, we found strong evidence of a significant relationship between inflation, real-estate price, fixed asset investment and nonperforming loans. The study also showed that change in export and foreign direct investments have an effect on NPLs of banks. This implies that regulators and central banks in China have to be wary about increasing NPLs

during periods of low growth and tight financing. The EWS model suggests that slowing economic growth, declining CPI, and an increase in unemployment would lead to deterioration in the asset quality of banks. In addition, the asset price, which is generally pushed up by strong credit expansion, is a useful leading indicator of banking distress. These results have both practical applicability and policy implications for banking regulation in regional China. The regressions' coefficients along with assumptions on macroeconomic variables and asset prices are able to be used in macro-stress testing to assess the stability of the banking sector based on some indicative threshold. Moreover, our study highlights the central role of NPL. Because NPLR is still a permanent feature of banks' balance sheets, policymakers should remain alert to prevent excessive risk-taking during upturns. The thesis also suggests that a stronger focus on macro-prudential regulation, particularly through capital and liquidity buffers, and countercyclical provisioning, could help mitigate the impact of macroeconomic risks on the banking system. From a policy perspective, it should strengthen the monitoring and prevention of systemic and regional financial distress in a concrete manner. Since that EWS has substantial value in helping supervisors to anticipate banking distress if it is employed carefully and sensibly, developing a reliable EWS, which is able to obtain clearer signals to inform regulators to take action to prevent financial turmoil, could be one of the major targets for policy makers.

6.2. Limitations of the Research

It is needed to be noticed that this thesis may have some limitations in the method of analysing financial stability and in the process of applying stress-testing. These limitations are addressed below.

*The contagion effect within the banking system***:** In usual circumstances, the central bank uses aggregate data to test the change of credit risk of regional banking system in the assumption that is takes place from the top to bottom. Nevertheless, when we use aggregate data to treat the credit risk of the entire banking system as a risk factor, it is

equal to carrying out the micro stress-testing with the aggregate data, ignoring the structural problems within the financial system. In the case of severe adverse shocks, individual banks may become insolvent at the initial stage and the effect of the shocks would extend throughout the whole banking system, and even the financial system, due to the contagion effect. Therefore, it is necessary to emphasise the internal interaction problems within the financial system when implements macro stress-testing in future work. This issue has not been taken into account in this thesis, because that analysis of the banking system at the aggregate level would be more useful for the monetary authorities.

Normal distribution assumption within the stochastic simulation technique: In the stress-testing approach, it usually sets a random variable from a presumed statistical distribution to represent the error terms. For this study, the distribution of non-performing loan rates is represented by the random variable based on the macroeconomic credit risk model. It is commonplace to assume that error terms follow normal distribution in the economic and financial studies. However, the probability of extreme values, which is characterised by fat tails, could not perfectly be forecasted by normal distribution. Therefore, in future work, we could try other alternative distribution to generate the random variable and simulate the distributions of independent variables. Thus, it would be possible to capture the extreme values in stress scenarios.

6.3. Future Research

Overall, for future studies, it would be useful to apply different methods of financial stability and compare the validity of these methods. With the development of definitions of ‘financial stability’, it would be possible to construct a more comprehensive index which covers different measures of financial stability and a more thoughtful indicator system that involves macroeconomic performance, financial system performance, and financial market structure, among others. Moreover, due to

the fact that the validity of both stress-testing and EWS is highly dependent on the quality and quantity of input data, a future study would be improved by employing a larger sample size and high-frequency input data. In the context of Chapter 4, the contagion effect would be a further extension topic to examine inter-bank mechanisms, which facilitate the spread of the shocks throughout the system and hence weaken the stability of the financial system. Furthermore, one can include some horizontal stress-testing analyses of developing countries, particularly for East Asian countries, to achieve a global or regional perspective to assess the financial stability condition. The work in Chapter 5 could be further extended by introducing different approaches for the EWS, such as the neural networks approach which can model the relationship between a set of inputs and a set of outputs, under the assumption that the relationship is nonlinear, an approach that differs from classical risk management methods.

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APPENDIX A

The following table describes the abbreviations used throughout the thesis.

Table A.1: Abbreviation List

Abbreviations and Definition of Terms	
ABC	Agricultural Bank of China
ADBC	Agricultural Development Bank of China
AMC	Asset Management Companies
BOC	Bank of China
BIS	Bank for International Settlements
BCBS	Basel Committee on Banking Supervision
CAR	Capital Adequacy Ratio
CBRC	China Banking Regulatory Commission
CCB	China Construction Bank
CPI	Consumer price index
CSFP	Credit Suisse Financial Products
CSRC	China Securities Regulation Commission
EDF	Expected Default Frequencies
EIBC	Export-Import Bank of China
G-SIFI	Global Systemically Important Financial Institution
IFRS	International Financial Reporting Standards
IPO	Initial Public Offering
IRB	Internal Ratings Based
LGD	Loss Given Default--The fraction of credit exposure that will not be recovered in the event of default on a specified obligation.
EU	European Union
FDI	Foreign direct investment
FSB	Financial Stability Board
FSAP	Financial Sector Assessment Program
G-10	Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom, and the United States (and sometimes Switzerland is involved)
GDP	Gross domestic product
GFC	Global financial crisis in 2008

Abbreviations and Definition of Terms	
GMM	Generalized Method of Moments
ICBC	Industrial & Commercial Bank of China
IMF	International Monetary Fund
JCB	Joint-Equity Commercial Bank
M2	A measure of broad money supply
NBS	National Bureau of Statistics of China
NPLs	Non-Performing Loans
NPLR	Non-Performing Loan Ratio
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PBC	People's Bank of China
OTC	Over the Counter
PD	Probability of Default
RPI	Retail Price Index
SDBC	State Development Bank of China
SOE	State-Owned Enterprise
SOCB	State-Owned Commercial Bank
US	United States of America
VaR	Value at Risk
VAR	Vector autoregression

APPENDIX B Appendix for Chapter 2

Table B.1: Milestones in the History of Risk Management

Time	Events
1730	First futures contracts on the price of rice in Japan
1864	First futures contracts on agricultural products at the Chicago Board of Trade
1900	Louis Bachelier's thesis "Theorie de la Speculation"; Brownian motion
1932	First issue of the *Journal of Risk and Insurance*
1946	First issue of the *Journal of Finance*
1952	Publication of Markowits's article "Portfolio Selection"
1961-1966	Treynor, Sharpe, Lintner and Mossin develop the CAPM
1963	Arrow introduces optimal insurance, moral hazard, and adverse selection
1972	Futures contracts on currencies at the Chicago Mercantile Exchange
1973	Option valuation formulas by Black and Scholes and Merton
1974	Merton's default risk model
1977	Interest rate models by Vasicek and Cox, Ingersoll and Ross (1985)
1980-1990	Exotic options, swaptions and stock derivatives
1979-1982	First OTC contracts in the form of swaps: currency and interest rate swaps
1985	Creation of the Swap Dealers Association, which established the OTC exchange standards
1987	First risk management department in a bank (Merrill Lynch)
1988	Basel I
Late 1980s	Value at risk (VaR) and calculation of optimal capital
1992	Article by Heath, Jarrow and Morton on the forward rate curve
1992	Integrated Risk Management
1992	RiskMetrics
1994-1995	First bankruptcies associated with misuse (or speculation) of derivatives: Procter and Gamble (manufacturer, rates derivatives, 1994), Orange County (management funds, derivatives on financial securities, 1994) and Barings (futures, 1995)
1997	CreditMetrics
1997-1998	Asian and Russian crisis and LTCM collapse
2001	Enron bankruptcy
2002	New governance rules by Sarbanes-Oxley and NYSE
2004	Basel II
2007	Beginning of the financial crisis
2009	Solvency II (not yet implemented in April 2013)
2010	Basel III

Source: Dionne (2013). Risk Management: History, Definition, and Critique

APPENDIX C Appendix for Chapter 4

The motivation of building VAR model is that the default rate can be used for forecasting and impulse response analysis. To achieve this goal, the selection of the lag length of the VAR is a critical step. To determine the optimal lag length for the VAR model, we launched the Likelihood Ration Test, Residual Normality Test, and Residual Serial Correlation LM Test.

Table C.1: Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-458.59	NA	0.005	20.33	20.69	20.46
1	-189.38	421.38	1.62e-06	12.15	15.72	13.49
2	-105.09	98.94	2.12e-06	12.00	18.80	14.55
3	36.86	111.10	5.46e-07	9.35	19.37	13.11
4	580.04	212.55*	4.35e-14*	-10.74*	2.49*	-5.78*
* Indicates lag order selected by the criterion						
LR: sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SC: Schwarz information criterion						
HQ: Hannan-Quinn information criterion						

To ensure the validity of ours VAR model, we should make sure the stationary of the VAR model which might directly affect the results of impulse response. Besides the unit root tests, we also report the inverse roots of AR characteristic polynomial in Figure C.1, which indicate the VAR is stable since almost all the roots are less than one and keep inside the unit circle.

Figure C.1: Inverse Roots of AR Characteristic Polynomial

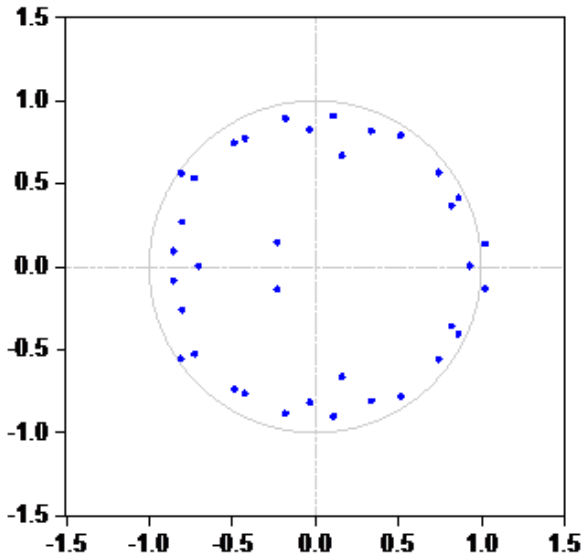
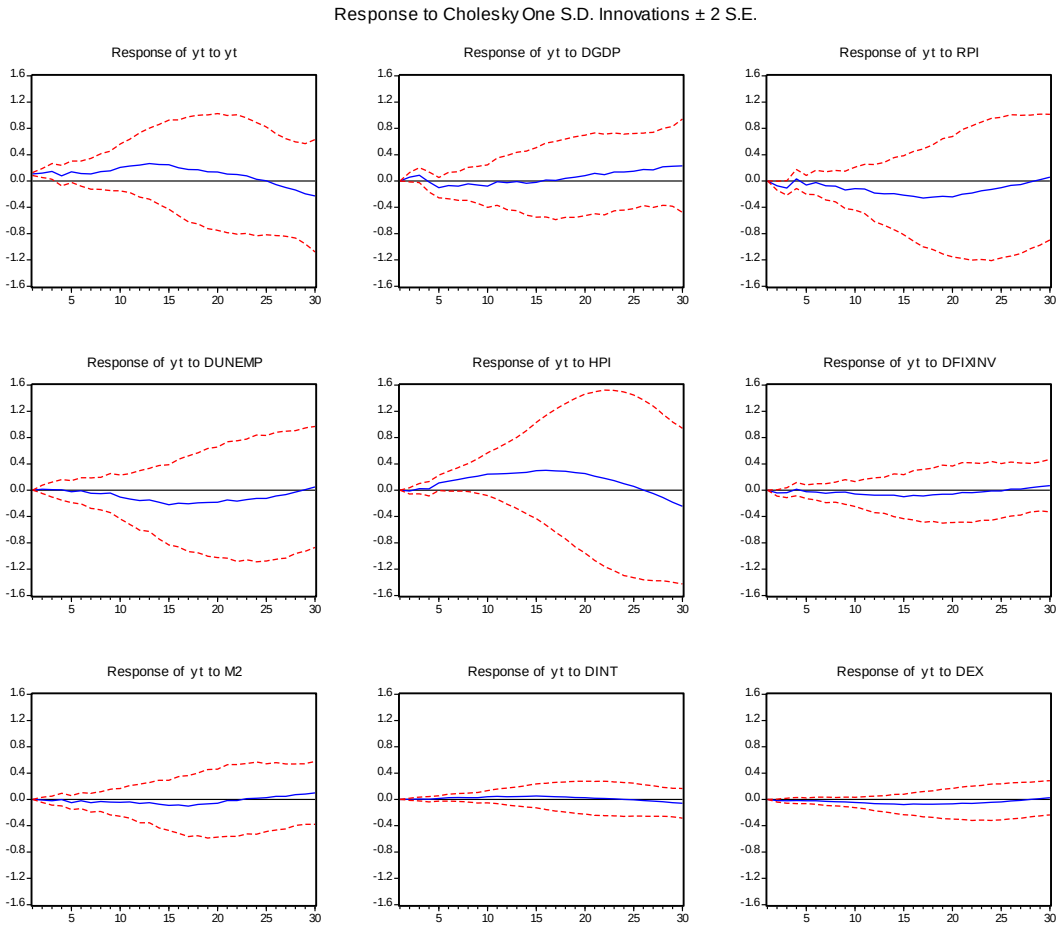


Figure C.2: Impulse Response Results



The idea of Granger causality test was raised by Granger (1969, 1980), which is designed to detect causal direction between two time-series variables X and Y. More precisely, a time-series variable X Granger causes another time-series variable Y, if present value of Y can be better predicted by using past value of both X and Y than it can by using the past value of Y alone. Later, Sim (1980) introduce the Granger causality test into the VAR model.

Results of Granger causality tests are presented in Table C.2. The results show that the default rate is Granger caused by a series of macro-economic variables, including GDP, fixed investment, money supply, and interest rate. These findings indicate that the downturn of the macro economy and credit crunch would lead to the increase of default rate, and thus the deterioration of quality of banks' asset. Meanwhile, there is also a unidirectional Granger causality running from the default rate to real-estate price, which means that the distress of banking system would have a feedback impact on the real-estate market.

Table C.1: Tests of Granger-Causality

Dependent Variable	**Chi-sq**								
	y_t	DGDP	RPI	DUNE	HPI	DFIX	M2	DINT	DEX
y_t		10.21**	6.27	7.33	7.02	16.39***	8.62*	9.10*	6.92
DGDP	4.21		2.85	6.53	0.15	1.93	2.95	3.97	1.60
RPI	4.95	5.95		1.13	1.05	5.66	8.44*	2.15	1.57
DUNE	7.31	4.19	8.34*		11.49**	7.73	2.67	7.67	1.07
HPI	9.10*	15.21***	5.97	16.19***		7.13	6.44	4.24	5.34
DFIX	0.49	4.73	6.29	1.67	2.82		1.52	1.82	5.24
M2	3.83	2.87	1.61	0.89	0.52	4.76		2.59	1.90
DINT	4.93	6.66	3.22	5.08	0.21	12.42**	5.55		1.53
DEX	1.48	3.08	3.19	0.82	2.85	4.33	2.02	1.54	

*, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively.

APPENDIX D Appendix for Chapter 5

Table D.1: Division of China's Regions

Administrative District	Administrative District (in Chinese)	Region Division
Beijing	北京	east region
Tianjin	天津	east region
Hebei	河北	east region
Shanghai	上海	east region
Jiangsu	江苏	east region
Zhejiang	浙江	east region
Fujian	福建	east region
Shandong	山东	east region
Guangdong	广东	east region
Hainan	海南	east region
Shanxi	山西	central region
Anhui	安徽	central region
Jiangxi	江西	central region
Henan	河南	central region
Hubei	湖北	central region
Hunan	湖南	central region
Chongqing	重庆	west region
Sichuan	四川	west region
Guizhou	贵州	west region
Yunnan	云南	west region
Tibet	西藏	west region
Shannxi	陕西	west region
Gansu	甘肃	west region
Qinghai	青海	west region
Ningxia	宁夏	west region
Xinjiang	新疆	west region
Guangxi	广西	west region
Innermongolia	内蒙古	west region
Heilongjiang	黑龙江	north-east region
Jilin	吉林	north-east region
Liaoning	辽宁	north-east region

Figure D.1: China Regional NPRL in 2011