Chapter 1

Introduction

This thesis brings together research on credit and liquidity risks of banks in stress conditions. It investigates banks’ reactions to those risks, presents macro stress-testing models and analyses policy measures to contain the risks during the 2007-2009 financial crisis. Banks are important financial intermediaries because of their risk and maturity transformation function. This inherently exposes them to credit risk, which is basically the risk of default on loans, and liquidity risk, i.e. the risk of funding drying up and reduced tradability of assets. The recent financial crisis has shown that both credit and liquidity risk can assume a systemic dimension in times of stress and can undermine financial stability and economic growth. A thorough understanding of the transmission channels through which credit and liquidity risks affect the banking sector is needed to analyse and address the causes of the crisis. This goes beyond an analysis of traditional measures that are based on balance sheet information, such as non-performing loans, liquidity and capital ratios. Rather a macro perspective is needed, which views the banking sector in relation to the economic environment and other financial sectors. Due to the crisis, authorities responsible for financial stability have realised this and have been adopting a ‘macroprudential’ approach, which aims at supervising the financial system as a whole, in the context of the environment (De Larosière Report, 2009). The research in this thesis also takes a macro perspective, by concentrating on the features of credit and liquidity risk, and the interaction between both risk factors, which have the potential to move the financial system into the tail of the loss distribution.

1.1 Context

The context of this thesis can be explained by the role of banks in the financial cycle. The cycle is driven by the various components of the financial system that are mutually dependent and interact through various transmission channels. In the economic and market environment of banks, debts may rise and asset prices can become overvalued. Banks themselves may contribute to such financial imbalances, by excessive lending and extended financial market exposures. Generally, these financial activities are pro-cyclical due to the financial accelerator effect (Bernanke et al., 1996). This effect amplifies and propagates shocks to the economy and works through endogenous developments in credit markets. Key mechanisms for the pro-cyclicality are the external finance premium and the net worth of borrowers, which both fluctuate with the financial cycle. Shocks can also have magnifying effects on the economy through banks’ balance sheets. This channel may arise from changes in
monetary and regulatory policy or capital losses, which may force banks to adjust the cost and supply of credit. Next to that, the recent crisis has raised the importance of the liquidity channel, which could reinforce the traditional bank balance sheet channel or create additional transmission channels. In literature on the liquidity channel, high leverage ratios and maturity mismatches in banks’ balance sheets are considered determinants of the propagation of funding liquidity shocks to bank lending and the real economy (see, for instance, Gauthier et al., 2010). The potential for pro-cyclical reactions by banks has grown over the last decade, due to their increased reliance on wholesale funding and the practise of mark-to-market valuation of assets. These factors act as mechanisms that transmit high market volatility to banks’ balance sheets, through swings in the prices of their assets and in the availability of liquidity, as was underscored by the recent crisis (FSF, 2008).

The exposures of banks on other sectors of the economy - in particular if they are the result of a pro-cyclical spiral - involve risks, of which credit risk and liquidity risk are usually dominant. Credit risk can become manifest through defaults on loans or downgradings of bonds outstanding on the asset side of banks’ balance sheets. If the exposures have to be written-down, the solvency position of banks will be affected. In the credit crisis, banks had to write-off over USD 1,600 billion worldwide, mainly on credit exposures (IMF, 2010b). This major shock destabilised the sector and necessitated government injections of capital into a number of banks. Liquidity risks can become manifest in a drying up of funding sources (‘funding liquidity’), for instance related to a decline of retail deposits. Another manifestation of liquidity risk is an evaporation of liquidity on financial markets (‘market liquidity’), leading to reduced tradability of assets and mark-to-market losses on bank exposures. Declining funding and market liquidity can culminate in liquidity problems and may impair the intermediary function of banks. This liquidity channel was an important mechanism in the recent crisis (IMF, 2008b). Credit and liquidity risks both assumed a systemic dimension, because financial imbalances were built up on a large scale, which caused massive credit losses and serious liquidity drains in the downturn.

If banks react to emerging risks by reducing the liquidity supply to wholesale counterparties or the credit supply to companies and households, adverse feedback effects on financial markets or the economy emerge. Such effects can reinforce the downturn in markets or the economy. In the recent financial crisis the economy in the euro area was sheltered to some extent, since European banks reacted foremost by withdrawing their exposures in wholesale markets and less so by reducing credit supply to the real economy (Giannone et al., 2011). Banks’ reactions may have systemic repercussions within the banking sector too, for instance if interbank credit exposures are adjusted. In the 2007-2009 crisis, the strong risk aversion among banks indeed led to a freeze of the interbank market, which was evident by a drop in trading volumes and a hike of credit spreads, in particular for funding with medium and long-term maturities (Cassola et al., 2010). This was the main reason for central banks to extend their intermediary role in the market, by supplying additional liquidity through unconventional measures.
The credit crisis was a unique tail event, driven by adverse developments in credit and liquidity risk that will probably not recur in the same form. However, the episode has provided valuable data on the role of bank behaviour and adverse feedback loops, two important channels through which risks can assume a systemic dimension. A deeper understanding of these dynamics helps to assess the relevant risks from a macro perspective, which is crucial information for central banks and financial regulators to take adequate measures to contain a financial crisis or to prevent the next one. An important policy response after the 2007-2009 crisis has been the new supervisory framework for banks (“Basel III”). It aims to enhance the shock absorption capacity of banks and encourages countercyclical behaviour (BCBS, 2010a).

1.2 Research questions

The thesis concentrates on three closely related research questions that emerge from the developments in the banking sector as presented in the previous section.

1. How did banks adjust their credit and liquidity risk management during the crisis and how do empirical estimates of banks’ reactions relate to the behavioural assumptions as generally used in the theoretical literature? The crisis has stimulated new research on phenomena that can explain departures from the efficient market hypothesis (EMH).\(^1\) The validity of the EMH has been questioned due to the excessive behaviour of market participants that contributed to the bubble preceding the crisis and the subsequent crash. Departures from the EMH relate, for instance, to herding, fire sales, leveraging and risk taking, externalities and liquidity spirals (Brunnermeier, 2001). Furthermore, leveraging and deleveraging, driven by behavioural incentives, have been important amplifying forces in the crisis (Adrian and Shin, 2010). However, most research in this field is theoretical and lacks an empirical underpinning, although the crisis provides a rich set of data on such phenomena.

2. How can the impact of tail events on banks that involve credit and liquidity risk, and banks’ reactions to those risks, be modelled? Tail risks are typically characterised by correlation breakdowns, non-linear developments and feedback effects. Such elements provide another argument to depart from the EMH, which assumes representative agents and the system being in equilibrium. To capture the dynamics that are typical for extreme situations, non-standard analytical

\(^1\) The efficient market hypothesis (EMH) assumes that market participants are fully rational and make sensible decisions based on all information available in the market (Ross, 2005). The EMH implies that agents understand the underlying model structure and the distribution of shocks. In fact, the literature has recognised that perfectly efficient markets are a theoretically useful benchmark rather than an accurate characterisation of reality.
frameworks that are not yet widely accepted in economics can be useful (Trichet, 2011). Disequilibrium models provide for such a framework, for instance heterogeneous agent models that focus on the interactions of bounded rational agents (Hommes, 2006). These models describe the behaviour of investors that may follow rule of thumb strategies and they are mostly concerned with financial market applications. A different, more policy oriented, approach to model tail events is represented by stress-testing models. They provide a framework to analyse the impact of tail events on banks and their reactions to stress events. The latter is usually not captured in traditional stress-testing models, but requires a more advanced approach that includes feedback effects of banks’ management actions on the economy and/or the financial system.

3. How should the policy responses to the eruption of credit and liquidity risks during the 2007-2009 crisis be assessed, both with regard to the possible distortionary effects on behavioural incentives and the impact on the economy? In the crisis there were no blueprints available for central banks, governments and supervisors to optimally respond to the rapidly evolving threats to financial stability. They had to act under great uncertainties and were in unchartered territory. Although policymakers were aware of possible undesired effects of the measures they took and the new regulation they developed, the extent of the market distortions and economic costs were uncertain. Research on these side-effects is scarce, although such analysis is very useful to guide policymakers in the design and calibration of their responses to (future) financial crises.

1.3 Research approach

In this thesis the research questions are addressed by analytical instruments that are not (yet) part of the standard paradigm of economic modelling. The first research question is addressed by analysing the credit and liquidity management of banks empirically from a bottom-up perspective. This means that we use granular data to capture the variations at the portfolio or bank level and differing responses of banks. In particular, we use firm-specific data of Dutch banks, derived from a unique data source on assets and liabilities available at De Nederlandsche Bank (DNB). Based on these micro observations we investigate general trends in bank behaviour, by specifying indicators and time series models, which capture the responses of banks to stress situations. A multi-equation time series approach (panel vector autoregressive (VAR) model) is used to take into account the dynamic interrelations among instruments of bank liquidity management. The empirical techniques map the micro information to the level of the banking system. So they capture both the time dimension (‘pro-cyclicality’) and cross-sectional dimension (‘dependencies’) of systemic risk (Borio, 2006). We analyse concrete manifestations of these dimensions, in particular the size and direction of balance sheet adjustments, herding, liquidity hoarding and fire sales. Moreover, the empirical approach provides insight in the
interactions that pose a risk to the financial system and the economy, such as correlated balance sheet adjustments and the linkage between funding liquidity risk and bank lending.

The second research question is addressed by modelling the interactions between tail events in the external environment on the one hand and banks’ credit and liquidity risk on the other in a stress-testing framework. This provides for methodologies to map stress in the macro-environment into indicators that can be used to estimate the impact of stress scenarios on the balance sheets of banks, their responses to stress and the related second round effects in the financial system and the economy.

In the literature those steps are covered by two types of models; i) those that establish the link between macro variables and micro risk drivers and ii) integrated models that include liquidity risk and feedback effects (Foglia, 2009). The methods used in this thesis enclose these two strands and are operationalised by a suite of models, such as reduced form satellite models (that specify a particular relationship between a balance sheet indicator and macroeconomic variables by a single equation), VAR models and calibrated simulation tools. This eclectic approach is motivated by the absence of a fully fledged model that integrates all the potential interlinkages. For that reason stress-testing frameworks are not single coherent economic models, but typically a combination of separate modules (ECB, 2010d). Moreover, according to Knight (1921), there is no distribution of probabilities of extreme events, which implies that models are prone to large parameter and model uncertainties. In combination with the scarcity of data on tail events, this makes standard regression techniques less appropriate for modelling credit risk and even less so for modelling liquidity risk in tail situations. Hence we use several, most fairly basic, simulation and stress-testing techniques to analyse credit and liquidity risks and the dynamics related to banks’ responses to stress events.

The modelling approach has some limitations. First, there is not yet a generally accepted analytical framework for macro stress-testing, implying that simulation techniques have subjective elements, for instance regarding the assumptions concerning the behaviour of banks. This well-known problem in behavioural economics is obviated to some extent by keeping the behavioural assumptions simple and by embedding them in a plausible story, based on the empirical insights from the analysis conducted in the context of the first research question. Second, there is fundamental uncertainty with regard to risks in tail situations, implying that the model outcomes are also surrounded by large uncertainties. This caveat is taken into account by the use of scenario analyses and loss distributions, including quantifications of losses in the extreme tail. Despite its limitations, the stress-testing framework enhances the understanding on how credit and liquidity risks may evolve in crises, how they affect banks and what the possible feedback effects of banks’ reactions are on the financial system and the economy. For that reason, stress-testing has evolved as a crisis management instrument for supervisors and central banks, to shape crisis measures and restore market confidence.
This leads us to the third research question, i.e. the assessment of policy responses to the crisis. First, this is addressed by analysing the short-term crisis measures taken by central banks and governments in 2007-2009, with a particular attention to the undesired side-effects on the incentives of market participants and the functioning of the financial sector. We investigate the empirical evidence of potential distortionary effects as found in market prices, trading volumes and market shares of financial institutions. Second, the effects of longer-term measures taken by regulators in response to the crisis are analysed, in particular the macroeconomic effects of Basel III. The new regulatory standards for capital and liquidity will affect bank behaviour and lending and thereby the economy, both in the transitional phase and in the new steady state. The (admittedly uncertain) effects on lending in the transition phase are simulated with reduced form satellite models and DNB’s structural macroeconomic model of the Dutch economy. The effects in the steady state are even more uncertain, given the as yet unknown possible adjustments of banks’ business models. Therefore, we rely on simulation outcomes and conceptual insights from the literature to assess possible effects in the new steady state.

1.4 Outline

The outline of the thesis is as follows. Chapters 2 and 3 deal with the first research question on bank behaviour during the crisis. The second research question, on modelling the impact of shocks in credit and liquidity risk on banks and their reactions to those risks in a stress-testing framework, is covered in Chapters 4 to 7. The third research question, which focuses on the responses of policymakers, is addressed in Chapters 8 and 9.

1.4.1 Bank behaviour during the crisis

Chapter 2 provides empirical evidence of behavioural responses by banks in the recent crisis. This is based on aggregate indicators of macroprudential risk, constructed from firm-specific balance sheet data. The indicators provide tools to empirically test the concepts of macroprudential risks, i.e. the time dimension and the cross-sectional dimension, as described by Borio (2006). The empirical measures of size and herding show that balance sheet adjustments have been pro-cyclical in the crisis, while responses became increasingly dependent across banks and concentrated on certain market segments. The analysis shows that while banks usually follow a pecking order in their balance sheet adjustments (by making larger adjustments to the most liquid balance sheet items compared to less liquid items), in the crisis they were more inclined to a static response (by reacting with instruments proportional to the composition of their balance sheet). This suggests that banks have less room for a pecking order in their liquidity risk management during stressed circumstances. The chapter concludes
that the behavioural indicators are useful tools for monetary and macroprudential analyses and argues that they can contribute to the micro foundations of financial stability models.

Chapter 3 extends the empirical evidence on bank behaviour to the relationship between funding liquidity and adjustments on the asset side of banks’ balance sheets. This liquidity channel of financial transmission focuses on lending adjustments, liquidity hoarding and fire sales. These behavioural concepts from the literature on disequilibrium models are empirically tested by a panel VAR model using data of Dutch banks. The model takes the endogeneity between asset side adjustments and funding into account. Orthogonalized impulse responses show that in reaction to shocks in money market spreads and repo funding, banks reduce wholesale lending in favour of retail lending. Moreover, a shock to wholesale funding costs urges banks to hoard liquidity through accumulating liquid bond holdings and central bank reserves. Another insight is that fire sales of equity holdings are more likely to be triggered by constraints in funding liquidity than by constraints in banks’ solvency position.

1.4.2 Macro stress-testing
Chapter 4 gives an overview of stress-testing methods for banks, based on the literature and policy practise, focusing on macro stress-testing. It distinguishes micro from macro stress-testing and bottom-up from top-down approaches. The chapter assesses the different use of bottom-up macro stress-tests by authorities in Europe and the US during the crisis. The overview of top-down stress-testing approaches covers the range of modelling approaches developed by central banks to link macro variables to micro risk drivers in bank portfolios (mainly applied to credit risk) and integrated models that include liquidity risk and feedback effects within the financial sector.

Chapters 5, 6 and 7 present several applications of macro stress-testing models for credit and liquidity risk. Chapter 5 presents a tool kit for scenario analysis and macro stress-testing of credit risk. First, macroeconomic scenarios are simulated by a structural macroeconomic model. The scenarios are then mapped in banks’ loan portfolios, by estimating reduced form satellite models that link the exogenous shocks in the macro variables to micro drivers of bank risk, i.e. credit quality indicators and an interest income measure. To capture the different responses of banks and portfolios in stress situations, we use disaggregated data for a panel of individual banks and a break-down of domestic and foreign portfolios. We further explore the variation in the credit loss distribution by estimating both the probability of default (PD) and the loss given default (LGD) in bank loan books by using nonlinear specifications. An important contribution to the literature is that we propose an additional alternative approach for scenario simulation, based on a vector autoregressive (VAR) model. It allows for simultaneous changes in the macro variables and portfolio drivers of bank loans and changing correlations between them in stress situations. The stochastic VAR simulations generate loss distributions that provide insight in the extent of possible extreme losses.
Chapter 6 presents a stress-testing model for liquidity risks of banks. It focuses on both market and funding liquidity risk and combines the multiple dimensions of liquidity risk into a quantitative measure of banks’ liquidity position. It takes into account the first and second round (feedback) effects of shocks, induced by reactions of heterogeneous banks, and reputation effects. The impact on liquidity buffers and the probability of a liquidity shortfall is simulated by a Monte Carlo approach. An application to Dutch banks illustrates that the second round effects in specific scenarios could have more impact than the first round effects and hit all types of banks, indicating systemic risk.

Chapter 7 extends the liquidity stress-testing model, by incorporating the proposed Basel III liquidity regulation, unconventional monetary policy measures and credit supply effects. In the extended model, banks react according to the Basel III standards, endogenising liquidity risk. The model shows how banks’ reactions interact with extended refinancing operations and asset purchases by the central bank. The results indicate that Basel III limits liquidity tail risk, in particular if it leads to a higher quality of liquid asset holdings. The flip side of increased bond holdings by banks is that monetary policy conducted through asset purchases gets more influence on banks’ balance sheets relative to refinancing operations.

1.4.3 Policy responses

Chapter 8 analyses the (temporary) financial crisis measures taken between 2007 and 2009 by central banks and governments, including the potential distortionary effects on behavioural incentives and market functioning. We assess the effects of the policy interventions on the level playing field between supported and non-supported institutions, on the capital flows between market segments and on investor confidence. The chapter shows that in the longer term, interventions by governments and central banks may lead to excessive risk taking and moral hazard problems. The main policy conclusion is that such negative side effects can be limited in the design of the support measures (market compatibility) and in the exit strategy (timely withdrawal).

Chapter 9 analyses the long-term measures taken by regulators to strengthen the banking sector. In particular the effects of Basel III on the economy are simulated, both in the transitional phase and in the new steady state. Outcomes of satellite models for lending and loan spreads are used as input in DNB’s structural macroeconomic model. The results of the exercise indicate that the negative impact on Gross Domestic Product (GDP) during the transitional phase to higher capital and liquidity buffers will be limited to a few tenths of a percent. Another conclusion is that a sufficiently long transitional period will limit the costs in the early years, because it will give banks more scope to adapt. Insights from the literature indicate that once banks have adapted to the new standards, the benefits of a more solid financial system will outweigh the disadvantages, since higher buffers make a financial crisis in the future both less likely and less deep, while economic growth will be more stable in normal times.

Chapter 10 concludes.