Regulation of Banks

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Contents

Abstract 6

Zusammenfassung 7

1. Introduction 8
   1.1. Motivation .................................................. 8
   1.2. Structure of the Thesis .................................... 12

2. Banking Regulation – Existing Framework and Proposed Changes 16
   2.1. Contemporary Regulatory Framework .......................... 20
       2.1.1. Crisis Prevention / Early Intervention ................. 23
       2.1.2. Crisis Management ......................................... 27
       2.1.3. Restructuring of Banks / Insolvency Procedures .......... 32
   2.2. Shortcomings of Existing Regulations ....................... 34
       2.2.1. Capital Requirements – Lack of Macroeconomic Perspective and De-
          ficiencies at Microeconomic Level .......................... 36
       2.2.2. Insufficiency of Bank Equity Capital ..................... 42
       2.2.3. Fair-Value Accounting ....................................... 42
       2.2.4. Shadow Banking Sector ....................................... 43
       2.2.5. Leverage .................................................. 44
       2.2.6. Liquidity .................................................. 45
       2.2.7. Maturity Mismatch ........................................... 47
       2.2.8. Large Complex Financial Institutions ................. 48
       2.2.9. Bank Governance Arrangements ......................... 48
       2.2.10. Mispriced Guarantees ....................................... 50
       2.2.11. Insufficient Transparency and the Counterparty Risk Externality ... 53
       2.2.12. Lack of Adequate Resolution Schemes / Exit Mechanisms .... 54
       2.2.13. Financial Innovations and Regulatory Arbitrage .......... 56

3
3. Liquidity Risk – Basic Model

3.1. Introduction
3.2. The Model
3.2.1. Technologies
3.2.2. Consumers
3.2.3. Investors
3.2.4. Banks
3.2.5. Regulatory Environment and Main Assumptions
3.3. Equilibrium Concept
3.3.1. Definition of Equilibrium
3.3.2. Banking Default and Work Out Procedures
3.4. First-Best Allocation
3.4.1. Summary of the Main Insights
3.5. Equilibria Without Regulation
3.5.1. No Banking Default
3.5.2. Banking Default
3.5.3. Summary of the Main Insights

4. Liquidity Risk – Regulation

4.1. Liquidity Requirements
4.1.1. Summary of the Main Insights
4.2. Liquidity Insurance
4.2.1. Summary of the Main Insights
4.3. Liquidity Risk Taxes
4.3.1. Summary of the Main Insights
4.4. Main Result
Abstract

The aim of the present thesis is to explore several important issues of banking regulation. We first analyze the existing regulations and discuss their major flaws. For this purpose, we examine how financial regulation failed in the recent financial crisis. Second, we present some of the policy proposals and academic contributions that aim at designing a more stable and resilient financial architecture. One of the important, still unresolved issues that is subject to ongoing debate is which type of rules should be used to regulate liquidity risk. As a third part, we develop a theoretical model of the banking system that provides a clear rationale for the regulation of liquidity risk. We show that the unregulated economy leads to a banking crisis in case of a large negative macroeconomic shock, and that the economy suffers high losses. We compare three types of regulatory intervention: liquidity requirements, liquidity insurance and liquidity risk taxes. Our main insights are as follows. Regulation with both liquidity requirements and liquidity insurance can prevent banking defaults if the regulator knows the size of the macroeconomic shocks. Moreover, with these two types of interference, we can achieve the socially optimal outcomes regarding the expected wealth of all market participants and the expected output of the economy. Interference via liquidity risk taxes can prevent banking defaults only if the negative macroeconomic event is not too severe. Furthermore, the resulting equilibrium allocations are not socially optimal. We come to the conclusion that taxing liquidity risk is inferior to mandatory liquidity requirements and mandatory liquidity insurance.
Zusammenfassung


1. Introduction

1.1. Motivation

There is ample evidence that the welfare costs of financial crises are high. The harm done to output growth, employment and capital stocks explains why throughout the world, the design of more resilient financial systems is a prominent issue in politics and the academic world. According to Reinhart and Rogoff (2009), severe financial crises are protracted affairs, and in the aftermath of such crises, all economic developments share the following three characteristics:

- Deep and prolonged collapse of asset markets. “Real housing price declines average 35 percent stretched over six years, while equity price collapses average 55 percent over a downturn of about three and a half years” (Reinhart and Rogoff (2009), p. 466).

- Profound adverse effects on government finances. “The real value of government debt tends to explode, rising an average of 86 percent in the major post-World War II episodes ... the big drivers of debt increases are the inevitable collapse in tax revenues, as well as often ambitious countercyclical fiscal policies ... aimed at mitigating the downturn.” (Reinhart and Rogoff (2009), p. 466).

- Significant declines in employment and output. “The unemployment rate rises an average of 7 percentage points over the down phase of the cycle, which lasts on average over four years. Output falls (from peak to trough) an average of over 9 percent, although the duration of the downturn, averaging roughly two years, is considerably shorter than for unemployment.” (Reinhart and Rogoff (2009), p. 466).

The next figure demonstrates the medium-term output dynamics in the aftermath of severe financial crises.
1. Introduction

As we see in Figure 1.1, financial crises impose large losses on the output growth, which does not return to its precrisis trend for several years.

The fragility of the banking system has been a concern throughout modern history, and the banking sector has been subject to continuous regulatory changes. The current regulatory framework has been powerless to prevent the recent crisis, and may have even contributed to the rapid decline of the output following the initial shock. The current structures of banking regulation consist of three layers:

- Crisis prevention
- Crisis management
- Crisis resolution.
1. Introduction

The instruments of the first layer aim at preventing the instability of financial markets. The policy measures of the second regulatory layer are dealing with the containment of a financial crisis. They are supposed to restore confidence and to prevent the fallout of the crisis on the real economy. The policy instruments of the third regulatory layer address the restructuring of the banking system. They are supposed to resolve nonviable banks and restore the banking sector to profitability and solvency.

In order to explore potential improvements, we will start with the analysis of the existing banking regulations. We identify this regulations’ shortcomings, and examine the main causes of the recent financial crisis, which have triggered loud calls that it is imperative to limit the banks’ appetite for liquidity risk through appropriate regulations.

Then we will present some of the policy proposals aimed at designing a more stable and resilient financial architecture, including a number of different proposals addressing liquidity risk. The regulation of liquidity risk is one of the important regulatory issues that have to be examined and incorporated in the regulatory framework. The two components of liquidity risk: the risk of a collapse of short-term funding (funding liquidity risk), together with the risk that assets cannot be converted into cash without substantial losses on the original value (market liquidity risk), have been a concern throughout the history of banking. The two forms of liquidity risk are closely linked and can amplify each other. For instance, when assets of banks are illiquid, negative information regarding their returns may trigger a collapse of short-term funding. We will call such situations “liquidity risk”, throughout this thesis.

We will develop a variant of the model of Gersbach (2010), and derive a clear rationale for the regulation of liquidity risk. Furthermore, we will compare three different types of regulatory interference within the framework of this model:

- **Liquidity Requirements:**
  The banks have to hold a fraction of their assets in cash or near-cash assets.

- **Liquidity Risk Taxes:**
  The banks need to pay taxes on investments that rely on short-term funding.

- **Private Liquidity Insurance:**
  The banks have to buy a particular amount of liquidity insurance contracts. In such a contract, the banks pay a premium, while they will receive a prespecified amount of cash, or cash-near assets, in the event of a liquidity crisis.
The model we will examine consists of a banking sector with a long-term illiquid investment opportunity that has to be financed by short-term debt and by the issuance of equity. The returns on the long-term investment are subject to a macroeconomic shock, which can be positive, moderate or negative. Refinancing of the long-term investment in the middle of its life-time is risky, as the next generation of potential short-term debtors may not be willing to provide funding if there are bad signals about the return prospects on this investment. Thereby, an early liquidation of long-term investments generates high losses. In our model framework, we are able to show that the regulation of liquidity risk can prevent large-scale banking defaults. Moreover, regulation via liquidity requirements and liquidity insurance induces socially optimal investment decisions of the banks, and maximizes the expected welfare of all market participants. Regulation via liquidity risk taxes can also prevent banking collapses if the negative shock is not too severe. The equilibrium allocations induced under liquidity risk taxes, however, are not socially optimal.

Together, our analysis of the existing regulation, our discussion of some policy proposals and the thorough examination of the opportunities and drawbacks of the model of liquidity risk regulation which we developed in this thesis, are an attempt to explore potential solutions for an old, yet unresolved problem.
1. Introduction

1.2. Structure of the Thesis

This thesis consists of three main parts.

Banking Regulation – Existing Framework and Proposed Changes (Chapter 2)

After this introduction, Chapter 2 first presents a thorough analysis of current banking regulations and then gives an overview of policy proposals aiming to address the shortcomings of existing regulatory framework.

We start by giving the main rationales for regulating banks. All of them are closely related to the existence of market failures caused by market imperfections. These failures create distortions, which might result in taking risks that are much higher than the socially optimal risk levels. We discuss already existing and broadly-used regulatory measures. We classify them into three layers: crisis prevention, crisis management and crisis resolution. Then we point out the main shortcomings of the existing regulations and introduce some of the policy proposals addressing these problems. To assess the proposed changes, it is crucial to understand how financial regulation failed in the recent financial crisis. Thus, we discuss why the recent crisis could not be avoided and which flaws of the current regulations contributed to it - or even exacerbated it. Having this discussion in mind we proceed to present and discuss the policy proposals and academic contributions that are aimed at designing a more stable and resilient financial architecture.

In the last part of the chapter we summarize the set of recommendations for banking regulation issued by the Basel Committee on Banking Supervision. We discuss and assess it briefly. We come to the conclusion that Basel III fails to address the fundamental flaws of the existing regulatory framework and is just a small step in the right direction, which is far from being sufficient to make the financial system more stable and robust.

Liquidity Risk – Basic Model (Chapter 3)

In this chapter we develop a model of the banking system which provides a clear rationale for the regulation of liquidity risk and allows to compare three different types of regulatory interference. We consider a three-period economy populated by two types of households: consumers and investors. The economy incorporates a short-term risk-free technology and a long-term risky illiquid investment opportunity, which is only accessible for banks. The returns on the risky investment are subject to a macroeconomic shock, which can be positive, moderate or negative. Banks have to finance their investments by short-term debt (bank deposits) and by the issuance of equity. Short-term financing of a long-term risky investment
1. Introduction

poses huge risks. Banks have to refinance their long-term investment in the middle of its life-time, and to be able to do this they have to obtain access to new funding, but the next generation of potential short-term debtors may not be willing to provide funding if there are bad signals about the return prospects on the risky investment. Thereby, if banks cannot refinance their long-term investments these investments must be liquidated immediately, which generates very high losses.

We show that if the macroeconomic shocks are large, i.e. if the returns on investment in case of a negative shock are very low (and those in case of a positive shock very large), banks are not able to refinance the illiquid long-term investments and large-scale banking defaults occur. The long-term investments must be liquidated early. Moreover, in order to exploit their limited liability, banks overinvest in the risky technology, which, in turn, lowers the expected aggregate output of the economy and makes the losses in case of a negative shock particularly severe.

Liquidity Risk – Regulation (Chapter 4)

In the last chapter, we analyze and compare three types of regulatory intervention in our economy: liquidity requirements, liquidity insurance and liquidity risk taxes. Our main insights are as follows. If the regulator knows the size of the shock, banking defaults and early liquidation of long-term investments can be avoided with both liquidity requirements and liquidity insurance. These two regulatory measures provide banks with the amount of fresh liquidity that is sufficient to refinance the long-term investment in the middle of its life-time if the negative macroeconomic shock occurs. Banks would not have access to these funds in the unregulated economy for the following reasons. First, the amount of liquidity, which banks hoard voluntarily, is too small. Second, the potential providers of fresh liquidity would not deposit their savings by banks, since the return on risky investment is very low and all market participants know that at the end of the economy, when the output of bank investments is realized, banks will not be able to repay their debt. Moreover, the equilibria induced by these two types of regulation are socially optimal regarding the expected utilities of market participants and the investment amounts in technologies. As opposed to liquidity requirements and liquidity insurance, the interference via taxing investments in the illiquid risky technology does not impose the first-best solution. Banks investment into the risky investment opportunity falls below the socially optimal level causing the expected aggregate output of the economy to decline. Moreover, liquidity risk taxes do not guarantee avoidance of banking defaults if the returns on risky investment in case of a negative shock are very low, i.e. smaller than a particular threshold. We come to the conclusion that the regulator should prefer liquidity requirements and liquid-
I. Introduction

ity insurance to liquidity risk taxes. In the remainder of the chapter we provide an example to illustrate our model and the impact of different types of regulatory intervention.
2. Banking Regulation – Existing Framework and Proposed Changes

There are two (opposite) concepts regarding financial regulation. The first is based on the belief that markets are self-regulating, and are even able to recover from market failures without any external help. The advocates of this concept prefer an imperfectly-competitive market to an imperfectly-regulated one. Some of them argue that market failures are not large enough to justify intervention, others argue that governments act in their own interest and are neither willing nor able to provide sound regulation. What is more, if regulation is inadequately designed, it might distort incentives and generates moral hazard problems. Thus financial institutions have strong perverse incentives to incur excessive risks, and to endanger the stability of the whole financial system. This might lead to the conclusion that financial market intervention may be more harmful than helpful.¹

The counter-opinion is that banks cannot regulate themselves, due to the market failures caused by market imperfections like the presence of market power or the importance of externalities and of asymmetric information. These market failures seem to be large enough to justify regulation. According to the advocates of this opinion, government intervention is necessary to alleviate the negative impact of market failures, even if the regulatory measures themselves can distort the incentives in financial markets, and foster moral hazard.

Let us take a look at the arguments that are usually listed in favor of banking regulation. They start from the observation that market failures create distortions that result in a risk level that is higher than socially optimal.

¹See e.g. Freixas and Rochet (2008).
Important Issues – Justification of Banking Regulation

There are market failures and they create distortions resulting in risk that is above a socially optimal level.² A variety of issues needs to be taken into account when analyzing these failures:

- **Importance of externalities**
  Bank failures generate negative externalities that banks do not take into account when making business decisions.

  According to Freixas and Santomero, bank failures cause negative externalities for two reasons:

  (i) First, specific capital is destroyed (loss of the relationship with clients, loss of specific knowledge),

  (ii) Second, a bank failure can be contagious: it can spread to other financial institutions very quickly, and even lead to a collapse of the financial markets. This contagion spreads through two channels. On the one hand, it can be due to the changing expectations of depositors (bank runs). On the other hand, bank failure may spread due to the interconnectedness of the banks, as a consequence of reciprocal claims, interbank borrowings, connected payment systems etc.

  The social costs of a financial crisis exceed the private costs to individual financial institutions by far. These negative externalities have to be internalized.

- **Asymmetric information between buyers and sellers**
  The consumers of financial services are less well informed than their suppliers. Financial markets are said to be prone to information asymmetries because information is often closely kept by a small number of market participants. It is difficult and costly to obtain, and – due to its complexity –, hard to evaluate. Moreover, very often payments for financial products and services are due in the current period, while the benefits from these financial transactions are promised for a distant future. These information asymmetries may cause the vulnerabilities of the uniformed party, be it exploitation, adverse selection or principal-agent problems.

- **Presence of market power**
  Providers of financial services (investment banks, rating agencies, for instance) may exploit their market power and behave opportunistically, which would result in excessive

²See e.g. Freixas and Santomero (2002).
prices, inefficient allocation of resources, and in distorted quality of financial market products. This market failure becomes even more complex because it is partly generated by the regulation itself (regulatory measures reducing liquidity and bankruptcy risks).

Other Justifications of Banking Regulation.³

- **Protection of depositors and small unsophisticated investors** from the risk of a failure of their bank. They are unable to assess the soundness of financial institutions or the quality and correct prices of financial services supplied. This implies that depositors have a very strong incentive to free-ride on each other’s attempt to monitor banks, which will result in insufficient monitoring.

- **Maintaining financial stability**
  As all businesses rely on access to financing and liquidity, a financial collapse can trigger a recession in the real economy. Due to the “moral hazard” problem, the financial institutions have very strong incentives to take excessive risks. These perverse incentives endanger the stability of financial systems. Although the regulatory measures themselves give rise to such distorted behavior (explicit and implicit government guarantees like deposit insurance, TBTF guarantee etc.), regulation is needed to address moral hazard and to minimize distortions.

³Clearly, they are closely related to the market failures.
Banking regulation – Possible methods

We will start from the assumption that government intervention in the banking system is inevitable to guarantee the soundness of the financial system.

Next we will classify and briefly discuss the possible intervention tools, including already-existing and broadly-used measures, as well as the new regulatory proposals.

Let us classify the government intervention and the corresponding policy tools into three layers:

1. Crisis prevention / Early intervention
2. Crisis management and
3. Restructuring of banks / Bankruptcy procedures.

This classification does not necessarily constitute separate and sequential phases of a financial crisis and regulatory intervention. In practice, the “different” layers of banking regulation overlap and cannot be separated from each other strictly. Early intervention, for instance, may merge very fast into restructuring of impaired institutions. On the one hand, preventive measures are necessary to restrain excessive risk-taking by banks, which in turn would make crisis management and crisis resolution less costly. On the other hand, a sound crisis management influences expectations. It fosters trust in the banking sector and has a crisis-prevention effect.

According to Acharya and Yorulmazer (2007), there is strong evidence that a bail-out policy impacts the banks’ risk-taking behavior. This must be considered when determining the optimal crisis prevention measures.

We will discuss the three regulatory layers in greater detail in the following subsections. In Figure 2.1, we briefly summarize the existing regulatory measures and policy proposals. We assign them to the corresponding layer of banking regulation.
Let us now describe the contemporary regulatory framework and point out its shortcomings.

**2.1. Contemporary Regulatory Framework**

The Basel II framework - a most prominent form of international financial governance - is the cornerstone of national banking regulations. It is a set of guidelines for the measurement and monitoring of banks’ regulatory capital, and was designed to ensure the safety of financial markets and to harmonize banking regulation across countries. Basel II was implemented progressively by many countries who have banks operating internationally.

The Basel II framework is built on three pillars, that are supposed to mutually reinforce each other, as illustrated in the next figure.
The first pillar aligns the minimum amount of capital a bank has to put aside to bank’s major risks of economic losses, i.e. credit risk, operational risk and market risk. The aim of the second pillar is to give regulatory authorities power and discretion to intervene, in particular, to increase capital requirements if they find weaknesses in the bank’s internal capital assessment procedures. The third pillar intends to help exert effective market discipline. It incorporates requirements to disclose information, which is relevant for the banks’ risk and capital levels, thereby increasing transparency, which is essential for market discipline.

We will discuss the Basel II rules, their advantages and shortcomings, later in this subsection.

Let us first summarize which policy measures the national banking regulators have been using, including measures based on Basel II directives, and assign them to the objectives they are targeting.

In the previous subsection we identified the main objectives of banking regulation. We classify them as follows

- Market failure correction
  - Increasing transparency, quality and availability of information,
  - Addressing negative externalities arising from bank failure/limiting contagion,
2. Banking Regulation – Existing Framework and Proposed Changes

- Efficiency enhancement (certain resource allocation goals),
- Protection against systemic risk / financial stability,
- Consumer / investor protection, including protection against monopolistic pricing.

The regulators use a variety of instruments to achieve these objectives. We classify the regulatory tools and their objectives in the following table.

Table 1: Existing regulatory framework: measures and objectives

<table>
<thead>
<tr>
<th>Measures</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prevention / reduction of the risk of crises</strong></td>
<td></td>
</tr>
<tr>
<td>Capital requirements</td>
<td>– Consumer protection</td>
</tr>
<tr>
<td></td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Restrictions on asset holding, on activities</td>
<td>– Reducing information asymmetries</td>
</tr>
<tr>
<td></td>
<td>– Less risk-taking</td>
</tr>
<tr>
<td></td>
<td>– Consumer protection</td>
</tr>
<tr>
<td></td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Accountability requirements</td>
<td>– Reducing information asymmetries</td>
</tr>
<tr>
<td></td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Deposit insurance</td>
<td>– Consumer protection</td>
</tr>
<tr>
<td></td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Disclosure standards</td>
<td>– Efficiency enhancement through high quality information</td>
</tr>
<tr>
<td></td>
<td>– Consumer protection</td>
</tr>
<tr>
<td>Conduct of business rules</td>
<td>Establishing confidence and transparency ⇒</td>
</tr>
<tr>
<td></td>
<td>– Efficiency enhancement</td>
</tr>
<tr>
<td></td>
<td>– Consumer protection</td>
</tr>
<tr>
<td>Inspection / examination of banks</td>
<td>Limiting excessive risk-taking ⇒</td>
</tr>
<tr>
<td></td>
<td>– Consumer protection</td>
</tr>
<tr>
<td></td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Anticollusion / contestability rules</td>
<td>– Consumer protection</td>
</tr>
<tr>
<td>market structure policy</td>
<td>(from monopolistic pricing)</td>
</tr>
<tr>
<td></td>
<td>– Efficiency enhancement</td>
</tr>
<tr>
<td>Regulation of interest rates</td>
<td>– Preventing “excessive competition”</td>
</tr>
<tr>
<td>(including interest-rate ceilings)</td>
<td>– Systemic stability</td>
</tr>
<tr>
<td>Entry requirements, e.g.</td>
<td>– Limiting competition</td>
</tr>
<tr>
<td>– Minimum amount of capital</td>
<td>– Reducing exposure to capital flight</td>
</tr>
<tr>
<td>– Restriction of foreign funds</td>
<td>– Systemic stability</td>
</tr>
</tbody>
</table>

22
### Measured Objectives

<table>
<thead>
<tr>
<th>Crisis management / containment</th>
<th>Objectives</th>
</tr>
</thead>
</table>
| **Liquidity provision** | - Restoring confidence  
- Avoiding the fallout of the crisis on the real economy  
- Time provision to identify the causes of the crisis and measures to address them |
| **Blanket guarantees** | - Restoring confidence  
- Reducing pressure on Lender Of Last Resort (LOLR)  
- Buying time to design more comprehensive policies |
| **Purchase of equity stakes in banks** | Bank recapitalization |
| **Unusual asset purchases** | Liquidity provision |
| **Regulatory forbearance** | - Postponing bank resolution  
- Avoiding bank runs |
| **Relaxation/change of rules for troubled firms, e.g.** | - Avoiding contagion  
- Giving banks time to attempt market-based financial restructuring |
| **Administrative measures, e.g.** | Stop liquidity outflow if confidence is not restored |
| **Resolution of nonviable banks** | Remove nonviable banks from the system |
| **Restructuring of viable undercapitalized banks** | Return viable banks to profitability (private solutions preferred, if necessary supported by government; if no private solutions possible takeover by government) |

### 2.1.1. Crisis Prevention / Early Intervention

The regulatory instruments of this policy layer aim at the prevention of situations endangering the stability of financial markets. They are expected to ensure the soundness of the financial system.

- **Prudential supervision.** Prudential supervision focuses on the safeguarding of the sta-
2. Banking Regulation – Existing Framework and Proposed Changes

bility of individual institutions (microprudential perspective). It contains the following elements:

– Licensing, authorization or chartering of financial institutions.
  The regulator verifies whether the institutions entering the financial market meet the relevant requirements;

– The regulator monitors the health and conduct of financial institutions continuously, based on the criteria set out in the Directives / Regulations. In particular, the regulator examines the quality of assets, of management, of business conducts, and of the earnings;

– The regulator sanctions and penalizes financial institutions which do not comply with the Directives.

• Disclosure rules / Promoting transparency. The banks must provide sufficient - and timely information about their conditions and their business conduct. In particular, banks have to disclose information regarding:

  – Corporate structure
    * Organization of the banking group,
    * Consolidation of subsidiaries for regulatory and accounting purposes;

  – Capital structure and adequacy
    * The amount of capital held by a financial institution,
    * The composition of this capital;

  – Risk management
    * Exposure to credit risk,
    * Exposure to market risk,
Exposure to operational risk.

The guiding principle is that it is crucial for the well-functioning of the financial markets that accurate and timely information is available to all market participants, and that it is possible for the market participants to base their decisions on this information. Promoting transparency aims at enhancing market discipline. Financial institutions are supposed to be monitored by their business counterparties, their customers and their investors, who might reward or punish them according to these institutions’ degree of compliance with standards and financial soundness-benchmarks.

- Direct market discipline can be expressed via funding costs;
- Indirect market discipline can be expressed through pricing of information in the primary and secondary markets for bank assets.

Capital requirements. The Capital Requirements Directives regulate the capital adequacy of banks and of other financial institutions, based on market, credit and operational risk. The minimum capital requirements are based on three fundamental elements:

- Definition of regulatory capital
- Risk-weighted assets
- Minimum ratio of capital in relation to risk-weighted assets.

The purpose of capital requirements is to strengthen the stability of the banking system by imposing a higher equity capital ratio (reserves). On the one hand, higher equity is supposed to serve as a buffer against losses, and on the other hand, it is supposed to counteract excessive risk-taking behavior by a higher amount of capital at risk. We will discuss capital requirements and their shortcomings in greater detail in the next subsection.
2. Banking Regulation – Existing Framework and Proposed Changes

- **Deposit insurance.** Deposit insurance is a guarantee that all, or a limited amount, of the principal – and in some cases, interest accrued on deposit accounts – will be paid if a bank fails. The guarantee may be given either explicitly through law or regulation, or may be inferred implicitly from the verbal promises and/or past actions of the authorities. Its basic goal is to avoid bank runs by small, uninformed depositors. Banks are prone to runs because of their key economic function to provide liquidity. They borrow “short” and lend “long”, which may result in a maturity mismatch. Hence a bank that is solvent can face a liquidity shortage if depositors withdraw their money collectively. Deposit insurance aims at preventing panic runs on banks by reassuring depositors, who then know that their funds will be protected up to a certain amount in case of bank failure.

- **Early intervention tools.** The early intervention tools are remedial actions designed to restore the stability of an individual bank, or of banking groups, at an early stage, i.e. when problems arise. These tools include powers for the supervisor to prohibit payment of dividends, to require the replacement of bank managers and directors, to prevent a bank from engaging in certain business activities, to increase its equity capital above the minimal requirements. They even include a supervisor’s power to take over an ailing bank for a limited time-period, to restore it to financial health. These early intervention tools expand the supervisor’s power to intervene and prevent the ailing institution from becoming insolvent.

- **Asset / portfolio restrictions.** The regulator establishes rules that determine the admissibility or non-admissibility of particular financial contracts (including material product specifications and prices), and set quantitative limits on certain asset holdings, like limits on the amount of loans in particular categories or to individual borrowers, for instance. This type of regulation aims at reducing the competitive pressure among financial institutions and at reducing these institutions’ risk profile, as well as reducing moral hazard.
problems.

- **Accountability requirements.** The international accounting and reporting rules are a basic set of standards according to which banks report their financial position. They are supposed to be designed in a way that allows analysts, investors and regulators to understand how well a financial institution has performed in a certain period, and to assess how much the institution is worth. Widely-accepted accounting rules are the key instrument to amending information asymmetries in financial markets.

  Current accounting rules are based on the mark-to-market principle, which prescribes that most of the financial assets on a bank’s balance sheet have to be fair-valued or mark-to-market-valued, i.e. the value of assets and liabilities on the balance sheet has to be based on market prices, implying that changes in valuation are reflected immediately in current earnings or in shareholders’ equity.

- **Regulation of interest rates.** The regulatory authorities impose interest-rate ceilings and other pricing rules. These regulatory measures aim at limiting competition and at restricting the operation of market forces. Interest-rate ceilings also intend to limit the cost of funds / recapitalization costs, to enlarge bank profits, and to reduce the probability of bank runs.

### 2.1.2. Crisis Management

It is very difficult – and costly – to reduce the probability of banking crises to zero. Hence, the regulatory authorities deal with the possibility of financial crises upfront. We define “crisis management” as the set of regulatory measures aiming at the containment of a financial crisis, at restoring confidence and at avoiding the fallout of the crisis on the real economy. One should keep in mind that crisis-containment policy instruments are merely supposed to buy time to identify the causes of the crisis and to adopt more comprehensive measures to counteract these
causes. Generally, containment measures alone are not sufficient to restore trust in financial markets if the macroeconomic situation continues to deteriorate.

- **Provision of timely and adequate liquidity / LOLR function.** Liquidity support provided by the LOLR is an essential element of crisis containment. There is an institution, such as the central bank, that has the ability to create money to support financial institutions facing liquidity shortage, and to counteract the public tendency to flee into money. The LOLR is expected to provide liquidity to illiquid, but solvent, banks at a penalty rate and against good collateral, thereby preventing asset fire-sales and cut-off of lending. The key aim of this regulatory measure is to prevent sound institutions that are temporarily illiquid from becoming insolvent as a result of lack of trust and of panics in financial markets. In case of a severe crisis, the LOLR may need to provide uniform support to all banks that are short of liquidity; even if some of them are suspected of being insolvent, the LOLR may have to relax solvency and collateral requirements as well as to waive the penalty rate.

Generally there are three channels through which the LOLR can inject liquidity into financial markets

- Open market operations on the monetary market. For instance, the repos and reverse-repos. They are designed to offset the system-wide liquidity shortage. The open market operations are, as a rule, collateralized and conducted at the discretion of the central bank.

- Direct intervention on the distressed asset markets. The LOLR can purchase troubled assets until their prices stabilize

- Direct liquidity support to a specific financial institution that is in trouble (emergency liquidity assistance) through emergency lines of credit, e.g. via the discount
2. Banking Regulation – Existing Framework and Proposed Changes

window. In that case, the bank in distress is allowed to keep its assets until prices rebound, and then reimburses the LOLR.

- **Blanket guarantees.** Blanket guarantees are a commonly-used crisis containment measure. In case of a systemic crisis, the government can provide guarantees on bank assets, deposits and other liabilities. By guaranteeing bank assets, the government intends to support their value indirectly, and to help limit the loss of confidence in banks on the part of other financial market participants. The purpose of guarantees on repayment of bank deposits and of other liabilities is to prevent wholesale or retail bank runs, and to reduce pressure on the LOLR function. Moreover, blanket guarantees are expected to signal that the state is prepared to partly absorb the losses of the financial system, and to represent a first phase in the process of allocating and distributing losses across different stakeholders.

The provision of blanket guarantees, as well as of emergency liquidity assistance, is intended to give the regulatory authorities time to identify the causes of the crisis, and to diagnose the condition of the banking system, to design comprehensive policy responses, and to intervene and restructure the banks without incurring the risk of contagion.

- **Recapitalization of viable, but ailing banks.** To recapitalize viable, but undercapitalized banks, the regulator, in general, has two options: the direct or the indirect approach

  - Direct recapitalization is the purchase of common or preferred equity stakes of banks. This recapitalization method results in a partial or a full government ownership of financial institutions.

  - Indirect recapitalization is the purchase of troubled (nontransparent, illiquid) assets. Removing those assets that are difficult to value from the bank’s balance
sheet is supposed to clarify the true value of the institution. Moreover, by buying troubled assets, the government intends to

(i) establish these assets’ market prices, and thereby help other financial institutions with their own asset valuations,

(ii) bid up the prices of these assets (establish prices that are higher than the values on the bank books, and higher than the ones the investors are currently willing to pay).

The goal of both recapitalization methods is to restore confidence in the troubled bank, as well as in the whole banking system, and to prevent global deleveraging (asset fire-sales, cutting of lending).

- *Relaxation or changes of rules and regulations for distressed banks.* The regulator can ease accounting rules for troubled institutions by allowing them to suspend fair-value accounting for certain financial assets, for example. The main idea is to relieve the ailing institutions from fair-value losses and to avoid the immediate regulatory costs from supervisory interventions by counteracting the procyclicality of fair-value accounting.

- *Regulatory forbearance and administrative measures like standstill requirements.*

  Regulatory forbearance postpones the resolution of insolvent banks. The regulator refrains from the application of those rules that prescribe to resolve the insolvent institution, and allows this institution to remain in business. The rationale behind regulatory forbearance is the following. First, a bank closure can trigger a bank run, due to loss of trust in the soundness of other financial institutions and to the desire of depositors to switch into money. Second, if the government closes a bank, it has to use public funds to cover the difference between the liabilities and the assets of the insolvent institution (including payment to depositors), meaning that the government also has to acknowledge that the supervision of the insolvent institution failed. Third, the regulator may hope that
by granting the insolvent institution an extension, this institution may be able to work out the non-performing loans and to liquidate the assets which otherwise would have to be liquidated under fire-sale conditions, which would not reflect their fair market value.

Administrative measures like standstill requirements (deposit freezes, bank holidays) are a regulatory crisis containment instrument that puts the claims of various bank creditors on hold for a certain time. These measures change the contractual terms of bank liabilities. For example, a deposit freeze is a depositor timeout lasting from a few weeks to a few months. During the timeout, the withdrawal of deposits is restricted. This administrative measure curtails the liquidity of affected depositors and reduces the aggregate money supply. The main idea of standstill requirements is to buy time, which will allow the government and the private financial market participants to assess to which extent the financially-unhealthy institution is in trouble. For instance, the rationale behind a several-days bank holiday is to diagnose the depth of insolvency of an individual financial institution and to recommend and impose haircuts on the claims of uninsured depositors and creditors before they are able to liquidate or collateralize their exposure in the distressed bank. As a rule, such regulatory instruments are emergency measures that are only taken in case of severe bank runs, to stop further contagion effects.

Regulatory forbearance and the administrative measures accompanying it are supposed to give the banks some “breathing space” by providing them with the time necessary to find liquidity and the capital sources needed to remain in business. Moreover, buying time may also allow the financial markets – once they have overcome panic – to assess the real value of the banks’ financial position, and to be able to distinguish between solvent and insolvent institutions.
2. Banking Regulation – Existing Framework and Proposed Changes

2.1.3. Restructuring of Banks / Insolvency Procedures

After the crisis containment, the regulator turns as rule to the restructuring of the banking system and to the resolution of nonviable banks, in order to restore the banking sector to profitability and solvency. The policy measures of this regulatory layer address the write-down of impaired assets, deal with distressed institutions on a long-term basis, and aim at improvement of the operating environment for all financial institutions. The restructuring of the banking system typically begins with a diagnosis of the financial health of every individual institution. After the evaluation of the financial viability, the regulator tries to adopt appropriate restructuring and/or resolution measures.

- Restructuring of viable, but undercapitalized banks

  - If the regulator classifies a financial institution as viable, its shareholders are the first party retaining responsibility to recapitalize and restructure their bank. They can be required by the regulator to provide the missing capital. The existing capital-holders and creditors are in the first loss position, as they also are the ones who have most to gain if their bank restores to financial health.

  * If existing shareholders and creditors are unable to recapitalize, the regulator usually favors an unassisted private merger, or a takeover by a healthy institution as a next solution. Regulatory authorities may force an impaired institution to transfer the whole, or part of, its assets and liabilities to another private sector entity (unassisted merger effected by national authorities), or initiate and facilitate a sale of the failing bank, or its business, to private-sector investors. The price the buyer is willing to pay might be inadequately low, such that the government has to step in to honor the excess liabilities, or to extend the credit of the sold/merged institution (assisted merger effected by national authorities).
If the distressed institution is taken over by another private entity, its incumbent managers and shareholders will be penalized as a rule. It is very likely that the managers of merged or sold institutions will be replaced, and that the shareholders’ claims will be curtailed.

* Regulatory authorities may enforce a splitting-up of the bank’s assets, the so-called “good bank” / “bad bank” solutions. If private investors are not willing to pay a positive price for an impaired institution, the government can divide this institution into two parts. Under the “good bank” approach, the clean assets (assets whose valuation is accurate) and the deposits of the old bank “constitute” a new bank, capitalized with government money or, if possible, with a combination of government money and new private funds. The old bank is compensated by receiving the market value or the fair-value of the clean assets it loses and the value of the deposits it gives up. The “bad bank” approach involves identifying the impaired assets of the bank’s balance sheets, and allocating them – as well as the old debt of the bank – to a new “bad bank”. The other assets remain on the balance sheet of the old bank.

Takeover and management by the regulatory authority. If the private solutions of bank-restructuring fail, the institution can be taken over by the government. Typically, governments nationalize systemically-important large financial institutions. In that case, the shareholders of the bank loose all their investments and claims, while the depositors and creditors of the institution remain protected. This restructuring measure imposes high costs on the taxpayers and increases these taxpayers’ exposure to bank losses. Moreover, the lending and investment decisions of a nationalized bank are often based on political pressure and hence remain inefficient. The advocates of this approach argue that in case of bank nationalization, the government has more control over this bank’s business decisions, and if the
nationalized bank has upside profit potential, it can be captured – as a whole or partly – by the taxpayers, as they have financed the restructuring.

- **Closure and liquidation of nonviable banks.** The government has the option to close a nonviable bank. Usually, this option is used when dealing with small and medium-sized banks. The regulator suspends business for liquidation and activates the close-down process according to the insolvency procedures in force. The assets of the institution are liquidated, its creditors are paid out according to their seniority and to the priority level of their claims. This is the most radical approach to put an end to a bank’s failing. If an institution is not systemically-important to the extent that its closure would induce panics and trigger a bank run, the liquidation of this nonviable institution might be the most efficient way of dealing with its failing. Many economists argue that continued funding of such an institution with the taxpayers’ money would only increase the costs of a collapse that is unavoidable.

### 2.2. Shortcomings of Existing Regulations

Let us first discuss what we consider to be the main problems of contemporary banking regulation. Then we will introduce some of the policy proposals addressing these problems. We summarize our view of the major shortcomings of the existing regulation in the next figure.
Among economists, a widely-spread opinion is that the flaws of the financial architecture have largely contributed to the range of the last financial crisis. Therefore, it is important to reconsider the banking regulation at both macroeconomic level (scope and scale) and microeconomic level (instruments).

In our opinion one of the main weaknesses of the contemporary regulatory framework is that it mostly aims at achieving financial stability from the microeconomic perspective. According to Hanson, Kashyap, and Stein (2010), within microprudential framework, regulation is partial-equilibrium in its conception and targeted at the safeguarding of the soundness of individual financial institutions, as well as at the way they respond to exogenous risks, while macroprudential regulation recognizes the importance of general-equilibrium effects and is aimed at safeguarding the financial system as a whole. In the next table, we summarize the main differences between macro- and microprudential regulation perspectives.
2. Banking Regulation – Existing Framework and Proposed Changes

Table 2: Comparison of macro- and microprudential perspectives (source: Borio 2003, p. 6)

<table>
<thead>
<tr>
<th></th>
<th>Macroprudential</th>
<th>Microprudential</th>
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<tbody>
<tr>
<td><strong>Proximate objective</strong></td>
<td>limit financial system-wide distress</td>
<td>limit distress of individual institutions</td>
</tr>
<tr>
<td><strong>Ultimate objective</strong></td>
<td>avoid output (GDP) losses</td>
<td>consumer (investor/depositor) protection</td>
</tr>
<tr>
<td><strong>Risk modelling</strong></td>
<td>partly endogenous</td>
<td>exogenous</td>
</tr>
<tr>
<td><strong>Correlations and common exposures across institutions</strong></td>
<td>important</td>
<td>irrelevant</td>
</tr>
<tr>
<td><strong>Calibration of prudential controls</strong></td>
<td>in terms of system-wide distress; top-down</td>
<td>in terms of risks of individual institutions; bottom-up</td>
</tr>
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The actions that an individual institution takes to enhance its soundness may undermine the soundness of other financial institutions. Hence, a financial regulation that lacks systemic perspective can amplify financial crises and make them more costly.

However, sound risk management starts at the firm level. Thus, we think that it is very important that the shareholders and the managers of financial institutions bear the costs of bad risk management, and benefit from sound risk management. Many economists are of the opinion that flaws in microprudential rules have, in fact, provided bankers with “head-we-win-tail-they-lose” incentive structures, fostering excessive risk-taking, deterioration of lending standards and perverse behaviors.  

2.2.1. Capital Requirements – Lack of Macroeconomic Perspective and Deficiencies at Microeconomic Level

The risk-sensitive capital requirements of Basel II, progressively adopted by many countries with internationally-active banks, are the cornerstone of the contemporary banking regulation.

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4Borio (2008); Buiter (2007); Kashyap, Rajan, and Stein (2008); for a discussion, see Cannata and Quagliariello (2009).
2. Banking Regulation – Existing Framework and Proposed Changes

According to Hellwig (2008), the main shortcomings of the bank capital regulation under the Basel Accords are the following

- The purpose of capital requirements is unclear,
- the dynamics of capital regulation are not taken into account, and
- the systemic effects of capital regulation are ignored.

Let us briefly explain these points, as well as what we consider to be other major flaws of the current capital regulation.

**Purpose of capital requirements**

First of all, the purpose of capital requirements is not clear. In general, equity regulation has three purposes, which partly counteract each other.

1. Equity capital should serve as a buffer against losses. The higher a bank’s equity, the larger the losses it can absorb before becoming insolvent.

2. Capital regulation should control moral hazard, i.e. the excessive risk-taking behavior of banks, induced by limited liability. The higher a bank’s equity, the larger the amount of capital at risk, and hence, the more reluctant the bank is to gamble.

3. Regulation of equity capital enables supervisory intervention before the onset of bankruptcy if capital does not provide a sufficient buffer against risk.

The potential conflict between the first and the third purpose is obvious. The latter requires a strict enforcement of capital requirements, which makes it impossible to use equity capital as a buffer. Only equity in excess of minimum requirements can be used to absorb the losses. This paradox of equity regulation has not been solved yet.
Lack of theoretical foundation of the dynamics of capital regulation

Most findings on the impact of capital regulation are based on static models and come from a two-period framework. The dynamics of capital regulation are neglected. In reality, banks make repeated refinancing and portfolio choices. While the initial impact of capital requirements is important, the consequences of a strict enforcement of these requirements in subsequent periods have to be taken into account as well. The interactions between minimum equity requirements, actual bank capital, lending and economic activity have not been analyzed comprehensively until now.

Ignoring the systemic effects of capital regulation

- Risk measurement models

The capital charges for credit, market and operational risks are based on the quantitative risk assessment models of individual banks. Basel II advocates the use of Value-at-Risk (VAR) as the risk-measurement approach for internal models. VAR-based estimates of risk have a number of serious drawbacks at both macroeconomic and microeconomic level. First, such models do not incorporate exposure to systemic risks. Hellwig (2008, p. 52): “I have come to accept the assessment that... there is no way in which the quantitative model of an individual bank could satisfactorily take account of the institution’s exposure to systemic risk. This being said, I wonder why the quantitative risk model of an individual bank should be accepted as the sole basis for determining the amount of equity capital that the bank must have to meet regulatory requirements.” The risks impacting financial markets are at least partly endogenous and can be attributed to the actions of market participants. See Danielsson and Shin (2003) for a thorough discussion.

2. Banking Regulation – Existing Framework and Proposed Changes

- “Domino effect” through asset fire-sales.

- “Domino effect” through contractual relations. If one institution defaults, other institutions have to write down their contractual claims on the failing institution.

- Information contagion effects. The observation of difficulties at one institution induce investors to be worried about other institutions that may have followed the same strategies, and to withdraw their funding from them.

There is a number of further serious concerns regarding VAR-based risk assessments. Let us examine two of them.\(^7\)

- VAR models assume elliptical distribution of returns\(^8\), although according to empirical evidence, the distribution of credit risks, market risks and operational risks is heavy-tailed. Hence, it is crucial to estimate returns beyond VAR, as VAR models do not provide any information about risks or loss distribution in the tails. However to assess risks correctly, one needs exact information about the shape of the loss function beyond a certain extreme threshold.

- Any portfolio risk measurement has to satisfy subadditivity. In case of VAR models, this is only true for elliptical distributions. However, as already mentioned, the distribution of credit risks, market risks and operational risks is non-elliptical. Moreover, the VAR of a portfolio of assets can exceed the sum of the VARs of the assets, implying that VAR does not yield the upper limit of losses faced by the portfolio holder. Hence VAR-based models underestimate the risks faced by the financial institutions.

\(^6\)One bank failure may lead to another, due to contagion within the banking industry.

\(^7\)For a thorough discussion, see e.g. Danielsson et al. (2001) and Brunnermeier et al. (2009).

\(^8\)Normal distribution is a special case.
2. Banking Regulation – Existing Framework and Proposed Changes

- **Procyclical impact of capital requirements**

Moreover, it is often argued that current regulation of bank capital is procyclical. There is a strong argument that risk-sensitive capital requirements imposed by Basel II are a bit of a paradox: on the one hand, the main purpose of Basel II was to make capital requirements more comprehensive and risk-sensitive, while on the other hand – and exactly for the same reason – Basel II encourages procyclical risk-taking behavior, increasing the probability of financial crises – and their severity when they occur. Under the current regulation, capital requirements are an increasing function of the probability of default, loss given default, and the exposure at default, and these inputs are rising in times of recession and falling in boom times. Thus, when the borrowers’ credit-worthiness declines in a downturn, bank capital requirements rise, contracting the supply of credit. In boom times, capital requirements decline, and banks expand their lending.

“Current regulation failed to provide any check against or barrier against boom-and-bust cycle in the financial system. It was largely a bystander during the build-up of leverage and the erosion of credit standards in the credit boom and has been largely powerless as the boom has turned to bust with a devastating impact on real economy” (Shin (2009), p. 1).

The pitfalls of VAR as risk-measure and of VAR-based capital requirements are summarized in the following box. (Source: The Turner Review (2009), p. 23).
Box 1: VAR-based risk measure (source: The Turner Review (2009)).

**Basic approach**

- VAR = threshold value that the losses should not exceed in a given time period with a given confidence level
- Standardized parameters: one-sided confidence interval of 99%, holding period of 10 days and at least 1 year of historical data
- Observe, over a past period (last year), the profit and loss distribution resulting over 10 days of a given portfolio
- Capital requirement (charge) sufficient to cover some multiple of the calculated VAR

**Procyclicality**

Short-term observation (one year) might induce procyclicality

- Observation 1 is associated with low volatility and hence low risk $\rightarrow$ lower capital charges, banks increase positions reinforcing market liquidity
- Observation 2 is associated with high volatility and hence higher risks $\rightarrow$ higher capital charges, need to raise capital / reduce exposure to risk, hence liquidity dries up, which in turn reinforces volatility

**Volatility in a specific market**

**Failure to capture fat-tail risk**

Short-term observation periods and assumption of normal distribution (special case of elliptical distribution) imply significant underestimation of risks in case of extreme events.

**Failure to capture systemic risk**

Approach does not incorporate systemic risk by construction. Interconnectedness of market events (network externalities) is ignored, each bank is treated as an individual agent, who does not affect the market.
2. Banking Regulation – Existing Framework and Proposed Changes

2.2.2. Insufficiency of Bank Equity Capital

Equity capital buffers that are too thin increase the probability of systemic crisis and system-wide balance-sheet contraction. There is strong evidence that banks worldwide have been economizing on equity. The equity of large banks like Deutsche Bank or UBS declined from about 10 percent of the balance sheets in the early nineties to about 3 percent in the recent past. Such a reduction of equity capital could occur due to the reliance of capital requirements on the banks’ internal quantitative risk models. Many economists argue that such small equity buffers are insufficient to absorb the consequences even of small, unforeseen shocks. When the market prices of banks’ assets fall, for instance, the banks have to react immediately by selling assets or cutting back lending in order to deleverage and to fulfill regulatory capital requirements. Deleveraging may create a downward spiral of asset prices, and trigger a systemic crisis.

2.2.3. Fair-Value Accounting

The choice of accounting or of financial reporting standards is crucial for the design of a financial architecture, as accounting rules are the basis for any performance evaluation of individual firms. Accounting is the main channel through which all the financial-market participants and the public have access to the information about financial institutions. Hence, the choice of accounting rules is crucial for the efficiency of market discipline.

Recently, fair-value accounting has been widely criticized with regard to its system-wide properties (like potential procyclicality). Mark-to-market pricing of assets is very problematic if financial markets are in distress and do not function well. Marking-to-market means that all the price changes are immediately visible on the financial institutions’ balance sheets. If the market price of an asset is distorted, e.g. if it falls under the expected present value of its future payoffs, mark-to-market pricing forces the bank to a write-off that would be reasonable only if the bank liquidated its assets immediately. This problem arises when the reliance on market
2. Banking Regulation – Existing Framework and Proposed Changes

prices distorts those same market prices (Shin (2008)). Hence it is often argued that fair-value accounting intensifies the financial crisis and promotes the downwards spiral.

Fair-value accounting is also widely criticized with regard to its firm-specific properties. It includes three levels of fair-value measurement. The first level is applied when the current market price of the asset is available (mark-to-market pricing), the second level represents the current price for a similar asset in a liquid market, which needs to be adjusted to obtain the fair-value of the asset to be valued. Finally, the third level uses asset valuation models (mark-to-model pricing) if no market prices are available. Hence, in times of financial turmoil when no market prices are available for many financial instruments – as for many assets no liquid markets exist – one has to rely on mark-to-model pricing. Especially with regard to very complex financial structures, the approximated valuations are very uncertain and / or false.

2.2.4. Shadow Banking Sector

From a macroprudential / fire-sale point of view, any kind of large financial and systemically-important institution, and the ones relying on short-term debt in particular, can potentially exacerbate the asset fire-sale problem and trigger a crisis, as such institutions are also subject to wholesale financing runs. Current banking regulation leaves non-bank financial firms largely unregulated. The banking industry was able to set up a shadow banking sector of special investment vehicles and conduits that remain undisclosed, unregulated and undercapitalized. A leverage ratio close to 100 percent is not an exception. This shadow banking system allows the banks to transform on-balance-sheet loans and assets into off-balance sheet contingent liabilities, thus exploiting the loopholes of Basel II.
2. Banking Regulation – Existing Framework and Proposed Changes

2.2.5. Leverage

Following Adrian and Shin (2007b), let us now define leverage as the ratio of total assets to equity, where equity (or net worth) is the difference between assets and liabilities:

\[
\text{Leverage} = \frac{\text{Total Assets}}{\text{Total Assets} - \text{Liabilities}} = \frac{\text{Total Assets}}{\text{Equity}}.
\]

Basel II does not regulate the leverage of financial institutions directly.

The view that excessive leverage largely contributed to the current crisis is widely spread. Among others, Adrian and Shin (2007a, 2007b) argue that in combination with mark-to-market accounting, leverage is strongly procyclical because banks constantly adjust their balance sheets to the fluctuations in the asset values. The regulators require banks to value the assets up and down on their balance sheets, in line with the changes of market value. If banks were passive and did not adjust their balance sheets according to the changes in equity, leverage would be countercyclical, since it is inversely-related to the value of total assets. Increasing asset prices would be paired with higher equity and lower leverage, while decreasing prices would imply a decline in equity and higher leverage. However, banks manage their balance sheets actively. There is strong empirical evidence that the relationship between changes in asset values and changes in leverage is positive. The reason behind it is that banks target a fixed leverage level by adjusting their liabilities to the changes in asset values.

The leverage adjustments are illustrated in the next figure.
In this sense, leverage is strongly procyclical. If the banks’ balance sheets are strong, their leverage is too small and they have surplus funds which they try to employ. In turn, to be able to use these surplus funds, banks expand their balance sheets. (Adrian and Shin (2007b)).

2.2.6. Liquidity

Basel II relies mostly on capital adequacy requirements, which are supposed to help banks overcome their financial problems. This might reflect the belief that a strong capital base for financial institutions establishes trust in financial markets and hence limits the impact of liquidity shocks. However, “as is very well known, capital adequacy may provide some reassurance to market participants, but even well capitalized banks can face severe liquidity problems in exceptionally adverse conditions” (Gualandri, Landi, and Venturelli (2009)).
As already mentioned earlier, liquidity risk consists of two components: market liquidity risk and funding liquidity risk. Market liquidity risk is the risk that a bank cannot easily unwind a position at an adequate price. For example, when selling an asset depresses the sale price. Funding liquidity risk is the risk that a bank will be unable to meet its obligations / fund its positions over a certain time horizon and hence will be forced to unwind. The two components of liquidity risk are closely linked and can amplify each other in so called liquidity spirals.

As illustrated in the next figure, initial losses of financial institutions, as caused by credit losses, for instance, can start a systemic liquidity spiral.

Figure 2.5. Downward liquidity spiral (sources: Brunnermeier and Pedersen (2009) and Pedersen (2008)).
2. Banking Regulation – Existing Framework and Proposed Changes

If many financial institutions face funding problems, all of them have to reduce their positions. This leads to less trading and to a decline of asset prices. The mark-to-market requirement implies that the losses appear on the banks’ balance sheets immediately, leading to equity decreases and to leverage above the target level. As a consequence, the banks are forced to deleverage by selling more assets, hoarding cash and tightening their risk management. This exacerbates funding problems, and the banks are forced to make further fire-sales. Additionally, the increase in margins – due to backward-looking risk measures, time-varying volatility and adverse selection (Dewatripont et al. (2009)) –, implies that with the same assets, the amount of available liquidity declines, thus worsening funding problems further, and so on.

It is important to stress that liquidity is endogenous and that from a microeconomic point of view, it might be optimal for a distressed financial institution to start deleveraging, by selling assets and / or cutting back lending towards other market participants. Yet, from a macroeconomic point of view, such behavior might cause financial turmoil.

2.2.7. Maturity Mismatch

To a large extent, the banks use short-term debt – either deposits or short-term wholesale funding –, which includes repurchase agreements and commercial papers to fund long-term assets, for example (e.g. real estate assets). Though such maturity mismatch is the major risk endangering financial stability, it is not addressed by Basel II. As the banks finance long-term credits by short-term debt, they need to refinance permanently. Hence financial institutions are vulnerable to any shock that constrains the availability of funds. If an individual bank is unable to acquire financing on the market, it is forced into a fire-sale of its long-term assets, and / or has to cut lending to repay its short-term debt.
2.2.8. Large Complex Financial Institutions

Basel II treats all financial institutions that are subject to regulation equally. However, not all banks are alike. There are large, complex financial institutions (LCFIs) that are systemically-important, i.e. whose failure might lead to extremely high social losses. These institutions are viewed as “too-big-to-fail” and “too-interconnected-to-fail”. As a rule, LCFIs enjoy an implicit safety net and thus tend to excessive risk-taking. Hence, it is often argued that LCFIs should be treated differently than other financial institutions and face ex ante stricter regulatory rules.

2.2.9. Bank Governance Arrangements

Many economists argue that managerial agency problems are not adequately dealt with by current microprudential regulation. Remuneration policies, in particular, are often claimed to provide perverse incentives to bank managers. The remuneration schemes that are in use at most banks combine limited downside-risk with high upside-potential. Let us illustrate this in the following figure.
As we can see from Figure 2.6, bank managers (as well as equity holders) will always prefer the riskier investment, which yields either a return $A$ or a return $B$ with the same probability $\frac{1}{2}$, to the risk-free outcome $C$. If the outcome is ‘bad’, the rest of the losses will be borne by the taxpayer and uninsured debtholders.

Thus, existing remuneration practices are not fostering sound ex ante risk measurement.

Moreover, bank managers are claimed to be under pressure to take excessive risks to keep up with their peers. This encourages excessive risk-taking and “... no doubt played a role in the recent build-up of risk, as in all previous ones.” (Borio (2008)).
The agency / governance problem, which is also claimed to remain unsolved by current regulation, is an important issue, especially with regard to the composition of bank capital. Bank equity holders are always concerned that the bank managers’ bad business decisions might dilute the value of their equity shares. As a consequence, investors require a high premium for providing banks with equity, making this source of bank-financing very expensive. As opposed to equity holders, short-term creditors are much better protected against bad bank management decisions. This implies lower financing costs for the banks if they rely on short-term debt to a large extent – rather than on equity. Hence, excessive leverage of the banks may be a response to this governance problem, arising from the lack of trust of the equity holders in the bank managers. Moreover, it is argued that this problem cannot be resolved by higher capital requirements (Kashyap, Rajan, and Stein (2008)).

2.2.10. Mispriced Guarantees

Many economists believe that financial institutions enjoy a number of governmental guarantees and subsidies, without being adequately charged for them. Governmental guarantees give the banks an incentive to increase their leverage to very high levels, as despite rising bank leverage – and a rising probability of failure –, the banks’ costs remain the same, while the costs to the government’s guarantees are going up. If the governments charged a fair price for guarantees, the banks would have to pay for excessive risk-taking, and would price risks correctly. However, there is a strong belief that this is not the case. Moreover, many economists argue that government guarantees make market discipline ineffective. Without government guarantees the banks that gamble, and thus face a high default probability, would be punished by high funding costs (debt and equity). Bank debtors, for instance, would monitor the business decisions of the bank, knowing that the government would not step in and bail out the bank if it gets into trouble. But as long as bank debt is guaranteed by the government, be it explicitly or implicitly, bank debtors do not have an incentive to monitor the banks.
Hence, many economists believe that subsidies and governmental guarantees distort incentives and encourage the banks to take more risks rather than promote financial stability. Moreover, it is not even clear whether the banking system would be able to pay for the subsidies it receives (see for instance Acharya and Franks (2009)).

The most controversial guarantees are listed below.

- **Deposit Insurance.** Bank deposits constitute an important source of bank funding. They are, explicitly or implicitly, insured by the government in most countries. It is common that regulators do not charge an appropriate insurance premium for this public guarantee. Being “underpriced”, deposit insurance is associated with an implicit subsidy to the banks. “It is rather surprising that most countries’ funds have no insurance premium being charged and the few countries whose funds charge a premium (such as US) do so in a manner that is not sufficiently risk-sensitive and pro-cyclical, so that the funds are almost certain to be strapped for capital when insurance claims materialize” (Acharya (2009), p. 2). On the one hand, deposit insurance might prevent bank runs by depositors, but on the other hand, depositors no longer have an incentive to monitor the banks, knowing that they will not lose their money. Moreover it is often argued that, in most countries, deposit insurance has evolved into a system putting the protection of those banks that are facing financial troubles as a main function, before the protection of their depositors. When a financial institution gets into trouble, and when the insolvency risk becomes apparent, the regulators step in and cover the losses to prevent the erosion of market confidence, rather than let troubled institutions fail and pay their debtors back themselves.

- **Implicit Too-big-to-fail (TBTF) and Too-many-to-fail (TMTF) Guarantees.** The explicit and implicit TBTF and TMTF guarantees are claimed to induce moral hazard and to encourage excessive risk-taking by these financial institutions. It is obvious that the ex-post bail-out policy might have an effect on ex-ante incentives of the banks to take
risks. The implicit TMTF guarantee tends to give financial institutions the incentive to make correlated risky investments – and thus increase the opportunity to fail together –, in order to exploit the governmental subsidies to the full extent. TBTF guarantee might induce big banks to make excessive risk-taking investment decisions. Since the rescue policy, even if it is ex-post optimal, may distort incentives from the ex-ante point of view, it is important to jointly analyze ex-ante and ex-post regulatory measures (see Acharya and Yorulmazer (2007) and, Acharya and Franks (2009)).

Moreover, TBTF guarantees tend to give the banks incentives to grow bigger. The bigger the financial institution, the greater its competitive advantage over smaller banks. If capital markets realize that TBTF banks will always be bailed out by the governments, no matter which investment decisions they make and no matter how troubled they are, it becomes easier for them to raise capital and to recapitalize at lower costs, compared to smaller institutions – which, in turn, allows them to grow even bigger.

- **Loan Guarantees** Loan guarantees in interbank markets or monetary markets, which are supposed to restore trust in lending between banks and hence stimulate the markets, have a number of caveats, apart from the already-discussed moral hazard concerns. The points of criticism are the following. First, guaranteeing interbank loans does not ensure the soundness of the borrowing institutions. Second, a government’s guaranteed loan in the interbank market is, in fact, a loan from the state to the borrower, implying that the benefits of the interbank borrowing disappear. In most cases, the banks have to pay an insurance premium, and only banks that are in genuine trouble are willing to pay very high interest rates (including insurance premia). This implies that the risk of the insurers increases, which, in turn, raises the risk premia, and so on (adverse selection problem).

However, one can also argue that government guarantees might have a positive effect on the banks’ risk-taking, through their effect on charter value and bank margins. Higher charter values give the banks an incentive for more prudent business decisions, since banks are more
2. Banking Regulation – Existing Framework and Proposed Changes

reluctant to threaten future rents by excessive risk-taking. Empirical evidence shows, however, that the negative effects of guarantees outweighs their advantages, and that protected banks tend to take more risks.⁹

2.2.11. Insufficient Transparency and the Counterparty Risk Externality

The view that the disclosure requirements of Basel II are poor and far from being sufficient to encourage market discipline is widely spread. The lack of information on loan structure, provisions, financing structure, the financial instruments held by the banks as well as the existence of nearly unregulated non-bank financial sector, which is neither subject to reporting nor to disclosure requirements, are both blamed for making market discipline ineffective. See Alexandre, Bouaiss, and Refait-Alexandre (2010) for a discussion.

Financial markets cannot be efficient if the market participants and the regulatory authorities lack information about the financial instruments, their value and their risks, and if important financial actors are opaque and not subject to regulation. If investors are unable to price (complex) financial instruments correctly, and do not even know who holds these instruments, they cannot assess the exposure of financial institutions to risks properly, as well as the losses these institutions might face. This lack of information results in generalized uncertainty, excessive risk-aversion, mistrust towards business counterparties, and in further erosion of market confidence.

For market discipline to be effective, it is crucial that the market participants are able to assess the performance of financial institutions correctly, and assess their risk profiles, in particular. Such an assessment is directly linked to monitoring (control) and to the fact that the stockholders and debtors should be willing and able to influence banks decisions (Bliss and Flannery

⁹ For a thorough discussion, see Gropp, Gründl, and Güttler (2010).
Thus, market discipline is only possible if the banks make regular disclosures to the market in a way that permits an assessment of their financial health by investors, in other words, if they are more transparent.”¹⁰

2.2.12. Lack of Adequate Resolution Schemes / Exit Mechanisms

The existence of reliable and rapidly implementable resolution schemes for failing financial institutions, which minimize the systemic impact of bank failure, is claimed to be crucial for financial stability and for the efficiency of market discipline. “Since the onset of the crisis the absence or limited scope of such regimes has been shown up globally, including within the European Union (EU)” (Cihak and Nier (2009), p. 3). If market discipline is to be enforced, the orderly resolution of failing institutions must be a credible option.

If bank resolution schemes were a clear, adequate and credible option, the liabilities of financial institutions would be correctly priced, i.e. fair-priced. Each holder of bank liabilities would know the amount of the losses he would make in case of a systemic shock and in case of an individual bank failure. Additionally, deposit insurance premia should be risk-based. Clear-cut bankruptcy rules, with bankruptcy costs that are common knowledge, would eliminate uncertainty, decrease bargaining costs, and prevent the potential conflicts between different claim-holders. Moreover, an orderly bank resolution procedure should not impose huge costs on the taxpayer, as the contractual costs of renegotiation and bankruptcy decline if ex ante defined contracts determine how the rights of debtors of a financial institution that faces bankruptcy will be restructured (Freixas (2009)).

In the absence of adequate resolution schemes, the regulators are often forced to choose between two alternatives when they deal with a failing institution: “bail-out” (e.g. the case of

2. Banking Regulation – Existing Framework and Proposed Changes

American International Group (AIG)) and “disorderly bankruptcy” (e.g. the case of Lehman Brothers). A disorderly bankruptcy can amplify the systemic impact of bank failure by disrupting market confidence (uncertainty with regard to the magnitude of exposures, possible recovery rates on these exposures etc.), and / or by destroying access to the key services of bankrupt institutions (e.g. payment and settlement services). Hence, disorderly resolution imposes a huge threat on systemic stability. The other option available to regulators is to bail out the troubled institution by injecting public funds. This alternative imposes huge costs on the taxpayer and promotes moral hazard (excessive risk-taking by banks). We illustrate the regulatory authorities’ dilemma in the next figure.

Figure 2.7.: Fiscal cost and systemic impact of resolution regimes (source: Cihak and Nier (2009)).

On the one hand, a dedicated special resolution regime could shift costs from the taxpayer to the bank shareholders. On the other hand, it could mitigate the impact of bank failure on the
whole financial system\textsuperscript{11} (Cihak and Nier (2009)).

\subsection*{2.2.13. Financial Innovations and Regulatory Arbitrage}

Regulatory authorities have to deal with the increased innovation capacity and the complexity of financial instruments. The pressure to innovate in financial markets is believed to be more intense than in other markets because product cycles are shorter. Hence, even very sophisticated investors are not always able to understand the risk profiles of new, complex financial structures. Therefore, it is hardly surprising that the banking supervisors find it difficult to keep up with financial products that are changing constantly and are becoming more complex by the day. Moreover, financial innovations create a favorable environment for regulatory arbitrage. “... [F]inancial innovation created a set of securities that were highly effective at exploiting skewed incentives and regulatory loopholes” (Kashyap, Rajan, and Stein (2008), p. 21). It is often argued that financial innovations are not as beneficial as innovations in other markets, since the risk for financial institutions to go bankrupt if an innovation fails is limited, due to the safety net. Hence, the risk of financial innovations is merely one-sided, which makes innovations in financial market less efficient. Moreover, there is a strong belief that many innovations are designed to get around the regulatory rules.

\subsection*{2.2.14. Implementation Problems and Distorted Incentives for Supervisors}

It is desirable to base the regulation of banks on goals and principles that are agreed upon and well understood. Furthermore, to restore confidence and to have a positive impact on expectations, it is important to have a high degree of consensus regarding the policy instruments used to achieve the objectives agreed upon. However, most of the systemically-important banks are

\textsuperscript{11}Note that the fiscal cost of “disorderly bankruptcy” can also be large.
international. Hence, the regulatory aims and the corresponding procedures have to be coor-
dinated at an international level. This is a very challenging task, as only the state – and hence
its taxpayer –, can cover the systemic risks, and will be hit by systemic bank failures. Thus,
the question arises which nation’s taxpayers will have to pay if a multinational institution gets
into trouble. It is argued that only an ex-ante commitment to a clearly-defined burden-sharing
among countries could eliminate this implementation problem. The European Union has no
common regulatory framework either. Banking supervision is carried out at a national level,
international banks are monitored by a headquarter country. Deposit insurance is also orga-
nized at a national level, as well as banking crisis management. However, one should keep
in mind that national bank regulation also has a number of advantages. It fosters a better
knowledge of the local banking sector and offers easier access to the financial institutions, for
instance.

Another variety of issues regarding banking regulation is related to the supervisors themselves,
as they respond to distorted incentives like the other market participants. Some of these issues
are listed below and represented in Figure 2.8.

- Sound banking regulation imposes huge costs, and the supervisors may wish to mini-
mize those costs. Furthermore, lax supervision reflects the concern that the domestic
banking industry could be put at disadvantage compared to foreign competitors, due
to a tougher regulation. There is also the concern that harsh regulation might induce
domestic banks to shift parts of their business to regulatory heavens.

- To make banking regulation less mechanical, the policy-makers have to take a more
managerial role. Graduated responses require the exercise of judgment from bureau-
crats, who, as a rule, are reluctant to take responsibility for their own decisions (Hellwig
(2008)).
2. Banking Regulation – Existing Framework and Proposed Changes

Figure 2.8.: Relationship between regulators and financial institutions (source Freixas and Santomero (2002)).
Figure 2.8 illustrates the complex relationship between regulators and financial institutions (regulated agent). Its purpose is to show the limitations of banking regulation, and the regulation’s outcome.

Before we proceed with a discussion of new policy proposals and of academic contributions that are aimed at designing a new financial architecture, it might be useful to take a look at the last financial crisis. The current regulation failed to prevent it. Moreover, the mainstream view is that the regulatory flaws have greatly magnified the effects of the primary subprime mortgage crisis in the United States and largely contributed to the outbreak of the global financial crisis. To assess the proposed changes of the financial architecture, i.e. to analyze what kind of regulatory reform is needed, it is important to understand why the global crisis could not be avoided and which flaws in the current regulatory framework contributed to it – or even exacerbated it.

2.3. The Financial Crisis of 2007-2009: Need for Regulatory Reform

According to Acharya et al. (2009), it is generally agreed that the trigger of the crisis was the combination of a real-estate bubble and of a credit boom in the United States. When the housing bubble burst, the collapse of the US-subprime-mortgage markets was the natural consequence, which took neither the market participants nor the regulators by surprise. However, the breakdown of these markets does not explain the outbreak of a worldwide financial crisis. The IMF estimates the losses in mortgage-backed securities at 500 billion dollars. They are much smaller than the losses in the stock market after the crash of the technology bubble in 2000, or the losses of the US savings and loans industry incurred at the peak of the S&L crisis in 1990, for instance (Hellwig (2008)). The global financial system should be
able to absorb such losses. According to Hellwig (2008), the crucial difference between the subprime-mortgage crisis, which triggered the global financial crisis, and the other crises “is not in the magnitude of the primary losses, but in the systemic linkages and repercussions... in the subprime mortgage crisis, there has been no surgial separation of failing assets and failing institutions from the rest of the financial system” (Hellwig (2008), p. 36). The shock in the US mortgage markets must have hit some amplifying mechanisms. It is often argued that to a very large extent, this amplification must be attributed to the poor regulatory framework. To put it differently, the global financial crisis was triggered by regulatory failure (Brunnermeier et al. (2009), Tabellini (2009)), “... [T]he very founding principles of regulation have amplified the effects of a shock that in reality was not that large” (Tabellini (2009), p. 2).

**Regulation and financial crisis of 2007-2009**

To move forward and to improve regulatory framework, it is crucial to understand “how financial regulations failed and try to find new approaches to regulation before regulating everything in sight.” (Danielsson (2009), p. 54)

Simplifying greatly, let us now outline the different interpretations of the role of financial regulation in the recent financial crisis in the next figure.
Different diagnoses of the crisis, with different interpretations of the role of financial regulation in the crisis, call for different, partly mutually exclusive, regulatory changes.

In the next table, let us examine the theories about what went wrong, as well as these theories’ policy implications, in greater detail.
2. Banking Regulation – Existing Framework and Proposed Changes

Table 3: Theories about the role of financial regulation in the crisis of 2007-2009 and their policy implications

<table>
<thead>
<tr>
<th>Rationale</th>
<th>Policy Implication</th>
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<tbody>
<tr>
<td>Lack of Regulation</td>
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<tr>
<td>Economic agents often make irrational decisions. In particular, investors systematically make mistakes, due to loss-aversion, limited foresight, overconfidence, and/or irrational herding behavior. Hence, the prices in financial markets rather reflect actions of irrational agents than the available information. This irrationality creates price bubbles that end in crises after the bubble burst.</td>
<td>No reliance on financial markets and on modern finance theory. A very extensive set of rules and regulations is needed → the scope of regulation must be increased (more of the same regulation?). This is the 'best' way to protect markets against financial crises.</td>
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</table>
| Insights and policy implications of finance theory will always systematically mislead us when designing appropriate and effective rules and regulations. The regulatory mistakes in the recent crisis were often based on what academics believed to be the best economic theories. For example:  
  – No regulation of credit-default swaps (economists believed that they reduce systemic risk)  
  – Encouragement of securitization by giving securitized financial products lower risk weights (academics strongly believed in benefits of securitization)  
  – Heavy reliance on rating agencies (modern economics believes that firms’ concerns about good reputation prevents them from excessive risk-taking). | No basing of regulation on finance theory. The best way to protect financial markets against crises is to impose far higher buffers of all sorts on financial institutions (much higher minimal equity, liquidity, greater restrictions regarding risk-taking). |
### Rationale – Lack of Regulation

The global financial crisis revealed that market failures are much bigger (or of different types?) than assumed before.

Some (Keynes-inspired) economists argue that the recent financial crisis is the result of deregulatory measures in the 1980s and 1990s. They refer to the following regulatory changes, for instance:
- Repeal of the Glass-Steagall Act (1999), which prohibited banks from both accepting deposits and underwriting securities (segregation of investment banks from commercial banks).
- In 1990s banks obtained the allowance to hold risky assets off their balance sheets in structured investment vehicles (SIVs), that are not subject to capital requirements.
- Regulators allowed banks to use their own internal models to measure risk. This kind of (deregulatory) changes is claimed to have resulted in excessive risk-taking, which triggered the crisis. Strong belief that leniently-regulated markets are very unstable, prone to fraud and manipulation by insiders.

The ‘best’ way forward is to increase the scope of the same regulation.

Call for a sharp shift from 'light' to 'tight' regulation of financial markets (similar to the shift that took place in 1930s after the great crash). Strict financial regulatory system is imperative.

### Rationale – Overregulation

Some economists believe that markets are largely self-correcting and need to be free to thrive.

Regulatory intervention in financial markets set perverse incentives, encouraged excessive risk-taking and set the context for the outbreak of the crisis.

Strong belief that markets are self-correcting, blocking the ‘invisible hand’ of financial markets causes crises. Hence, the regulations of financial markets must be limited and lenient. Requirement to decrease the scope of regulation is the consequence.
### Rationale vs. Policy Implication

<table>
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<tr>
<th>Lack of Regulation</th>
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<td>These economists refer to heavy reliance on rating agencies, encouraged by regulators, for instance. Competitive markets might have produced less biased information. A widespread argument is that regulators set perverse incentive to invest in highly-rated securities, by penalizing banks that did not do so with higher capital charges.</td>
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<tr>
<th>Financial crisis as natural occurrence</th>
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<tr>
<td>Some economists believe that periodical financial crises are unavoidable, as a natural consequence of the cyclical nature of financial markets. There is a strong belief that market forces can overcome any crisis, and recover relatively quickly. Regulation and regulatory mistakes do not play a major role in financial crises occurrence.</td>
<td>No call for imperative regulatory reforms. Neither scope nor scale of regulation has to be changed.</td>
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<tr>
<th>Flawed and ineffective regulation</th>
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<tr>
<td>A view widely held among economists is that not the scope of regulation, but rather its very founding principles are ill-designed and flawed to such an extent that they amplified the effects of the initial subprime-mortgage crisis and triggered the outbreak of the global crisis. The main shortcomings of the current financial architecture were discussed in section 2.2</td>
<td>Redesign the financial architecture: Major changes are necessary. No consensus on concrete measures need to be taken (neither among academics nor among regulators and politicians).</td>
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</table>

Clearly, the diagnoses of the crisis differ widely, and thus, opinions differ as to which measures are appropriate to address it. As stated before, we do not believe that financial markets are self-regulating. Regulatory intervention is necessarily due to market failures that are large enough.
2. Banking Regulation – Existing Framework and Proposed Changes

to create distortions, which result in a risk-level higher than socially optimal. As highlighted in section 2.2., our view is that the very basic principles of the financial architecture are ill-designed and have, at least, largely contributed to the severeness of the financial crisis. We also believe that it is a mistake to abandon modern finance theory on the grounds that it cannot give us insights in how to design a better regulation. “... [T]he wildly unrealistic assumptions of the theories and the fact that these did not provide fertile ground to empirical corroboration proved to be an obstacle to their consideration as legitimic science... theories, instead of interpreting and predicting reality, were conceived to shape and transform reality. This ... led to practices by financial institutions that in fact amplified risk as well as financial and real fragility” (Caldentey and Vernego 2010, p. 2.). In our opinion, it would be wrong to give up on the finance theory. We rather have to rethink and revise its conceptional tools, and develop the new ones. We have to integrate macroeconomic thinking into the theoretical frameworks. Clearly, the existing research frameworks are inadequate to a very large extent, and not well-developed.

Starting with assumption that we need to redesign the basics of financial architecture rather than change the scope of the same regulation, it is important to understand which steps need to be taken first, or, to put it differently, which of the shortcomings of the current regulations are most devastating and need to be addressed first.

There is a wide agreement among academics regarding the major flaws of the current regulations. However, economists emphasize different weaknesses and thus recommend different steps as imperative if one wants to design a better financial architecture. Furthermore, when it comes to concrete proposals and to changes that have to be undertaken, there is even less agreement. Let us look at some short examples from the academic literature to demonstrate this.

According to Hellwig (2008), the main flaws of the current regulation that “involved the financial system in a downward spiral”, which triggered the outbreak of the global financial
2. Banking Regulation – Existing Framework and Proposed Changes

crisis and the necessary regulatory measures to address them are as follows

1. Insufficient bank equity capital

   Response: Significantly-increased capital requirements.

2. Unclear purpose of capital regulation (at least three goals with conflict potential)

   Response: Rethink the purpose of capital regulation.

3. Lack of transparency due to the unregulated “shadow banking sector”

   Response: Regulation of all interconnected and systemically-important financial institutions (also of non-banks).

4. Lack of systemic thinking in design of regulations

   - The current regulation is procyclical (capital regulation and mark-to-market accounting).

   - The systemic risk arising from maturity transformation is ignored.

   - The feedback from deleveraging into asset prices and other banks’ equity positions is ignored.

   - One relies on risk measurement by individual bank models that do not take correlations between underlying and counterparty risks into account.

   Response: Add an element of capital regulation that is independent of the risk calculations of internal bank models, introduce measures that reduce the procyclicality of capital regulation and mark-to-market accounting (e.g., time-varying capital buffers), require that institutions with long maturities of liabilities be less dependent on short-term funding.
According to Acharya, Pedersen, Philippon and Richardson (2009), the major flaws of the current financial regulation, and the appropriate measures to address them, are as follows:

1. **Distorted incentives caused by regulation**
   - Lack of proper pricing of deposit insurance
   - Too-big-to-fail guarantee

   ⇒ market discipline is ineffective, financial institutions engage in excessive risk-taking to exploit underpriced explicit and implicit guarantees.

   **Response:** Change the compensation schemes of bank managers (penalize managers who trade current gain for future losses), prevent regulatory arbitrage and charge appropriately for guarantees.

2. **Lack of systemic perspective when designing regulations, in particular in “Basel” capital regulation:**

   **Response:** Assess systemic risk, charge financial institutions for the contributions to systemic risk rather than individual risks.

3. **Unregulated “shadow banking sector” (loopholes in Basel II) ⇒ lack of transparency**

   **Response:** To be able to assess counterparty risks, enforce of better transparency of off-balance-sheet transactions and over-the-counter derivatives positions.

According to Freixas (2009), the main regulatory failures are the following:

1. **Capital requirements are based on incorrect risk measurements models.**

   **Response:** Improve risk measurement, e.g. compute higher weights for over-the-counter derivatives (risk premium), correct the price of collateral for possible bubbles, correct for discrepancies between ratings and spreads.
2. Banking Regulation – Existing Framework and Proposed Changes

2. The current regulation is procyclical

- Procyclical capital regulation,
- Procyclical accounting rules.

*Response:* compute anticyclical credit provisions and include an anticyclical mechanism in pillar 2, compute maturity mismatch capital charge, more prudent capital and dividend policy to account for higher balance-sheet fluctuations due to mark-to-market accounting.

3. There is no clear legally-defined structure of bail-out / liquidation procedures.

⇒ long bargaining processes and postponement of the resolution, which hurt the distressed institutions (“gamble for resurrection”) and the financial system.

*Response:* design specific bankruptcy procedures for banks, e.g., debt equity swaps, converse convertibles, good bank / bad bank, living wills, emergency recapitalization (insurance schemes with the support of the central bank). “Defining banks’ bankruptcy rules that could be contingent on the existence of a systemic crisis constitutes one of the most imperative changes in banking regulation” (Freixas (2009), p. 28).

4. The corporate governance is ill-designed

- Remuneration of bank managers
- Dividend policy

*Response:* adequate risk provisioning; compensation of bank managers should be lagged or based on stocks that are held for a long period of time, for instance, or taxpayers become bank owners during the crisis (represented at board of directors).

According to Van Reenen (2010), the main failure of financial regulation is that it induces moral hazard without mitigating risk-taking incentives. On the one hand, there are explicit
and implicit government guarantees to financial institutions to protect them from bankruptcy, which encourages gambling. On the other hand, the regulatory safeguards against excessive risk-taking are ineffective.

*Response:* Making bankruptcy credible $\implies$ disciplining device. According to Van Reenen (2010), two regulatory reforms are necessary to achieve this goal. First, bank oversize must be penalized. This can be done by taxing bank size (tax rate increases with rising bank size) or by setting quantity limits to the size of the balance sheets. Second, living wills have to be credible, such that each bank can be closed down and liquidated in a relatively short period. These regulatory changes are supposed to guarantee that no bank is “too-big-to-fail”. “Ideally, no institution should be systemic. Credible bankruptcy requires that no institution is too big, too complex or too central; regulators should ensure that this is the case” (Van Reeven (2010), p. 4).

2.4. Policy Proposals – Towards a More Stable and Resilient Financial Architecture

2.4.1. Mitigating Systemic Risk-Externalities

Obviously, different academics call for different regulatory changes, though there is much agreement regarding the flaws of the current regulation. Nearly everyone agrees that one of the main weaknesses is that regulation mostly aims at achieving financial stability from the microeconomic perspective alone. Hence, many reform proposals are focusing on systemic risk. Minimizing future systemic risk and implementing appropriate regulatory intervention / reaction when systemic risk is perceived to be high is at the center of these proposals. However, when one asks which concrete measures should to be taken, there is far less agreement.
Moreover, many of the existing suggestions are neither practical nor easy to implement.

In Table 4, we summarize the propositions of the “Geneva Reports”, the “NYU-Stern Report” and the “Financial Sector Taxation: IMF’s Report to the G-20 and Background Material” on how to handle systemic risk. We select these reports from the academic literature because they are detailed enough and because these reports demonstrate that there is no agreement among economists on how to incorporate systemic dimension in the current regulatory framework.

While all reports agree that financial regulation must include elements correcting/internalizing systemic risk externalities, there is no consensus on how to implement this. All possible solutions have potential advantages and shortcomings. We summarize them in Table 5.
Table 4: Internalizing systemic risk externalities (sources: Brunnermeier et al. (2009), Acharya, Pedersen, Philippon and Richardson (2009), IMF Staff (2010), Weder di Mauro and Klüh (2010)).

|------------------|---------------|------------------------|
| • Price charged by private sector  
• One regulator of systemic risk  
• The regulator assesses the contribution of financial institutions to systemic risk, based on i. Individual characteristics (leverage, asset quality)  
ii. Measures of interconnectedness and complexity of institutions (LCFs)  
iii. Statistical Measures. Use standard tools of risk calculation (value-at-risk, marginal expected shortfall, stress test, and macroeconomic scenario analysis) at the macroeconomic level.  
• Each institution is to charge according to its own contribution to the overall systemic risk. There are 3 ways to implement this i. Capital requirement proportional to the institution’s systemic risk contribution → Reduction of risk-taking (keeping capital reserves is costly) and higher equity buffer for losses; or, ii. Imposition of taxes based on the firm’s systemic risk contribution. Funds can be used to finance a systemic fund. Advantage: counteracts incentive to become too-big-to-fail; or, iii. Requirement on systemic institutions to buy insurance (partly private), which pays out in case of aggregate financial sector stress. The insurance payments will go to the public “bailout”-fund (alleviates moral hazard), the government provides the remaining funds based on insurance. | • Each year, Regulators / Supervisors assess the contribution of financial institutions (of all types) to systemic risk and classify them in 1. “Individually systemic” → large, massively interconnected, will not be allowed to fail 2. “Systemic as part of herd” (e.g. highly levered hedge funds) → may be small firms, but when they move together they can significantly increase systemic risk 3. “Non-systemic large” (not highly levered; e.g. insurance companies, pension funds) 4. “Tinies” → Macro-prudential regulation for 1. and 2.  
• Classification based on leverage ratios, maturity mismatches, estimation of bank credit – and asset price – expansion  
• Measurement of spillover risk via CoVar (VAR of financial institutions conditional on other institutions being in distress)  
• Options to internalize systemic externalities i. Capital charge (a cap on the debt / equity ratio). Option with the least policy obstacles, easiest to implement; or, ii. Pigouvian tax (periodic fee) → does not stifle competition, affects the profit of financial institution directly; or, iii. Private insurance scheme → less attractive, as government is a natural insurance provider in a crisis (flight to quality), connection between credit risk and counterparty risk; or, iv. Public / private insurance → private price discovery, but it is unclear if the goal of the optimal counter-cyclical charges is achievable. | • Focus on externality arising from too-big-to-fail guarantee  
• Internalization of this externality via i. A surcharge on capital; or,  
ii. Pigouvian tax. Capital requirements are already used to achieve multiple goals: buffer against losses, limiting risk-taking, these two goals are not necessarily compatible. Adding the goal to reduce procyclicality would exacerbate the problem (one instrument with at least three goals). Other disadvantage of a surcharge on capital: non-banks would be difficult to incorporate, funds remain on balance sheet, problems of risk migration (shadow banking sector) → Core element of European macro-prudential regulation should be a tax. The tax rate should increase with the systemic relevance of financial institution (of all types). The taxes should go to the European Stability Fund, which will serve as resolution tool. An optimal implementation requires that the tax rate is set such that the implicit funding cost advantage of systemically important institutions is eliminated. |
Table 5: Internalization of systemic risk externalities: Possible Advantages and Disadvantages (sources: Brunnermeier et al. (2009), IMF Staff (2010), Weder di Mauro and Klüh (2010), Doluca et al. (2010))

<table>
<thead>
<tr>
<th>Alternative Policy Tools</th>
<th>Capital Requirement proportional to the firm’s systemic risk contribution</th>
<th>Pigouvian Tax proportional to the firm’s systemic risk contribution</th>
<th>Mandatory Private Insurance with insurance premium proportional to the firm’s systemic risk contribution</th>
<th>Mandatory Public/Private Insurance with insurance premium proportional to the firm’s systemic risk contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro Arguments and Con Arguments</td>
<td>Pro Arguments</td>
<td>Con Arguments</td>
<td>Pro Arguments</td>
<td>Con Arguments</td>
</tr>
<tr>
<td></td>
<td>• Consistent with existing regulation (building on strong institutional framework), • Approach with the least political obstacles, • Transparent and easy to implement • Increase the risk exposure of equity holders (reduce moral hazard, enhance market discipline)</td>
<td>• Remove funds from the balance sheet • Can be used to create a systemic fund • Charging non-banks is possible (e.g., insurance companies) • Easy to adjust (more flexibility during crisis) • Smooth and continuous costs (no high up-front costs)</td>
<td>• No need for large capital reserves • Insurance premium based on market prices • Limit financial distress costs ex-post without distorting banks’ ex-ante incentives</td>
<td>• No need for large capital reserves • Insurance premium based on market price • Public power • It is easier for government to raise funds during a crisis • Limit financial distress costs without distorting ex-ante incentives</td>
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<tr>
<td></td>
<td>• Keeping capital reserves on balance sheet is costly • Capital requirements serve multiple purposes (limiting risk-taking, buffer against losses, base for supervisory intervention), adding one more goal will exacerbate the conflict between the goals • Problem to incorporate non-banks • Capital remains on balance sheets → banks will try to lever it up using regulatory loopholes</td>
<td>• No existing framework • Hard to figure out appropriate price • Taxes reduce firm’s profitability and charter value → less risk exposure of equity holders. If taxes are not sufficiently risk sensitive, risk-taking may increase</td>
<td>• Market is too small for real systemic risk • In times of severe crises, the government is a natural provider of funds (flight to quality) • LOLR still there → moral hazard issues</td>
<td>• Governance and coordination issues • Unclear whether it is possible to determine correct counter-cyclical charges</td>
</tr>
</tbody>
</table>
Capital charges, as well as taxes and insurance schemes, have the potential to internalize systemic risk externalities. However, all these policy tools have their shortcomings. Furthermore, since all of the proposed measures are based on the assessment of the individual contribution of the financial institutions to systemic risk, it is crucial to be able to measure it, as well as the overall systemic risk. Brunnermeier et al. (2009) proposes to use CoVar (conditional VAR), which measures the VAR of an institution conditional on other institutions being in distress. The NYU-Stern Report suggests to base systemic charges on the individual contribution of institutions to the aggregate tail risk. These suggestions are clearly targeting systemic risk as opposed to individual risks. However, much more work – empirical analysis, in particular – has to be done to find out whether these risk measures, or some combination of them, can really help identify systemic institutions and reduce the exposure of the financial system to systemic risk.

There are also economists who argue that since it is not clear yet how to measure systemic risk, and which financial institutions are systemic, a better way to contain systemic risk would be to significantly increase equity requirements. Thus, one could avoid mistakes that can be made when designing the charges for individual contributions of the firms to the overall systemic risk. There are also economists who believe that it is crucial for the financial stability to bring down the size of financial institutions, such that no institutions are sufficiently big to be systemic and to be able to endanger the soundness of the whole financial system. We will discuss this arguments in greater detail later in this chapter.

2.4.2. Regulation of Liquidity Risk

The recent crisis provides a clear rationale for the regulation of liquidity risk, as it has a significant systemic dimension. “A key avenue through which systemic risk flows today is via
funding liquidity combined with adverse asset price movements due to low market liquidity” (Brunnermeier et al. (2009), p. 39). There is a number of different policy proposals aiming at mitigating liquidity risk. In general, we can classify the policy options for liquidity regulations into four categories. They are summarized in the following table.
Table 6: Regulation of liquidity risk (sources: Brunnermeier et al. (2009), Rochet (2008), Perotti and Suarez (2011), Kashyap, Rajan, and Stein (2008))

<table>
<thead>
<tr>
<th>Quantity Requirement</th>
<th>Pigouian Tax (direct or indirect)</th>
<th>Insurance Against Liquidity Shortage</th>
<th>LOLR (properly priced ex ante)</th>
</tr>
</thead>
</table>
| Imposition of liquidity requirement (complementary to capital requirement) → creation of liquidity buffer | • Tax on short-term funding. Tax rate inversely proportional to maturity of liabilities → supposed to equate private and social costs of liquidity risk/short-term funding (e.g. Perotti and Suarez (2009))  
• Explicit capital charge for liquidity risk. Simple multiple to the current capital requirements (not a separate charge) (Geneva Report) | Financial institutions may be forced to buy insurance that pays out when the whole financial sector is in distress → automatic recapitalization (e.g. Gersbach, Kashyap et al.) | In case of financial distress (crisis) the central bank commits to providing credit lines under strict supervision of an independent banking regulator. The credit line are ex ante determined by the banking regulator (maximum credit amount, commitment fee, conditions under which credit is granted) → mitigates moral hazard. Loans may be made senior to all other liabilities of the financial institutions (Rochet) |

Pro Arguments | Con Arguments | Pro Arguments | Con Arguments | Pro Arguments | Con Arguments | Pro Arguments | Con Arguments
---|---|---|---|---|---|---|---
• Mitigates potential for runs (establishes confidence)  
• Buys time for corrective actions  
• Reduces need for asset fire sale  
• Rundown of buffers as signal of distress | • Procyclical if always binding  
• Very costly (used only under exceptional circumstances)  
• Micro perspective  
• Unclear if necessary in the presence of higher capital buffers | • Easy to adjust (e.g. in a crisis)  
• Makes short-term funding more costly → incentive to rely on long-term funding → reduction of propagation risk | • Measurement and calibration issues  
• Price discovery  
• Individual maturity mismatch does not capture systemic risk → taxes too low to internalize externality | • Reduces the costs of the crisis if it occurs (crisis probability always positive)  
• No “waste” of liquidity in normal times | • Market too small for real systemic risk  
• Moral hazard issues | • No “waste” of liquidity in normal times | • Moral hazard  
• Costly for the taxpayer  
• No incentives for financial institutions to reduce maturity mismatch

2. Banking Regulation – Existing Framework and Proposed Changes
There are different ways to regulate liquidity risk, and there is no agreement which approach, or which combination of regulatory measures, is most suitable.

In the next chapters of this thesis we will develop a theoretical model of banking system and derive a clear rationale for regulation of liquidity risk. Within our model framework, we will also compare the impact of three types of liquidity regulation: (quantity) liquidity requirements, liquidity insurance and liquidity risk taxes.

2.4.3. Regulation of Bank Equity

Basel II is focused on the regulation of bank equity. In section 2.2.1, we discussed its objectives and identified its main shortcomings. Before we introduce different proposals how to improve current capital regulation let us recall the main objectives of imposing bank capital requirements:

1. More “skin in the game” is supposed to curb excessive risk-taking

2. Capital reserves are supposed to serve as a buffer against losses in order to avoid insolvency

3. Equity requirements should enable supervisory intervention before banks become insolvent if capital does not provide a sufficient buffer against risk.

Obviously, current capital regulation failed to achieve the goals for which it was designed. There is an ongoing debate on how to redesign it. Different policy proposals are on the table. Some of them are based on changes / improvements of the current capital requirements, others are alternative regulatory options that target the same goals and are supposed to replace / complement equity regulation.
Appropriate level of bank capital

One of the most controversial issues being currently debated is how much equity banks should hold on their balance sheets. On the one hand, there is a call for significantly higher capital buffers, which are supposed to be the main step towards a better and more effective capital regulation. On the other hand, it is argued that a major increase of capital buffers would impose significant social costs, implying that one has to look for alternatives to such a radical measure. One could adopt a whole set of smaller changes that may, together, stabilize the system without imposing huge costs on society. We illustrate these regulatory alternatives in the Box on the next page.
2. Banking Regulation – Existing Framework and Proposed Changes

Box 2: Regulatory approaches

Key element of regulatory reform: Drastic increase in equity ratio (+ counter-cyclical buffers, i.e. higher than in a period of financial distress) + Mitigating systemic risk

Targets of Basel II capital regulation

- Loss absorption
- Signal for distress and basis for regulatory intervention
- Reducing incentives for excessive risk-taking

Set of new rules / improvements, that (may) complement each other, e.g.
- Taxing guarantees (curb excessive risk-taking, loss absorption)
- Contingent capital (loss absorption)
- Insurance schemes contingent on ex-ante specified event (loss absorption)
- Resolution schemes (curb excessive risk-taking, loss absorption)
- Time varying capital buffers (curb excessive risk-taking, used to absorb losses)
- Banking-on-the-Average Rules (Proposal by Gersbach and Hahn (2010)) (curb excessive risk-taking, loss absorption)
2. Banking Regulation – Existing Framework and Proposed Changes

In the table below, we summarize the main arguments on drastically-increased capital requirements.

Table 7: Arguments for and against drastically-increased capital requirements

<table>
<thead>
<tr>
<th>Pro Arguments</th>
<th>Con Arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• It reduces incentives for excessive risk-taking</td>
<td>• The costs of bank funding increase (as equity requires a higher return than debt, due to asymmetric information and managerial agency costs)</td>
</tr>
<tr>
<td>• It reduces deadweight costs associated with bailouts</td>
<td>• Capital is tied up → less lending, slower growth</td>
</tr>
<tr>
<td>• Greater equity buffers are similar to more “self insurance“ at market prices</td>
<td>• High equity ratios increase incentives for arbitrage and evasion → getting around the rules, large share of intermediation may be driven into shadow-banking sector</td>
</tr>
<tr>
<td>→ natural way to reduce the safety net (deposit insurance, too-big/interconnected-to-fail, other guarantees)</td>
<td>• Fire sales and credit crunch externalities are not eliminated if capital requirements are always binding</td>
</tr>
<tr>
<td>• Equity is the simplest and the most reliable buffer against losses (compared with contingent capital, insurance, for instance)</td>
<td>• High leverage is necessary for effective market discipline → creates stronger creditor discipline at the individual bank level and thereby better quality of bank loans and more liquidity (Calomiris and Kahn (1991), Diamond and Rajan (2001))</td>
</tr>
<tr>
<td>• High equity ratios focus on crisis prevention and reduce the probability of the need to resolve bankrupt institutions</td>
<td></td>
</tr>
<tr>
<td>• Modern finance theory will systemically mislead us in formulating regulation → best way to protect us against financial crisis is simply to drastically increase all sorts of buffers</td>
<td></td>
</tr>
<tr>
<td>• Higher equity requirements would reduce probability of banking default → lower risk premia on equity → offsets higher costs of equity funding compared to debt financing</td>
<td></td>
</tr>
</tbody>
</table>

There are two opposed views regarding drastically-increased capital requirements. The first is advocated, for example, by Admati et al. (2011, p. 58): “Setting equity requirements significantly higher than the levels currently proposed would entail large social benefits and minimal, if any, social costs. Approaches based on equity dominate alternatives, including
contingent capital... equity capital ratios significantly higher than 10% of un-weighted assets should be seriously considered.” Admati et al. (2010) argue that a significantly higher level of bank equity is the most important step towards systemic stability. This measure is considered to be superior to all other regulatory measures and reforms.

E.g. Miles et. al (2011, pp. 4, 41) come to the following conclusion: “Substantially higher capital requirements could create very large benefits by reducing the probability of systematic banking crises... we conclude that the amount of equity funding that is likely to be desirable for banks to use is very much larger than banks have had in recent years and higher than targets agreed under the Basel III framework... We believe... that there is a need to break out of the way of thinking that leads to the ‘equity is scarce and expensive’ conclusion.”

A contrasting view is advocated, for example, by Calomiris and Herring (2011, pp. 11, 14): “...[A] draconian increase in equity requirements would raise the costs of finance for banks. That increase in cost would translate into a contraction of banking activity, most importantly, bank lending. Equity is costlier to raise than debt for fundamental reasons associated with asymmetric information, and with managerial agency costs... In our view, raising equity requirements on SIFIs to 9.5 percent of risk-weighted assets, as under Basel III, makes sense, but a draconian increase in equity capital requirements would not be desirable, given that there are less-costly ways of lowering the risk of default at SIFIs.”

Europe Economics (2010, p. 2): “Increased capital requirements are, we think, very much a secondary consideration, which might serve at best to extend the period before future crises become acute, unless the other, more fundamental issues... are addressed adequately.”

Freixas (2009, p. 32): “It should be emphasized that adding additional layers of capital will impair the efficiency of the banking system if it is not accurately justified... A proposal of, say, tripling the capital requirement of banks would dwarf the banking industry while it is not clear that it would allow it to survive a repetition of the current crisis.”
2. Banking Regulation – Existing Framework and Proposed Changes

We conclude that although there is a broad agreement that the level of bank equity required under Basel II is too low and has to be increased, there is no consensus on the optimal level of bank capital. This issue has to be debated, all the potential costs and benefits of having the banks finance their businesses with more equity and less debt must be carefully examined and weighed up against each other when determining the level of required capital buffers.

**Additional capital requirements for systemically-important institutions**

As already mentioned before, many economists suggest to impose higher capital requirements on systemically-important, interconnected financial institutions than on smaller institutions facing the same underlying risks. Higher charges can be justified by

- *Too-big-to-fail guarantee by the government.* It distorts risk-taking incentives for systemic institutions and enables them to obtain cheaper funding. By imposing higher capital requirements on such institutions, one could offset the competitive advantage arising from cheaper funding. Moreover, since the probability of bank failure declines and as in case of bank failure, a greater amount of capital is available the costs imposed on the taxpayer will be reduced

- *Externalities / contribution to systemic risk.* The failure of a large, interconnected financial institution imposes much higher costs on society than the failure of a small one. By imposing higher capital requirements on these institutions, the regulator makes them internalize the externalities they cause

However, as already described before, the concrete steps to adjust capital requirements for systemic institutions are still an open issue. Moreover, it is not clear how systemic firms are to be identified. There is a number of detailed proposals regarding these issues (e.g. Brunnermeier et al. (2009), IMF (2010)), which have to be debated and developed further.
Contingent capital / Private crisis insurance

Many economists suggest to introduce mandatory insurance contracts as a complementary measure to capital requirements. There is a multitude of proposed insurance schemes. Despite their different features and characteristics, all of them can be viewed as an attempt to design a contingent contract that leads to an increase in bank equity during times of financial distress. The equity rises either directly when the contracts are executed, or indirectly, by creating incentives to raise a greater amount of equity voluntarily in good times. This unburdens the taxpayer.

One form of insurance contracts is contingent capital or contingent convertibles, often referred to as “CoCos”. CoCos generally involve banks being required to issue debt securities which automatically convert into equity if a particular stress trigger is activated (e.g. if a low pre-determined equity / asset ratio is reached). CoCos have two main objectives:

- Resolution mechanism. First, they should provide funds to distressed financial institutions when capital markets are illiquid. They are a form of self-insurance, pre-funded by private investors, to protect a bank’s solvency, and to unburden the taxpayer.

- Preventive measure. Second, CoCos are supposed to create incentives for bank managers to behave more prudently and to take corrective actions before debt converts to equity.

There is a number of different proposals how to design CoCos. All of them specify at least the following points:

- The amount of CoCos a bank has to issue,

- the trigger for conversion (e.g. if the trigger is a certain equity / asset ratio: low vs. relatively high, going concern vs. gone concern),
• the measurement of the trigger (accounting vs. market-valued numbers, supervisory assessment),

• the price at which CoCos are converted into equity, and

• the amount of CoCos that convert into equity when the trigger is activated.

Each of these features will impact the risk-taking behavior of the bank shareholders and of contingent capital buyers. Hence, if CoCos should become a part of capital regulation, it is crucial to design them appropriately. Otherwise, they can influence risk-taking incentives in a way that would rather undermine the financial stability than contribute to bank soundness.

When determining the key characteristics of CoCos the regulator should, in particular, provide incentives for the banks to take prompt corrective actions, like raising new equity, selling assets or taking other restructuring measures, all to avoid reaching the trigger. It is also important to ensure that CoCos have the same probability of loss as subordinated debt. Otherwise, banks would not be able to sell them.

The economists’ opinions on CoCos as a regulatory instrument diverge considerably. Let us summarize the main arguments of the advocates and opponents of contingent capital in the following table.
The mainstream view is that CoCos are a potentially promising supplementary measure to a simple equity requirement. First, if appropriately designed, they could create incentives for bank managers to avoid taking excessive risks and to raise a greater amount of equity, which would reduce the probability of financial crises. Second, CoCos could act as a crisis resolution instrument. In times of crisis, they would provide funds to the distressed financial institutions, funds which would be very difficult to raise otherwise. CoCos would impose the losses on the creditors and reduce the burden on the taxpayer. However, there are also strong arguments against CoCos. In particular, CoCos could make the financial system more complex, and

Table 8: Arguments for and against CoCos (sources: Admati et al. (2010), Goodhart (2010a), Flannery and Perotti (2011))

<table>
<thead>
<tr>
<th>Pro Arguments</th>
<th>Con Arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cheaper form of raising equity (compared to common equity)</td>
<td>• Too complicated to design properly, such that risk-taking incentives are not distorted</td>
</tr>
<tr>
<td>• Capital provision when it is needed most and when capital markets are illiquid</td>
<td>• Common equity has significant advantages compared to CoCos (higher equity requirement can provide the same buffer in a crisis, but is easier to implement, and more transparent)</td>
</tr>
<tr>
<td>• Imposition of losses on bank creditors → losses are spread more widely, less burden on the taxpayer</td>
<td>• Replacing part of the common equity with CoCos would allow the stockholders to reduce their share of risk-bearing. Bank managers may gamble to reach the trigger point to initiate the conversion of debt into equity</td>
</tr>
<tr>
<td>• Encourages market discipline by creditors, since buyers of CoCos fear losses from being turned into ordinary shareholders in case of bank distress</td>
<td>• If a bank is in a real trouble, CoCos would not provide funds enough to solve it</td>
</tr>
<tr>
<td>• CoCos' buyers determine CoCos' price → banks pursuing riskier investments would be penalized by higher interest rates on CoCos → market price discovery</td>
<td>• Risk of panic upon conversion, contagion from conversion → the value of CoCos would fall in other banks</td>
</tr>
<tr>
<td>• “If properly designed, a CoCo requirement can provide a more effective solution to the “too-big-to-fail” problem... and it can do so at a lower cost than a simple equity requirement.” (Calomiris and Herring (2011), p. 40)</td>
<td>• As soon as the conversion point is almost reached, equity prices would fall rapidly</td>
</tr>
<tr>
<td>• → no need to impose other charges on systemic institutions, appropriate charges being extremely difficult to calculate</td>
<td>• Very unattractive pay-off function. CoCos holders do not get a share of profits in good times but bear losses in bad times → banks will have to pay very high interest on them</td>
</tr>
<tr>
<td>• If appropriately designed, CoCos provide incentives to raise new equity in good times</td>
<td>• No adequately wide market for CoCos</td>
</tr>
<tr>
<td>• “A properly designed CoCo requirement creates incentives for banks to issue equity to maintain the right amount of capital (equity plus CoCos) relative to risk, CoCos not only encourage timely replacement of lost capital and better management of risk, they also encourage banks to respond to increased risk with higher capital.” (Calomiris and Herring (2011), p. 14)</td>
<td>• “CoCo holders would hedge against the possibility of loss from activation of the trigger by shorting the equity of the bank in which they held the asset, leading potentially to the amplification of systemic downwards spirals in the prices both of bank equity and of CoCos in the system as a whole.” (Goodhart (2010a), p. 4)</td>
</tr>
<tr>
<td>• Banks favor CoCos because they preserve the tax subsidies associated with debt financing</td>
<td>•</td>
</tr>
</tbody>
</table>

The mainstream view is that CoCos are a potentially promising supplementary measure to a simple equity requirement. First, if appropriately designed, they could create incentives for bank managers to avoid taking excessive risks and to raise a greater amount of equity, which would reduce the probability of financial crises. Second, CoCos could act as a crisis resolution instrument. In times of crisis, they would provide funds to the distressed financial institutions, funds which would be very difficult to raise otherwise. CoCos would impose the losses on the creditors and reduce the burden on the taxpayer. However, there are also strong arguments against CoCos. In particular, CoCos could make the financial system more complex, and
might lead to problematic market dynamics (Goodhart (2010a)).

Besides CoCos, economists propose various other insurance schemes.

For instance, Gersbach (2011) suggests the introduction of pure insurance contracts. Banks should be required to buy a certain number of insurance contracts issued by private investors. They pay a premium per insurance contract and in the event of a macroeconomic shock, or alternatively, if the average equity of the banking sector falls below a certain threshold, the contract issuers have to recapitalize the banks, i.e. to pay a pre-determined amount of money per contract. If the number of insurance contracts is sufficiently large, the banks could insure themselves fully against insolvency in a crisis. However, such an insurance scheme has a number of serious drawbacks. For instance, the insurance capacity of investors in a severe crisis may be too small to recapitalize the banking systems, as investors may also suffer losses, moreover, insurance contracts do not curb excessive risk-taking.

A similar insurance scheme is proposed by Kashyap, Rajan, and Stein (2008). It also involves requiring the banks to buy insurance contracts issued by private investors. These contracts stipulate a payment to be made if the banking sector as a whole is in bad shape, thereby increasing the amount of equity of the impaired institutions. To ensure that the contract issuers are able to honor their obligations in a crisis, these issuers are required to invest an amount of money that is equal to the sum insured in risk-free securities up front. Yet, this proposal cannot solve the problem of excessive risk-taking either: It does not link the aggregate risk contribution of the financial institutions to the premia they pay for insurance contracts, or to the amount of insurance they receive if the insurance payment is triggered.

There are various other suggestions containing private insurance schemes. All of them have their limitations. Moreover, in the case of a severe financial crisis, it is very unlikely that any amount of private money will be sufficient to recapitalize the banks. Hence, the public sector will always play the role of the lender of last resort. But despite all these shortcomings, some
sort of private insurance against systemic crisis is desirable. Even if its scale is limited, it has the potential to reduce the burden imposed on the taxpayers. Philippon (2009), for instance, argues: “My view is that having some insurance... would be invaluable... I would argue that an imperfect system is still preferable to ad-hoc LOLR interventions that create incentives for reckless risk taking ex-ante, and leave large liabilities for tax-payers ex-post.”

**Changes to regulatory risk weights**

There is no agreement among economists whether risk weights should be used to determine the capital charges, because the computation of risk weights is prone to measurement problems. A further serious problem regarding risk-weighted capital requirements is well-recognized by Calomiris (2009, p. 77): “The key problem with the current system of measuring asset values and risks is that it depends on bank reporting, supervisors’ observations, and rating agencies’ opinions. None of those three parties has a strong interest in correct and timely measurement of asset value and risk.” Calomiris suggests to cope with this issue by including market information into the regulatory risk-measurements process. For instance, one could tie the risk index of a loan to the interest rate that has to be paid for it. Riskier loans tend to pay higher interest rates. As a complementary measure, the regulator could require the banks to access uninsured credit markets and to issue some form of debt that remains (credibly) uninsured. This would enhance market discipline and create an incentive for the banks to assess the value and riskiness of their assets credibly. According to Calomiris, the interest paid on such risky debt would “provide valuable information about market perceptions of bank risk, which would be immune to manipulation by bankers, supervisors, regulators, or politicians.”(Calomiris (2009), p. 77).

Given that the capital requirements remain risk-based, there is broad agreement that risk-measurement models have to be revised, and that the risk weights, as well as other parameters in the risk-measurement frameworks, have to be calculated through-the-cycle, i.e. based on the
length of a complete business cycle rather than on point-in-time estimations only, or be based on estimations based on a certain period (that could be a boom) with the incorporation of tail risks, i.e. extreme events. Risk weights should, on the one hand, reflect the risk of underlying specific assets. On the other hand, they should be linked to the systemic importance of the various exposure types. Assets whose value is highly correlated with the economic cycle, or whose depreciation is expected to contribute to financial distress disproportionately, should have higher risk weights and be backed by higher capital buffers than other assets with a comparable risk level.

The choice of appropriate risk-weighting is crucial for risk-weighted capital charges. Since one cannot ensure that they are always correct, it is desirable to introduce an additional capital buffer that is not linked to the measurement of asset riskiness. Hellwig (2010), for instance, argues that in the recent crisis: “[m]any institutions had equity amounting to 1-3 percent of their balance sheets even as they were vaunting themselves as having 10 percent ‘core capital’. The latter quantity, which relates equity to risk-weighted assets, is of course useless if the risk weights have not been chosen appropriately.” One of the possible supplements to risk-weighted capital requirements is a (non-risk weighted) leverage ratio requirement.

A leverage ratio

Leverage ratio – non-risk weighted – can be introduced into the regulatory framework as a binding complement to risk-weighted capital requirements. Such a supplementary measure has no linkages to the banks’ internal risk measurement process. It is supposed to restrain the build-up of leverage in boom times. This would help reduce the pressure to deleverage in times of economic downturns. Since deleveraging processes are very likely to exacerbate the problems of an already-distressed financial system and damage the economy, a leverage ratio could have an important stabilizing effect. Currently, explicit formal leverage ratio requirements are in force in Canada, in the United States for commercial banks, and in Switzerland
Table 9: Potential advantages and weaknesses of a leverage ratio

<table>
<thead>
<tr>
<th>Pro Arguments</th>
<th>Con Arguments / Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Countercyclical measure. There exists strong empirical evidence that leverage is procyclical.</td>
<td>• Increased systemic risk due to</td>
</tr>
<tr>
<td>• Simplicity and transparency of leverage ratio. Its application and monitoring are simple and relatively cheap.</td>
<td>i. Distortion of risk-taking incentives. As leverage ratio treats all the assets equally (independent of their riskiness), banks have a strong incentive to build up riskier balance sheets.</td>
</tr>
<tr>
<td>• Less regulatory arbitrage since it is</td>
<td>ii. It is limited to balance sheet leverage and cannot include the entire off-balance sheet positions (even if some of the off-balance sheet positions are taken into account). Banks have a strong incentive to move positions off their balance sheets.</td>
</tr>
<tr>
<td>i. Difficult to manipulate.</td>
<td></td>
</tr>
<tr>
<td>ii. If risk-based capital requirements stay in place, it would be more difficult to arbitrage around two ratios than around just one.</td>
<td>iii. It tends to restrict lending during downturns. A leverage ratio that is always binding may be procyclical in a downturn, since it may force the banks to cut down lending even further (in a downturn, lending typically declines) to meet the regulatory requirements.</td>
</tr>
<tr>
<td>• It is a useful indicator whether a bank is in distress. There is strong empirical evidence that the smaller the equity ratio in a downturn, the more troubled the institution.</td>
<td></td>
</tr>
<tr>
<td>• Systemic risk reduction as leverage ratio limits the size of banks’ balance sheets. The aggregate size of exposures that might need to be unwound simultaneously in a downturn may be restricted better by a simple leverage ratio than by a risk-weighted capital ratio.</td>
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</tr>
</tbody>
</table>

2.4.4. Crisis Resolution

“Whatever reforms and enhanced regulations are applied to the financial system, there will always be financial crises” (Goodhart (2011), p. 20). Hence to ensure the well-functioning of the financial system, it is crucial to design effective crisis resolution mechanisms.
There is much agreement among economists on the main ingredients of a crisis resolution regime that would be more effective than the one that is currently in place. We represent these ingredients in the following figure.

Figure 2.10.: (Proposed) main building blocks of a crisis resolution regime

**Crisis resolution mechanism – Main ingredients**

- An effective mechanism for closure of a failed (non-viable) institution
  - Special bankruptcy procedure managed by banking supervisory authorities, enabling taking prompt actions
  - Requirement for banks to draw up living wills (⇒ reduction of informational uncertainties)

- An incentive-compatible resolution scheme
  - Shift resolution costs from taxpayers to banks and their creditors
  - An additional source for loss absorption
    - Debt-Equity Swap
    - Credit Default Swap (CDS)
    - Bail-in
  
- Higher equity capital requirements combined with the possibility of early intervention (prompt corrective actions), sanctions while the net worth of the bank is still positive and bankruptcy not unavoidable yet

**Special bankruptcy procedure**

First of all, regulatory authorities have to be able to liquidate a non-viable financial institution without any huge delay. “The success of the bailout/liquidation policy depends upon a clearly defined legal structure... The recent crisis has shed light on the costs of bargaining with the different stakeholders of a bank in distress...the renegotiation game implies a postponement of the resolution that hurts both the financial institution that may continue operating, possibly gambling for resurrection, and the overall financial stability...As the crisis has deepened, the too-many-to-fail issue arose and a generalized bail-out was the only option left to regulatory authorities.” (Freixas (2009), p. 19) There is a wide agreement that existing bankruptcy procedures are inadequate and inefficient to a very large extent. Many economists call for the
2. Banking Regulation – Existing Framework and Proposed Changes

design of a well-functioning insolvency procedure.

According to Freixas (2009), an efficient bankruptcy procedure should fulfill the following criteria:

1. A prompt recapitalization of the failing institution (reduction of debt and an increase in common equity) should be possible.

2. An effective bankruptcy procedure should enable the troubled institution to cope with the difficulties that it faces, no matter whether those difficulties are caused by its negative equity or its inability to pay its debts.

3. The “resulting” institution should be viable and able to operate in the interbank market, i.e. also be accepted as a partner by other market participants.

In order to achieve the above mentioned goals, the regulator needs a wide set of tools enabling to take actions like

- Direct change of claimholder rights, e.g.
  - “Reverse convertible debentures” (RCD) suggested by Flannery (2002). RCD convert automatically to equity when the equity falls short of a predefined threshold level. Flannery claims that the introduction of RCD is a simple and transparent way to deleverage a failing institution.
  - CoCos, which we thoroughly discussed in the previous subsection.

- The good bank / bad bank schemes which involve splitting up of the distressed institution into two parts: a “good bank”, that is viable and able to continue operating, and a “bad bank” that constitutes a shell for the residual impaired assets. This crisis resolution tool has already been widely applied (e.g. in Sweden)
2. Banking Regulation – Existing Framework and Proposed Changes

- A temporary take-over of the operations of an insolvent bank by a bridge bank to preserve the going concern value of the bank until it becomes solvent
- Nationalization of the failed institution as a last resort

In order to cope with informational issues and to make the resolution options that go beyond bailout of the whole banks less costly – and hence, credible –, one could require banks to draw up living wills.

**Living will**

Large, interconnected financial institutions can be required to draw up living wills. A living will is a detailed plan how the bank can be resolved in a rapid and orderly manner in case of financial distress. Many economists believe that such recovery plans have the potential to simplify bank resolution procedures and could help cope with too-big-to-fail issue. The main idea thereby is that living wills would reduce the uncertainty regarding

- the firm’s ownership structure and how the firm is connected to other institutions,
- the reaction of the firm’s counterparties and debtholders if one sells certain parts of the firm and/or changes the firm’s structure.

According to The Squam Lake Report (2010), these uncertainties are the main reason for the government bailouts of whole banks, together with all their subsidiaries. A reduction of these uncertainties would make it possible to rescue only the systemically-important parts of the banks, while less important parts could be sold or liquidated. “...[W]e believe that the concept of Living Wills is a promising beginning; its further development might allow systemically important banks to fail or, at least, to be unwound. The objective is to put in place, ex ante, conditions that would allow a wider range of options other than having the whole bank rescued” (Avgouleas, Goodhart, and Schoenmaker (2010), p. 2). Avgouleas, Goodhart, and Schoenmaker (2010) emphasize the ex ante effect of drawing up living wills. They
are supposed to force banks to simplify their structure and restructure their business operations. However, drawing up a wound-down plan is extremely difficult and time-consuming for all parties concerned. The main problem thereby is that large interconnected institutions are almost always international, more precisely, ‘international in life, but national in death’. When an international firm becomes insolvent, its national subsidiaries are subject to national bankruptcy procedures, which differ across countries, and are often inconsistent with each other. It is unclear yet how to overcome this cross-border issue.

Resolution mechanisms less costly for the taxpayers

There is a wide consensus that the costs of bank resolution should be shifted from the taxpayers to the banks and their debtors. This way, resolution schemes would become incentive-compatible. There are various proposals how to achieve this goal. Let us discuss some of them

- The leading proposal is to introduce *debt-equity swaps* (debt converts into equity automatically as soon as equity falls below a predefined threshold). However, it is unclear yet how to implement this policy instrument. It is very difficult (possible?) to design debt-equity swaps properly without distorting risk-taking incentives. Hence, the question arises whether it would not be easier and more effective just to raise the equity capital requirements accordingly.

- Hart and Zingales (2009) suggest the following CDS-Approach. The idea is that if the CDS-price rises above a predefined threshold level, the regulator requires the bank to raise additional equity (until the CDS-price falls below the threshold). If the bank does not fulfill this requirement, the regulator intervenes and may even liquidate the failing institution. In this approach, CDS-pricing is a market-based regulatory signal. It is supposed to reflect the probability that the bank might be in financial trouble and might not be able to fulfill its liabilities in full, as CDS-price is an insurance claim paying off
if the underlying institution becomes insolvent. The main weakness of this approach is that it may not work in case of systemic events, when the asset prices do not reflect their true value. According to Goodhart (2011), the value of equity of the first bank that is required to raise additional equity would fall and trigger contagion, such that the CDS-prices of other banks would also go up and exceed the threshold.

- “Bail-in” is another resolution option that shifts resolution costs from the taxpayers to the banks’ creditors. If the equity value of a financial institution falls below a certain benchmark, the regulator imposes predetermined haircuts on the value of the institution’s liabilities. Some liabilities may be even eliminated entirely.

The crisis resolution options discussed above involve changes in claimholder rights. This – will potentially – impose higher risk / costs on the debtholders, and, in turn, make debt – and hence bank funding – more expensive. However, this would reflect “…the true risk of bank debt and therefore enforcing clearly defined banks’ bankruptcy rules is much more efficient than imposing additional layers of capital.” (Freixas (2009), p. 29).

There are also various other proposals regarding the recapitalization of distressed financial institutions. Some economists suggest to create a crisis resolution fund that could be financed either through ex ante charges / taxes on banks, or ex post, by taxing the banks that survived the crisis, as proposed in the Dodd-Frank Act. However, ex post taxation tends to penalize the banks that were operating soundly, and exacerbates the moral hazard issue resulting from the free-rider problem. Moreover, taxing financial institutions in crisis times is a highly procyclical measure (Acharya, Adler and Richardson (2010)). Acharya, Adler and Richardson (2010) argue that that the idea of contingent capital and the related Bail-in idea do not have the potential to prevent a collapse of the whole financial system, as they just provide limited firewalls. Their suggestion is to combine this kind of measures with a “bottom-up” approach that involves automatic stabilizers incorporated into systemically-important parts of the banks’ capital structure. An appropriately-priced deposit insurance, lender of last resort
from the central bank against at market-rate fees and against eligible collateral, would be au-
tomatic stabilizers.

**Early intervention and higher equity buffers**

There is wide agreement that it is crucial for the regulatory authorities to have the power to intervene early when financial trouble starts in an institution. However, “[t]he problem with early intervention...is that it is not possible to come up with incontrovertible signs. Some cases will inevitably be missed while other potential problems will be identified which turn out not to be problematic after the event” (Mayes (2009), p. 56). There is also a wide consensus that equity buffers that are much higher than in the recent crisis are imperative to avoid a financial collapse in case of negative systemic events.

**2.4.5. Remuneration**

Another important issue that has to be dealt with is the compensation of bank managers. On the one hand, economists agree that the level of the bankers’ compensation should not be regulated by the governments, as it is a matter of corporate governance (see Buiter (2007), The Squam Lake Report (2010), for instance). However, on the other hand, many academics agree that the structure of the compensation should be changed in such a way that makes bank managers more sensitive to the downside-risk of their business decisions. The compensation should reflect not only the realized gains, but also potential / real losses. Banks could be required to pay a certain part of any bankers’ bonus in uninsured / junior debt, for instance. Alternatively one could make the bankers’ bonuses subject to unlimited liability, meaning that in case of a bad outcome, the bankers are liable for the losses with their bonus payments (Goodhart (2011)). This approach is supported by a number of economists. For example, Gersbach (2011) suggests to design “crises contracts” made specifically for bank managers.
These contracts are to design in such a way that in case of a crisis, “the top managers of major or highly interconnected banks contribute a portion of their earnings from the previous years to a rescue fund for the recapitalization of the banking system” (Gersbach (2011)). Such contracts would make excessive risk-taking less attractive, as bank managers would try to lessen the probability of banking crises, to avoid income depletion. E.g. The Squam Lake Report (2010) makes the following recommendations. “Systemically important financial institutions should withhold a significant share of each senior manager’s total annual compensation for several years...each holdback should be for a fixed dollar amount, and employees would forfeit their holdbacks if the firm goes bankrupt or receives extraordinary government assistance. In effect, holdbacks force employees to provide insurance against their firm’s failure...they earn a fixed amount (akin to an insurance premium) if the firm does well, and bear a loss if the firm does poorly” (The Squam Lake Report (2010), p. 50).

However, Goodhart (2011) doubts that this kind of changes to the bankers’ remuneration are feasible. In his opinion, the only change that could pass the political hurdle is the requirement that the bankers’ bonuses have to be paid out partly in the form of junior debt.

2.5. Basel III

In the wake of the recent financial crisis, the Basel Committee on Banking Supervision has issued a new set of recommendations for banking regulation.

Basel III – Key Changes to Basel II$^{12}$

Basel III does not replace the existing Basel II framework, it just supplements the existing regulations.

The major differences, compared to Basel II, are as follows.

$^{12}$Sources: Basel Committee on Banking Supervision (2010a,b,c).
Raising the quality, consistency and transparency of the capital base.

- The definition of what accounts as common equity is more restrictive
- The risk weights assigned to structured products and trading assets are set higher
- The minimum requirement for common equity goes up from 2% to 4.5%
- The minimum requirement for Tier 1 goes up from 4% to 6%.

Introduction of a harmonized non-risk-weighted leverage ratio

\[
\text{Tier 1 capital} \quad \frac{\text{Total assets} + \text{Off-balance sheet exposures}}{\geq 3\%}
\]

Reducing procyclicality – Requirement to build-up capital buffers

- Capital conservation buffer: set at 2.5% of common equity (and Tier 1 capital) \(\Rightarrow\) has to be built up during good times, and can be drawn down in stress periods. If a bank does not meet the additional capital requirement, it faces a reduction of its earning distributions.

- Countercyclical capital buffer: the regulator is required to monitor the credit growth, and if it is considered to be excessive, he may impose a countercyclical capital buffer, ranging from 0 to 2.5% on of risk-weighted assets.

Implementing a global liquidity regulation – Two liquidity standards

- Liquidity Coverage Ratio (LCR)
  \[
  \text{LCR} = \frac{\text{Stock of highly liquid assets}}{\text{Net cash flow over a 30-day stress period}} \geq 100\%
  \]

- Net Stable Funding Ratio (NSFR)
  \[
  (\text{NSFR}) = \frac{\text{Available amount of stable funding}}{\text{Required amount of stable funding}} \geq 100\%
  \]

In the next table, we summarize the purposes / rationales behind the proposed reforms, and the main issues arising from these proposals.

96
**2. Banking Regulation – Existing Framework and Proposed Changes**

Table 10: *Summary of rationales and issues of Basel III’s proposals. Sources: Basel Committee on Banking Supervision (2010a,b,c), Acharya (2011), Blundell-Wignall and Atkinson (2010), Europe Economics (2010), Repullo and Saurina (2011).*

<table>
<thead>
<tr>
<th>Rationale</th>
<th>Issues</th>
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<tr>
<td><strong>Raising the quality, consistency and transparency of the capital base</strong></td>
<td></td>
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<tr>
<td>Risk exposures should be backed by a high quality capital base. In particular, Tier 1 capital that is fully available to absorb losses on the going concern basis has to be strengthened. This is supposed to contribute to the systemic risk reduction.</td>
<td>The fundamental problems remain unsolved, i.e. capital requirements are based on static risk weights and lack systemic perspective.</td>
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<td></td>
<td>The problem that banks move their activities to the unregulated shadow banking sector remains unsolved.</td>
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<td></td>
<td>Banks are still allowed to use internal models to calculate risks.</td>
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<tr>
<td></td>
<td>Many economists argue that the levels of equity capital proposed currently are too low to make the financial system more resilient against systemic events.</td>
</tr>
<tr>
<td></td>
<td>Definitional issues remain open (e.g. treatment of unrealized gains, minority rules, contingent capital)</td>
</tr>
<tr>
<td></td>
<td>Calculation of capital requirements (decoupling from accounting disclosure requirements? mark-to-market accounting or historical cost basis?)</td>
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| **Introduction of a harmonized leverage ratio** | |
| The leverage ratio is supposed to restrain the build-up of leverage in boom times. This will potentially reduce the pressure to deleverage and the probability of deleveraging credit crunch in times of economic downturns. This way, a leverage ratio could have an important stabilizing effect. | There is an argument that the leverage ratio should not be seen as just a supplementary measure to risk-weighted requirements, since the risk-based approach proved to be ineffective. |
| | It is not entirely clear how to calculate leverage ratio, in particular which assets should be included in the nominator and denominator. |
| | It is unclear whether the leverage ratio and the risk-based capital requirements will interact well |
2. Banking Regulation – Existing Framework and Proposed Changes

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<th>Rationale</th>
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<tr>
<td><strong>Introduction of a harmonized leverage ratio</strong></td>
<td>together. On the one hand, if the leverage ratio is low, it becomes the maximum equity capital level. On the other hand, if the leverage ratio is set too high, it will induce banks to arbitrage risk weights, so that the level of equity they hold is not higher than required.</td>
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<tr>
<td>A leverage ratio is supposed to act as a supplementary measure to risk-based capital requirements.</td>
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**Reducing procyclicality – Requirement to build-up capital buffers**

Basel III proposes to introduce two new capital buffers: a *capital conservation buffer* and a *counter-cyclical buffer*.

The capital conservation buffer is designed to ensure that banks have capital reserves above the minimum requirements that can be drawn down to absorb losses in periods of financial stress. Banks will be required to build up these reserves in good times. This implies tighter capital requirements in boom periods and loosened capital requirements in times of economic downturn, meaning that capital conservation buffer is a countercyclical measure.

The countercyclical capital buffer is supposed to dampen the build-up of systemic risk. The buffer is to be deployed by the supervisor in times of excessive credit growth, which is based on the belief that credit growth is positively-correlated with systemic risk accumulating in the financial system. The buffer would go up and down in a countercyclical way.

It is argued that the capital conservation buffer will just imply ‘higher’ capital requirements. On the one hand, under the assumption that markets require banks to hold more equity in periods of downturn, banks would not be able to run down the additional capital buffers accumulated in good times. On the other hand, they are forced to build up higher capital levels in good times.

It remains unclear how the timing and the range of the cycles can be determined.

If a bank breaches the capital buffer targets, it will face restrictions on the payouts of dividends, share buybacks and bonuses. Investors might be worried about declining returns on bank investments for two reasons. First, the distribution of earnings might be restricted by the regulator. Second, due to the higher capital requirements in good periods, banks might not be able to exploit these periods to the same extent as before.

Using credit growth as the indicator for triggering the countercyclical buffer is likely to be a poor approach. Its main weakness is that credit tends to lag the cycle, such that “...[a] mechanical application of the new regulation would tend to reduce capital requirements in good times and increase capital requirements...”
2. Banking Regulation – Existing Framework and Proposed Changes

<table>
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<th>Rationale</th>
<th>Issues</th>
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<tr>
<td><strong>Reducing procyclicality – Requirement to build-up capital buffers</strong></td>
<td>in bad times, so it may end up exacerbating rather than ameliorating the inherent procyclicality of risk-sensitive bank capital regulation” (Repullo and Saurina (2011), p. 5)</td>
</tr>
<tr>
<td>These buffers are intended to be set large enough for banks to fulfill the minimum capital standards in periods of financial distress.</td>
<td></td>
</tr>
<tr>
<td>Promotion of more forward-looking provisioning.</td>
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| **Implementing a global liquidity standard** | |
| Basel III introduces the first global framework for the regulation of liquidity risk. Its purpose is to ensure that banks hold enough liquidity to promote the stability of financial systems. The framework consists of two liquidity ratios: A liquidity coverage Ratio (LCR) and a net stable funding ratio (NSFR). | The liquidity requirements approach is similar to the setting of capital requirements. Hence, they have the same weaknesses as capital requirements. First, they address the individual banks’ risks (no systemic perspective). Second, they are not countercyclical. Third, banks will be pushed “towards regulatory arbitrage of the liquidity weights, in particular, to the best-treated illiquid securities and systemically risky funding...the unintended consequence will be a concentration into these activities” (Acharya (2011), p. 22); incentive to move activities to the unregulated entities. |
| LCR is supposed to ensure that banks hold an appropriate amount of high quality liquid assets, which can be converted into money rapidly, such that banks are able to meet their cash commitments over a short-term period of financial distress. | It is unclear which assets should be considered as liquid (government bond? should all governments be included?). |
| NSFR is supposed to promote a medium-term and a long-term funding resilience for the banks, by providing incentives to fund assets that cannot be converted into cash rapidly with 'stable' funding. | It is not clear which institutions should be subject to liquidity standards. |
| The liquidity measures are complemented by a minimum set of tools for monitoring the liquidity risk and for exchange of information among the supervisors. | To a large extent, NSFR is an arbitrary measure, as it depends on the ability to model the behavior of investors that can be viewed as 'stable' in a period of financial stress. |
| “The liquidity proposals require more liquid assets to be held which, other things given, may lower returns. This may increase the incentive for excess risk taking in other areas” (Blundell-Wignall and Atkinson (2010)). | }
Basel III – Critical Assessment

Many economists argue that Basel III fails to address the fundamental flaws of the existing regulatory framework. In the following, let us give some examples of the arguments.

Acharya (2011): “I argue that Basel III, like its predecessors, is fundamentally flawed as a way of designing macro-prudential regulation of the financial sector” (p. 1). According to Acharya (2011) the main weaknesses of Basel III are as follows

- Like the previous Basel Accords, Basel III aims at regulating the individual banks’ risks, and does not address the systemic risk dimension, or endogenously-evolving risks. This means the capital requirements do not depend on the banks’ contributions to systemic risk.

- Basel III does not address the issue of the shadow banking sector. Banks can still get around the capital requirements by moving their operations into the unregulated shadow banking system.

- Concentration on the individual banks’ risk profiles might exacerbate the systemic risk. When making an effort to diversify the idiosyncratic risks, individual institutions might hold the same aggregate risk, and become more correlated.

- Basel III uses static risk weights, and neglects that risks of underlying assets might change over time.

- Moreover, Basel III’s static risk weights induce procyclicality. They prefer some asset classes over others, and hence give incentives for correlated investments in the favored asset classes, which, in turn, leads to deterioration of the quality of these assets. Once this risk materializes, the financial system overleveraged on these asset holdings is confronted with endogenously evolving liquidity risk.
According to Repullo and Saurina (2011): “…[t]he new regulation does not change the risk sensitivity of minimum capital requirements. The result is that bank capital regulation may amplify business cycle fluctuations. The effect could be especially important in downturns, with banks possibly facing a “capital crunch” that would further restrict their lending” (p. 19).

Basel III mostly focuses on an increase in the banks’ capital reserves. However, according to Perotti, Ratnovski and Vlahu (2011), recent evidence shows that financial institutions increasingly face tail risks. These risks materialize very rarely, but once they do, no plausible amount of initial equity capital would suffice to absorb the losses. “First, regulators should acknowledge that traditional capital regulation has limitations in dealing with tail risk. This is similar, for example, to an already-accepted understanding that it has limitations in dealing with correlation risk. Second, banks with significant excess capital may be induced to take excess risk (in order to use or put at risk their capital), as amply demonstrated by the crisis experience. Hence, simply relying on higher and “excess” capital of banks as a means of crisis prevention may have ruinous effects if it produces a false sense of comfort” (Perotti, Ratnovski and Vlahu (2011) p. 5).

Basel Accords are policy recommendations that lack a formal basis. According to Goodhart (2010b), this is the main flaw of the BCBS approach, namely the reluctance to penalize the banks that are not complying with proposed regulations. “The untoward result of this has been that virtually all those involved whether ratings agencies, market operators and commentators, or even the regulators themselves, have taken the BCBS proposed ratios as absolute minima which can never be infringed without serious reputational consequences...But this...indeed has destroyed, the potential buffering role of (required) capital, and has transformed the usable buffer into the shape of the much more exiguous margin above the required capital ratio. That has been a major drawback of the whole BCBS approach to date...the BCBS has still refrained from grasping this nettle” (Goodhart (2010b), p. 17).
To sum up, Basel III is just a small step in the right direction, but it is far from being sufficient to make the financial system robuster in periods of economic downturns. A number of fundamental problems remains unsolved, mispriced government guarantees, too little bank equity, too-big-to-fail issue and the lack of systemic perspective in the regulatory approach, in particular. Moreover, it is unclear how various cross-border issues are to be solved, which arise from the fact that large systemic financial institutions operate globally, but that their resolution is subject to a variety of different national laws.
3. Liquidity Risk – Basic Model

3.1. Introduction

Time scales for production and financing differ. Therefore, financial intermediaries have spe-
cialized in using short-term funds to finance illiquid long-term investments. In the recent
financial crisis, however, it appears that the fragility of many banks in the US and in some Eu-
ropean countries due to their reliance on short-term funding has been extrem (Brunnermeier
et al. (2009), Hellwig (2008)).
As is apparent from Figure 3.1, banks in the US have economized on cash holdings over the last two decades. Moreover they relied more and more on wholesale short-term investors (see Adrian and Shin (2009)). Conduits, special investment vehicles and investment banks were performing significant maturity transformation and played the yield curve exposing themselves to large scale funding risk. When panic withdrawals of such investors set in during the weekend when Lehman Brothers collapsed, banks were forced to sell assets, triggering asset price declines, further distress sales and undermined access to new financing. Dysfunctional interbank and wholesale money markets propagated the original shock in the US real estate market and considerably increased the scale of the crisis (Brunnermeier et al. (2009), Hellwig (2008)). The particular type and scale of liquidity problems in the recent crisis have triggered loud calls to limit banks’ appetite for liquidity risk.

In this chapter we develop a model of the banking system that first provides a rationale for
regulating liquidity risk and second allows to compare three types of regulatory interference:

- **Liquidity Requirements:**
  A bank has to hold a fraction of its assets in cash or near-cash assets.

- **Liquidity Risk Taxes:**
  Banks need to pay taxes on investments that rely on short-term funding, that poses a refinancing risk.

- **Private Liquidity Insurance:**
  Banks have to buy a particular amount of liquidity insurance contracts. For each contract banks pay a premium and receive a prespecified amount of cash or cash-near assets in the event of a liquidity crisis.

The model consists of a banking sector with long-term illiquid investment opportunities that need to be financed by short-term debt and by issuing equity. Refinancing of long-term investments in the middle of the life time is risky as the next generation of potential short-term debtors may not be willing to provide funding when there are bad signals about the return prospects of the long-term investments. Early liquidation of long-term investments generates high losses.

The chapter is organized as follows. Section 3.2 introduces the model. In section 3.3, we develop the equilibrium concept and describe banking default procedures. Section 3.4 explores the properties of the model in a frictionless environment and represents the socially optimal allocations. In section 3.5, we return to the economy with frictions and derive equilibria without regulation.
3.2. The Model

We consider a three-period economy \((t = 1, 2, 3)\). It is populated by two types of households: consumers and investors, who differ in their risk aversion, life-time and opportunities to invest. Each household is endowed with initial wealth \(\nu\) in the first period of its life and no wealth in other periods. The economy incorporates two production technologies: a short-term technology, which yields constant returns per unit of investment, and a long-term technology, which is subject to macroeconomic risk and exhibits decreasing returns to scale. There are \(n\) banks in the economy serving as financial intermediaries. They compete for funds of the households and undertake investments in technologies. The detailed description of the model is set out in the following subsections. (The list of notations can be found in Appendix C.)

3.2.1. Technologies

The model encompasses a short-term technology (henceforth STT) and a long-term technology (henceforth LTT). STT yields a constant gross return \(i (i > 1)\) in period \(t + 1\) for each investment unit in period \(t\). Thus investing one unit of wealth in STT in \(t = 1\) yields a risk free gross return \(i^2\) in \(t = 3\). Investment in LTT takes place in \(t = 1\) and the output is realized after two periods in \(t = 3\). Investment is risky and its return depends on the macroeconomic shock, denoted by \(\lambda\). \(\lambda\) can take three values: (i) \(\lambda = h\) represents high return and occurs with probability \(p_H\), (ii) \(\lambda = m\) represents moderate return occurring with probability \(p_M\), and (iii) \(\lambda = l\) represents low return with probability \(p_L = 1 - p_H - p_M\). The shocks \(h, m\) and \(l\) are real numbers that satisfy \(0 < l < m < h\). If the amount \(X\) is invested in LTT in \(t = 1\) and the

\(^{1}\text{The model is a variant of Gersbach (2010).}\)
3. Liquidity Risk – Basic Model

Investments are not liquidated earlier, the output in \( t = 3 \) is given by

\[
\lambda f(X) = \begin{cases} 
  h f(X) & \text{(high)} \quad \text{with prob. } p_H, \\
  m f(X) & \text{(moderate)} \quad \text{with prob. } p_M, \\
  l f(X) & \text{(low)} \quad \text{with prob. } p_L,
\end{cases}
\]  \quad (3.1)

where \( f(X) \) is the production function.

Hence the expected output of LTT in \( t = 3 \) is

\[
\mathbb{E}(\lambda f(X)) = f(X)(p_H h + p_M m + p_L l).
\]

We assume that LTT exhibits decreasing marginal returns: \( f'(X) > 0, f''(X) < 0 \), and satisfies Inada Conditions: \( \lim_{X \to 0} f'(X) = \infty \) and \( \lim_{X \to \infty} f'(X) = 0 \). The assumptions on \( f(\cdot) \) imply that there exists a uniquely determined \( X \) such that

\[
f'(X)(p_H h + p_M m + p_L l) = i^2.
\]

Note that

\[
f'(X)(p_H h + p_M m + p_L l) > i^2 \quad \forall X < X \quad \text{and} \quad f'(X)(p_H h + p_M m + p_L l) < i^2 \quad \forall X > X.
\]

Additionally we assume

\[
m f'(X) = i^2,
\]

i.e., \( m = \mathbb{E}(\lambda) \), which gives

\[
f'(X)(p_H h + p_L l) = (1 - p_M)i^2 = (p_H + p_L)i^2. \quad (3.2)
\]
To simplify notation let $r^h = hf'(X)$, $r^m = mf'(X)$, $r^l = lf'(X)$, and $r^e = p_H r^h + p_M r^m + p_L r^l$.

We assume that in period $t = 2$ all market participants observe $\lambda$ and thus the uncertainty about the output of LTT is resolved. Moreover, we assume that the returns on LTT are zero if the investments are liquidated in $t = 2$. This assumption makes losses in case of a bad macroeconomic shock very severe (represents a strong form of illiquidity) and makes the impact of banking regulation particularly transparent.

### 3.2.2. Consumers

The economy encompasses two overlapping identical generations of consumers, called the first and the second generation, each living for two periods. Each generation of consumers consists of a continuum of individuals with measure $\eta$ ($\eta \geq 1$). The first generation is born in $t = 1$, the second is born in $t = 2$ when the first generation is old. Consumers are risk-averse and want to smooth consumption over time. Let $u(c_t, c_{t+1})$ with $t = 1, 2$ denote a standard intertemporal concave utility function of a consumer exhibiting decreasing utility in consumption. The variables $c_t$ and $c_{t+1}$ denote the consumption of the consumer born in period $t$ when young and old, respectively. Suppose for the moment that consumers can transfer their wealth between two periods at the gross risk-free return $i$. Then, the consumer’s optimization problem is given by

$$\max_{c_t, c_{t+1}} u(c_t, c_{t+1})$$

s.t. $c_{t+1} = (\nu - c_t)i$.

The solution of the maximization problem is the optimal amount of savings of a consumer when young. We denote the individual savings by $s_t(i)$ ($t = 1, 2$). Note that $s_t(i) = \nu - c_t^t$. 

109
3. Liquidity Risk – Basic Model

The aggregate amount of savings of generation $t$ is denoted by $S_t(i) \ (t = 1, 2)$ and given by $S_t(i) = \eta_s t(i)$.

From now on we make the assumption that consumers do not have access to STT and LTT and can only transfer their wealth between periods via bank deposits. Let $D_t^c \ (t = 1, 2)$ denote the aggregate amount of bank deposits held by generation $t$ of consumers.

### 3.2.3. Investors

The second type of households are investors. This is a continuum of individuals of measure 1. Investors live for 3 periods from $t = 1$ to $t = 3$ and maximize their consumption in $t = 3$, i.e. they do not consume in $t = 1$ and $t = 2$. They are risk-neutral. Let $W$ denote the initial aggregate wealth of investors. There are three investment opportunities available to investors in $t = 1$: bank equity capital, bank deposits, and STT\(^2\). We denote the corresponding aggregate amounts of investments by $E_1$, $D_1^I$ and $L_1^I$, respectively. In $t = 2$ investors have only two investment opportunities: bank deposits, provided that at least one bank survives in $t = 2$, and STT. The aggregate amounts of investments in deposits and in STT in the second period are denoted by $D_2^I$ and $L_2^I$, respectively.

### 3.2.4. Banks

The model incorporates a competitive banking system with $n$ banks indexed by $j = 1, ..., n$. Banks act as financial intermediaries. They are the only agents having access to both STT and LTT. Initially banks are only a label (or name), offering investors equity contracts in exchange for funds. Buyers of equity contracts of a particular bank become its owners. They obtain

\(^2\)Investors can invest directly in STT but have no direct access to LTT as generating returns of such risky long-term investments requires the availability of monitoring technologies, which are only accessible for banks. There are many ways to justify why banks are needed to channel funds from depositors and equity holders to risky long-term investment projects. See, e.g., Diamond (1984) and Hellwig (1998).
3. Liquidity Risk – Basic Model

the right to participate in dividend payments in $t = 3$ according to the share of funds invested in initial equity of the bank. Equity holders are protected by limited liability as their losses cannot exceed the resources they have invested in initial bank equity of a particular bank. The amount of equity obtained by a bank is determined by the amount of funds offered by investors, which, in turn, depends crucially on the expected return on bank equity. Banks that receive a positive amount of equity in $t = 1$ are set up and begin to operate.\(^3\) If a bank does not default in $t = 2$, the returns of its entire investments will be realized in $t = 3$ and the bank will be liquidated. The residual value of the bank will be shared between the holders of its equity contracts, in proportion to the resources they have given to the bank in $t = 1$. Let $e^j_t$ denote the amount of equity capital of bank $j$ in period $t$ ($t = 1, 2, 3$). The aggregate amount of equity in period $t$ is denoted by $E_t$ and given by $E_t = \sum_{j=1}^{n} e^j_t$.

The second source of banks’ funding are deposits. Banks that are set up to operate offer households in $t = 1$ deposit contracts in a competitive market at the deposit rate $r^D_1$. Let $d^j_1$ with $d^j_1 = d^j_1C + d^j_1I$ denote the amount of deposits obtained by bank $j$, where $d^j_1C$ and $d^j_1I$ are deposits received from consumers and investors, respectively. The aggregate amount of deposits is denoted by $D_1$ with $D_1 = D^C_1 + D^I_1$.

After receiving funding from the households ($e^j_1 + d^j_1$), banks make investments in the interests of equity holders. We denote the individual amounts of investments by bank $j$ in LTT and STT by $x^j$ and $l^j_B$, respectively. The aggregate investment amounts are $L_B = \sum_{j=1}^{n} l^j_B$ and $X = \sum_{j=1}^{n} x^j$. Since investments in STT are risk-free and have a short economic life-time they represent liquid assets in our model, hence we will refer to $l^j_B$ and $L_B$ as \textit{voluntary liquidity}.

We assume that LTT is provided by a representative third agent, who receives the surplus of the risky illiquid investment. The third agent may represent another sector in the economy or agents in other countries. We assume that the market for investments in LTT is competitive.

\(^3\)In practice, banks are allowed to operate if they obtain an amount of equity which is greater than some minimum threshold level.
Hence banks obtain marginal returns on investment in LTT, implying that if bank $j$ invests $x^j$ in LTT in $t = 1$ it receives in $t = 3$ either $\lambda f'(X) x^j$ or zero if investments are liquidated earlier.

In $t = 2$ bank $j$ has to pay back $d^j_1 r^D_1$ to its depositors. It offers deposit contracts in a competitive market at the deposit rate $r^D_2$, to receive fresh liquidity. The new potential depositors are the second generation of consumers and investors. Let $d^j_2$ with $d^j_2 \geq 0$ denote the amount of deposits collected by bank $j$. The aggregate amount of deposits is $D_2$ with $D_2 = D^C_2 + D^I_2$.

Upon receiving new funding ($d^j_2 \geq 0$) bank $j$ faces one of the following situations: either it is liquid and able to pay back the first generation of depositors and it continues to operate or it cannot fulfill its obligations, and defaults. The condition for survival in $t = 2$ is

$$ l^j_B + d^j_2 \geq d^j_1 r^D_1. $$

(3.3)

If bank $j$ survives in $t = 2$ the output of its investments in STT and LTT is realized in $t = 3$ and it faces the same situation as in the second period. If the final output of the bank is sufficiently large, it fully repays the second generation of depositors, which requires

$$ \lambda f'(X)x^j + (l^j_B + d^j_2 - d^j_1 r^D_1)i - d^j_2 r^D_2 \geq 0. $$

After the repayment, bank $j$ will be liquidated and equity holders receive its residual value. If the output is not sufficient to fully repay the depositors, bank $j$ defaults and equity owners receive nothing. The default procedure will be described in detail in the following subsections.

The final equity of bank $j$ in $t = 3$ is then given by
\[ e_j^3 = \begin{cases} 
\max \left\{ \lambda f'(X)x^j + (l_B^j + d_2^j - d_1^j r_D^1)i - d_2^j r_D^2, 0 \right\} & \text{if} \quad l_B^j + d_2^j \geq d_1^j r_D^1 \\
0 & \text{if} \quad l_B^j + d_2^j < d_1^j r_D^1.
\end{cases} \] (3.4)

The objective of banks in the interests of bank owners is to maximize the expected return on equity\(^4\): 
\[ \max_{r_B, x^j} \left\{ \frac{e_j^3}{e_1^j} \right\}. \]
Since \(e_1^j (j = 1, ..., n)\) is given when investment decisions are made (in \(t = 3\)) and since bank owners are risk-neutral, banks maximize \(\mathbb{E}(e_3^j)\).

We illustrate the economy by the following figure:

---

\(^4\)This is standard limited liability characteristic of equity. We neglect conflicts of interest between bank managers and bank owners.
3. Liquidity Risk – Basic Model

3.2.5. Regulatory Environment and Main Assumptions

As a benchmark case, we analyze the model without regulatory intervention. However we assume an implicit guarantee of deposits by the government. The recent financial crisis has highlighted the fact that the governments rescue depositors in a crisis even if they are not protected by an explicit deposit insurance. In the remainder of this subsection we will introduce assumptions that will be needed throughout the model analysis and describe the initial situation in the economy.

First, we make assumptions on initial endowments of the households:

Figure 3.2.: Sequence of events
3. Liquidity Risk – Basic Model

Assumption 1

\[ W > (f')^{-1} \left( \frac{(p_H + p_M)^2}{p_H h + p_M m} \right) - \frac{S_2(i)}{i}. \]

We denote \((f')^{-1} \left( \frac{(p_H + p_M)^2}{p_H h + p_M m} \right)\) briefly by \(X_{\text{max}}\) and rewrite Assumption 1 as

\[ W + \frac{S_2(i)}{i} > X_{\text{max}}. \tag{3.5} \]

Assumption 1 will guarantee that the aggregate wealth of investors and the aggregate savings of consumers are so high that it is impossible to invest all initial resources in LTT and to earn at least the expected return \(i^2\) per unit of investment over two periods.\(^5\) Hence, it will turn out to be socially desirable to invest some of the resources in STT. Note that \(X_{\text{max}} > \overline{X}.\(^6\)

Second, we have:

Assumption 2

\[ S_t(i) < \overline{X} i \quad \text{with} \quad t = 1, 2. \]

Assumption 2 implies that the aggregate savings of one generation of consumers are not large enough to fully exploit the opportunities of LTT.

Third, unless otherwise stated, we have:

Assumption 3

\[ r_1^D = i \text{ and } r_2^D = i. \]

---

\(^5\)Recall that LTT exhibits decreasing returns to scale.

\(^6\)We prove this as follows. Using \(m = \frac{i^2}{f'(X)}\) and \(h f'(X) > i^2\) we obtain

\[ f'(X_{\text{max}}) = \frac{(p_H + p_M)^2}{p_H h + p_M m} = \frac{(p_M + p_H)^2 f'(X)}{p_H h f'(X) + p_M i^2} < \frac{(p_M + p_H) f'(X)}{p_H + p_M} = f'(X). \]

Finally, \(f''(\cdot) < 0\) gives \(X_{\text{max}} > \overline{X}.\)
3. Liquidity Risk – Basic Model

The intuitive reason for Assumption 3 is as follows. Deposit rates smaller than the risk-free return on STT cannot emerge in a competitive market. Deposit rates higher than $i$ cannot be generated due to Assumption 1.\(^7\)

Finally, we assume that there exists an upper level of $h$, denoted by $\overline{h}$:

**Assumption 4**

\[
h < \overline{h} := \frac{m}{p_H} \left( \frac{X_i}{D_2} - (1 - p_H) \right).
\]

Assumption 4 is a simplifying assumption that guarantees that banks default only if $\lambda = l$.\(^8\)

The initial situation in the economy is the following. At the beginning banks are only labels and identical in the eyes of potential equity holders. Thus each bank obtains the same amount of equity from investors such that $e^j_1 = \frac{E_1}{n}$ ($j = 1, \ldots, n$).\(^9\) The same reasoning applies to deposits such that $d^j_1 = \frac{D_1}{n}$. Hence in $t = 1$ bank $j$ chooses its optimal investments $x^j$ and $l^j_B$ under the budget constraint $x^j + l^j_B \leq \frac{E_1 + D_1}{n}$. In period $t = 2$ when the uncertainty about the returns on long-term investment is resolved, bank $j$ either obtains new funding and survives or does not obtain fresh liquidity ($d^j_2 = 0$) and defaults on its obligations.

### 3.3. Equilibrium Concept

Next we will develop an equilibrium concept.

---

\(^7\)The aggregate endowment of households is so high that it cannot be fully invested in LTT and yield an expected return higher than $i^2$ over two periods. As a consequence banks cannot pay depositors interest rates higher than expected returns from their investments.

\(^8\)We will show this later. The proof will require that return on investment in LTT in state $\lambda = h$ is smaller than $\overline{h}$, to guarantee that the expected return on bank equity is smaller than the return on investment in STT if banks survive only in the good state.

\(^9\)This holds if one applies a suitable version of the law of large numbers.
3. Liquidity Risk – Basic Model

3.3.1. Definition of Equilibrium

We will look for symmetric equilibria defined as follows.

**Definition 1 (Equilibrium)**

A competitive symmetric equilibrium (henceforth equilibrium) is a quadruplet \( \{X, E_1, L_B, L_I\} \) such that the following conditions hold

\[
\begin{align*}
\text{(i)} & \quad l^j_B \quad \text{and} \quad x^j \quad \text{solve} \quad \max \mathbb{E} \left( e^j_3 \right) \quad \text{s.t} \quad x^j + l^j_B \leq \frac{E_1 + D_1}{n} \\
& \quad \text{where} \quad x^j = \frac{X}{n} \quad \text{and} \quad l^j_B = \frac{L_B}{n} \quad \forall j = 1, \ldots, n \\
\text{(ii)} & \quad D_C^j + D_I^j + E_1 = X + L_B
\end{align*}
\]

\[3.6\]

\[
\begin{align*}
\text{(iii)} & \quad E_1 + L_I^j + D_I^j = W
\end{align*}
\]

\[3.7\]

\[
\begin{align*}
\text{(iv)} & \quad n \mathbb{E} \left( e^j_3 \right) \geq E_1 t^2 \quad \text{if} \quad E_1 > 0.
\end{align*}
\]

Condition (i) guarantees that the investment choice by bank \( j \) maximizes its expected equity, given return expectations. Condition (ii) represents the savings/investment balance of the banking system and of an individual bank, if we divide both sides by the number of banks \( n \). Condition (iii) represents the aggregate budget constraint of investors. Condition (iv) guarantees that investors are willing to invest into bank equity as it yields at least the same return as STT or bank deposits. Otherwise, banks would not be founded by investors.

Let us next introduce two tie-breaking rules to simplify the following calculations and exposition. First, we consider the case when the deposit rate equals the return on investment in STT. This is the implication of Assumption 3. In this case investors are indifferent between investing in STT and in deposits.

**Tie-breaking rule 1**

*If investors are indifferent between investing in STT and in deposits they choose the first.*
3. Liquidity Risk – Basic Model

It follows that $D^1_t = 0$ ($t = 1, 2$) and hence $D_1 = D^C_1 = S_1(i)$ and $D_2 = D^C_2 = S_2(i)$ if at least one bank survives in $t = 2$.

Second, we consider the case when the expected return on equity equals the return on investment in STT. Note that this requires a particular amount of investment in LTT and hence also in bank equity for the following reason. Recall that LTT satisfies Inada conditions. Hence, on the one hand, if the amount of investment in LTT ($X$) goes to zero, the expected return on investment in LTT ($r^e$) and thus also the expected return on equity, approach infinity. On the other hand, $r^e$ and, accordingly, the expected return on equity decline with increasing $X$. Hence, there exists a minimum amount of investment in bank equity with unique amount of investment in LTT and minimum amount of investment in liquidity (recall that, banks invest in liquidity at least $l_B$), such that the return on bank equity becomes equal to $i^2$.

**Tie-breaking rule 2**

If investors are indifferent between investing in bank equity and in STT they choose the minimum amount of investment in equity.

According to tie-breaking rule 2, bank $j$ will obtain exactly the amount of equity that is just sufficient to make investments in LTT and liquidity, which equalize the expected return on equity and the return on STT. Without this tie-breaking assumption banks could absorb an unlimited amount of resources from the households as banks can invest arbitrary amounts of funds in liquidity at a risk-free return $i$ per period.

The tie-breaking rules simplify the presentation. For example, the return on deposits would have to be slightly lower than the return on investment in STT in order to make investment in STT for investors strictly more attractive than deposit contracts. This would make our calculations substantially more complicated. Let us next proceed to describe banking default.
3.3.2. Banking Default and Work Out Procedures

By assumption, all market participants observe $\lambda$ in $t = 2$ and it becomes clear whether the final output that will be generated by bank $j$ in $t = 3$, provided it survives in $t = 2$, will be sufficiently high to repay the obligations towards its depositors in $t = 3$. We exclude the possibility that bank $j$ can receive funding from the households in $t = 2$ if it is certain that it will default in $t = 3$ and will not be able to repay them. Even if a complete explicit deposit insurance was in place it would be a weakly dominant strategy for the households to invest in safe banks.\(^{10}\) Hence, banking defaults occur in $t = 2$.

We observe that bank $j$ does not obtain new funding in $t = 2$ and defaults if there is no $d_2^j$ at the deposit rate $i$ such that $e_3^j > 0$. As $D_2 = S_2(i)$ if at least one bank survives in $t = 2$, bank $j$ faces in $t = 2$ one of the following situations

(i.) $d_2^j = \frac{S_2(i)}{n}$ if all banks are symmetric and survive together

(ii.) $d_2^j > \frac{S_2(i)}{n}$ if bank $j$ survives but at least one of the other $n - 1$ banks defaults

(iii.) $d_2^j = 0$ if bank $j$ defaults.

Therefore in any (symmetric) equilibrium, where banks either survive or default together, $d_2^j$ is given by

$$d_2^j = \begin{cases} \frac{S_2(i)}{n} & \text{if bank } j \text{ survives } (e_3^j \geq 0) \\ 0 & \text{otherwise.} \end{cases}$$

Next we observe the following condition for bank $j$’s amount of investment in voluntary liquidity in any equilibrium

$$l_B^j \geq \frac{S_1(i)}{n} - \frac{S_2(i)}{in}.$$  \hspace{1cm} (3.9)

\(^{10}\)By assuming that insurance covers only rates up to $i - \epsilon$ with $\epsilon > 0$ this dominance becomes strict.
3. Liquidity Risk – Basic Model

We derive condition (3.9) from the following considerations. Bank $j$ can always generate a return $\mathbb{E}(e_j^3) = \frac{E_j}{n}i^2$ if it invests the entire equity in voluntary liquidity. Hence the expected return on bank equity must be at least as large as $\frac{E_j}{n}i^2$, which requires that bank $j$ does not default at least in the good state $\lambda = h$. Recall that (3.3) is a necessary condition to avoid default of bank $j$ in $t = 2$ for any $\lambda$. That is, bank $j$ can only survive in $t = 2$ in the good state (the same holds for $\lambda = m, l$) if its liquidity in $t = 2$ is sufficiently high to pay back the first generation of depositors. This implies that bank $j$ will invest in liquidity voluntarily in $t = 1$ if it is clear that the amount of fresh funding that can be received from depositors in $t = 2$ in state $\lambda = h$ will not be sufficient to fulfill the obligations. As in any symmetric equilibrium\textsuperscript{11} $d_2^j \leq \frac{S_2(i)}{n} < \frac{S_1(i)}{n}i$, in order to survive in $t = 2$ at least in case $\lambda = h$, bank $j$ will voluntarily invest in liquidity. The investment amount has to satisfy

$$l_B^j + \frac{S_2(i)}{n}i \geq \frac{S_1(i)}{n}i,$$

which is equivalent to condition (3.9).

Summarizing, we have

**Lemma 3.1**

In any equilibrium

$$l_B^j \geq l_B := \frac{S_1(i)}{n} - \frac{S_2(i)}{ni} \forall j.$$  \hspace{1cm} (3.10)

$l_B$ denotes bank $j$’s minimal amount of voluntary liquidity in $t = 1$. The corresponding

\textsuperscript{11}Recall that by assumption both generations of consumers are identical and have the same preferences, implying that $S_1(i) = S_2(i)$. 

120
aggregate amount is denoted by $L_B$ and given by

$$L_B = S_1(i) - \frac{S_2(i)}{i}.$$ 

Next we observe that in any equilibrium without banking default the final equity of bank $j$ is

$$e_j^3 = \max\{\lambda f'(X)x^j + \left(l_B^j - \frac{S_1(i)}{n}i + \frac{S_2(i)}{n}i - \frac{S_2(i)}{n}i, 0\right) \}$$

with $l_B^j \geq L_B$.

Applying (3.11) we obtain

**Lemma 3.2**

*In any equilibrium, bank $j$ defaults in $t = 2$ if and only if $\lambda = l$ and

$$r^jx^j + \left(l_B^j - \frac{S_1(i)}{n}i\right) < 0.$$* (3.12)

**Proof of Lemma 3.2.**

Our proof starts with the observation that bank $j$ can never default in state $\lambda = h$ in an equilibrium. Otherwise, it will also default in states $\lambda = m, l$ and $E(e_j^3)$ would be zero. Moreover, we assume that banks do not default in state $\lambda = m$. In section 3.5.2. we will prove that this is true due to Assumption 4.12 Thus banking default can only occur in state $\lambda = l$. Next suppose that (3.12) is satisfied. Then bank $j$ would default in $t = 3$ for any level

---

12As the proof will require some considerations from the following subsections, it is convient to conduct it later.
of deposits $d^j_2$ it could have received in $t = 2$, i.e. $r^j x^j + \left( l^j_B - \frac{S(i)}{n} i + d^j_2 \right) i - d^j_2 i < 0$ for any $d^j_2 \geq 0$. Hence, it will not obtain fresh funding in $t = 2$ and will default already in that period. Suppose, on the contrary, that (3.12) were false. Then, as $l^j_B \geq l_B$, bank $j$ will be able to pay its obligations to the first generation of depositors in $t = 2$ in any state of the world ($\lambda = l, m, h$) if it obtains deposits $d^j_2$ with $d^j_2 \geq \frac{S(i)}{n}$. However, bank $j$ will also be able to pay back depositors in all states of the world in $t = 3$ for any amount of deposits it receives in $t = 2$. Hence, it will obtain fresh funding in $t = 2$ and will never default. We conclude that if and only if (3.12) is true and $\lambda = l$, bank $j$ defaults in $t = 2$, which is precisely the assertion of the lemma. 

\[ \square \] 

3.4. First-Best Allocation

Before we explore the properties of the economy with and without governmental intervention, it is useful to characterize the first-best allocation when no frictions are present. That is,

- Direct investment in both technologies is possible
  
  $\Rightarrow$ No financial intermediation is needed

- Financial contracts contingent on each state of the world in the Arrow-Debreu sense are available and perfectly enforceable.

We note that the case $W > \bar{X}$ is trivial as the resources of risk-neutral investors are sufficient to generate the return $i^2$ on investment in the risky LTT. Thus, risk-averse consumers could invest solely in STT and obtain the risk-free return $i$ per period. For the economically interesting case $W < \bar{X}$ we obtain:

**Proposition 3.1**

Suppose

$$\bar{X} > W \quad \text{and} \quad l_f(\bar{X}) > (\bar{X} - W)i^2.$$
3. Liquidity Risk – Basic Model

Then, the first-best allocation is characterized by

(i) $\overline{X}$ is invested in LTT.

(ii) $W + S_1(i) - \overline{X}$ is invested in STT in $t = 1$.

(iii) $(W + S_1(i) - \overline{X})i + S_2(i) - S_1(i) = (W - \overline{X})i + S_2(i)$ is invested in STT in $t = 2$.

(iv) Consumers buy one-period riskless securities with repayment $i$ per unit of investment.

(v) Investors buy risky securities which yield the following payoffs per unit of invested capital

\[
\begin{align*}
&\text{if } \lambda = h : \frac{(p_H + p_L)i^2}{p_H} \\
&\text{if } \lambda = m : i^2 \\
&\text{if } \lambda = l : 0.
\end{align*}
\]

(vi) The third agent running LTT obtains

\[
\begin{align*}
&\text{if } \lambda = h : hf(\overline{X}) - \frac{W(p_H + p_L)i^2}{p_H} - (\overline{X} - W)i^2 = hf(\overline{X}) - \overline{X}i^2 - \frac{p_L}{p_H}Wi^2 \\
&\text{if } \lambda = m : mf(\overline{X}) - Wi^2 - (\overline{X} - W)i^2 = mf(\overline{X}) - \overline{X}i^2 \\
&\text{if } \lambda = l : lf(\overline{X}) - (\overline{X} - W)i^2.
\end{align*}
\]

We outline the proof of Proposition 3.1 in the remainder of this section. We will denote by $Y^\lambda$ with $\lambda = h, m, l$ the aggregate output in $t = 3$ in the corresponding state of the world.

First, risk-averse consumers are fully insured against bad aggregate shocks by short-term securities with return $i$. The first generation of consumers invests $\overline{X} - W$ in the risky LTT, but both generations of consumers receive the return $i$ per unit of savings independently of whether the returns on LTT turn out to be high, moderate or low. Second, $lf(\overline{X}) > (\overline{X} - W)i^2$ and the
construction of risky securities for investors guarantee that risk-neutral investors’ insurance capacity is sufficient to insure both generations of consumers. Specifically, in the bad state the aggregate output in \( t = 3 \) is

\[
Y^l = lf(\overline{X}) + \left( (W + S_1(i) - \overline{X})i - S_1(i)i + S_2(i) \right) i \\
= lf(\overline{X}) + \left( (W - \overline{X})i + S_2(i) \right) i.
\]

The pay off to investors is zero, the second generation of consumers receives \( S_2(i)i \), and the third agent receives the residual which is non-negative due to assumption \( lf(\overline{X}) > (\overline{X} - W) i^2 \).

If \( \lambda = m \)

\[
Y^m = mf(\overline{X}) + \left( (W - \overline{X})i + S_2(i) \right) i.
\]

The repayments to consumers and investors in \( t = 3 \) amount to \( S_2(i)i \) and \( i^2 W \), respectively. The third agent obtains the remaining output. In the good state we have

\[
Y^h = hf(\overline{X}) + \left( (W - \overline{X})i + S_2(i) \right) i.
\]

\( Y^h \) is distributed among consumers, who receive \( S_2(i)i \), investors who receive \( \frac{W(p_H + p_L)i^2}{p_H} \), and the third agent who obtains the residual.

Third, by construction the expected payoff of risky securities per unit of invested capital is given by \( p_H \frac{p_H + p_L}{p_H} i^2 + p_M i^2 = i^2 \), and equals the return on one unit of investment in STT after two periods. Hence, investors are willing to buy these securities.

Fourth, the expected return on investment in LTT is equal to the return on investment in STT over two periods, which maximizes the expected aggregate output in \( t = 3 \).
3. Liquidity Risk – Basic Model

Fifth, maximization of the aggregate output is socially desirable as risk-averse agents are fully insured and thus there is no risk/return trade-off.

Sixth, the expected repayment from investment in LTT for consumers and investors is $(X - W)i^2 + p_H \frac{W(p_H + p_L)i^2}{p_H} + p_M W i^2 = Xf'(X)(p_H h + p_M m + p_L l)$. Hence, capital suppliers for LTT receive expected marginal returns on investment, and the third agent is the residual claimant.

Note that the expected aggregate output in $t = 3$, denoted by $\mathbb{E}(Y^{FB})$, is given by

$$\mathbb{E}(Y^{FB}) = (p_L l + p_M m + p_H h) f(X)(W - X)i^2 + S_2(i)i.$$

3.4.1. Summary of the Main Insights

It is useful to summarize the main results of the analysis of the frictionless economy. In the first-best world, we have:

- The aggregate expected output in $t = 3$ is maximized, which is socially desirable as risk-averse consumers are fully insured. The output-maximization is achieved by

  - Investment amount $\overline{X}$ in LTT,
  - Investment amounts $W + S_1(i) - \overline{X}$ and $(W - \overline{X})i + S_2(i)$ in STT in $t = 1$ and $t = 2$, respectively.

- The payments to consumers amount to $S_1(i)i$ and $S_2(i)i$ in $t = 2$ and $t = 3$, respectively.

- The expected payment to risk-neutral investors in $t = 3$ is $W i^2$.

- The expected payment to the third agent amounts to $f(X)(p_H h + p_M m + p_L l) - X i^2$, which is equivalent to expected output in $t = 3$ after the repayments to consumers and investors.
3. Liquidity Risk – Basic Model

In the following, we return to the economy with frictions and with financial intermediation.

3.5. Equilibria Without Regulation

Let us next characterize equilibria without regulatory intervention. We distinguish two cases: *No Banking Default* and *Banking Default*. Later we identify the conditions under which these cases are indeed equilibria.

3.5.1. No Banking Default

Suppose that $E_{1n}$ is at levels where banks do not default. Then, the expected equity of bank $j$ in $t = 3$ is given by

$$E(e^j_3) = r^e x_j + \left( l^B_j i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} i \right)i - \frac{S_2(i)}{n} i.$$  

Substituting $l^B_j = \frac{E_1 + S_1(i)}{n} - x^j$ (individual budget constraint of bank $j$) into (3.13) we can formulate the maximization problem of bank $j$ as

$$\max_{x^j} \{ E(e^j_3) \} = \max_{x^j} \left\{ r^e x^j + \left( \frac{E_1}{n} - x^j \right)i^2 \right\}.$$  

s.t. $\frac{E_1 + S_1(i)}{n} - x^j \geq l^B_j$.

Bank $j$ acts competitively and chooses its optimal investment amount $x^j$ given

$$r^e = \left. f'(X) \right| \left( p_H h + p_M m + p_L l \right).$$

We obtain the following result.
Lemma 3.3

In any equilibrium without regulatory intervention in which banks do not default in state \( l \) (and hence in states \( m \) and \( h \)), \( r^e = i^2 \) and \( l_B^j = l_B \).

The proof is given in Appendix A. Lemma 3.3 states that in any equilibrium in which banks do not default, individual investment amounts by bank \( j \) in LTT and in voluntary liquidity are given by \( X_n \) and \( l_B^j \), respectively. The corresponding aggregate investments are \( X \) and \( L_B \). Note that \( X \) is also the aggregate amount of investment in LTT in the first-best world. The equilibrium aggregate equity is then given by

\[
E_1 = X + L_B - S_1(i) = X - \frac{S_2(i)}{i}. \tag{3.15}
\]

Lemma 3.3 is derived under the assumption that banks’ equity is at levels where banks do not default. Since \( E_1_n \) is fixed at the level \( E_1_n = X_n - \frac{S_2(i)}{n} \), it is sufficient to absorb losses in the bad state only for returns that are higher than a certain threshold. Hence, next we examine under which conditions (in terms of the size of the macroeconomic shock) banks actually survive together (\( e^j_3 \geq 0 \) \( \forall j \) for \( \lambda = l \)) and thus Lemma 3.3 applies, i.e. \( x^j = X_n \), \( l_B^j = l_B \) and \( E_1_n = X_n - \frac{S_2(i)}{n} \) indeed constitute an equilibrium. According to Lemma 3.2 bank \( j \) defaults in \( t = 2 \) in state \( \lambda = l \) if and only if

\[
r^l x^j + \left( l_B^j i - \frac{S_1(i)}{n} i \right) < 0.
\]

That is, bank \( j \) defaults in state \( \lambda = l \) if \( l \) is so low, that banks are not able to generate returns that are sufficient to pay both generations of consumers the return \( i \) per unit of deposits. Since the uncertainty about the outcome of LTT is resolved in \( t = 2 \), if \( \lambda = l \) and \( l \) is too small, bank \( j \) does not obtain new funding in \( t = 2 \) and defaults immediately. Let \( l^{crit} \) denote the critical level of \( l \), at which a bank just survives. For the investment amounts derived in lemma 3.3 it
3. Liquidity Risk – Basic Model

is defined by:

\[ e^j_3 = l_{\text{crit}} f'(X) \frac{X}{n} - \frac{S_2(i)}{n} = 0, \]

which yields

\[ l_{\text{crit}} = \frac{i S_2(i)}{f'(X) X}. \quad (3.16) \]

Using equality (3.2) we derive the threshold level for \( h \), denoted by \( h_{\text{crit}} \), that corresponds to \( l_{\text{crit}} \):

\[ h_{\text{crit}} = \frac{i^2 X (p_H + p_L) - p_L i S_2(i)}{f'(X) X p_H}. \quad (3.17) \]

Note that \( h_{\text{crit}} < \bar{h}. \)

Finally, we observe that for \( l < l_{\text{crit}} \) there is no equilibrium in which banks do not default. We show this as follows. Suppose, contrary to our claim, that \( l < l_{\text{crit}} \) and banks do not default, i.e., \( e^j_3 \geq 0 \). Then according to Lemma 3.3 in any equilibrium \( x^j = \frac{X}{n} \) and \( l^j_B = l_B \). Given \( l < l_{\text{crit}} \) and \( X = X \), in state \( \lambda = l \) we have \( l f'(X) \frac{X}{n} - \frac{S_2(i)}{n} i < 0 \), which is a contradiction to \( e^j_3 \geq 0 \).

We summarize the results in the following proposition.

**Proposition 3.2**

**A.)** Suppose \( l \geq l_{\text{crit}} \) (\( h \leq h_{\text{crit}} \)).

---

\(^{13}\)We prove this as follows. By definition \( m f'(X) = i^2 \). Substituting \( m = \frac{i^2}{f'(X)} \) into \( h_{\text{crit}} \) yields \( h_{\text{crit}} = \frac{i^2 X (p_H + p_L) - p_L i S_2(i)}{f'(X) X p_H} \). Using \( p_L < 1 \) and applying Assumption 2 we obtain

\[ h_{\text{crit}} < \frac{m}{p_H} \left( p_H + \left( \frac{i X - S_2(i)}{i X} \right) \right) < \frac{m}{p_H} \left( p_H + \left( \frac{i X - S_2(i)}{S_2(i)} \right) \right) = \bar{h}. \]
3. Liquidity Risk – Basic Model

Then, there exists a unique equilibrium with

(i) \[ X = \bar{X} \text{ with } f'(X)(p_Hh + p_LL) = (p_H + p_L)i^2, \]
(ii) \[ L_B = L_B = S_1(i) - \frac{S_2(i)}{i} \]
(iii) \[ E_1 = \bar{X} - \frac{S_2(i)}{i} \]
(iv) \[ L' = W - \bar{X} + \frac{S_2(i)}{i}, \]

in which no banking defaults occur.

B.) For \( l < l^{crit} \) there exists no equilibrium in which banks do not default.

We note that we obtain the first-best allocation regarding the investments in LTT and STT and regarding the expected utility of consumers, investors and of the third agent. The equity of banks is sufficiently high to absorb the losses in the bad state and no banking defaults occur.

3.5.2. Banking Default

We next examine equilibria with banking default. By assumption banking defaults can only occur in bad times. Suppose momentarily bank \( j \) defaults in state \( \lambda = l \) in \( t = 2 \). As banks can exploit limited liability, i.e., \( e^j_3 = 0 \) if \( \lambda = l \), the expected equity of bank \( j \) in \( t = 3 \) is given by

\[
\mathbb{E}(e^j_3) = p_H \left( r^h x^j + \left( l^j_B i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} i - \frac{S_2(i)}{n} i \right) i - \frac{S_2(i)}{n} i \right) + p_M \left( r^m x^j + \left( l^j_B i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} i - \frac{S_2(i)}{n} i \right) i - \frac{S_2(i)}{n} i \right) = (p_Hr^h + p_Mr^m)x^j + (p_H + p_M) \left( l^j_B - \frac{S_1(i)}{n} \right) i^2. \tag{3.18}
\]
3. Liquidity Risk – Basic Model

Using \( l_B^j = \frac{E_1 + S_1(i)}{n} - x^j \) the optimization problem of bank \( j \) can be written as

\[
\max_{x^j} \mathbb{E} \left( e^i_j \right) = \max_{x^j} \left\{ \left( p_H r^h + p_M r^m \right) x^j + \left( p_H + p_M \right) \left( \frac{E_1}{n} - x^j \right) i^2 \right\}.
\] (3.19)

Bank \( j \) acts competitively and chooses its investment amount \( x^j \) taking returns as given and under the constraint \( l_B^j = \frac{E_1 + S_1(i)}{n} - x^j \geq L_B \). We obtain the following result.

Lemma 3.4

In any equilibrium in which banks default in state \( \lambda = l \), we have

(i) \( p_H r^h + p_M r^m = (p_H h + p_M m) f'(X^*) > (p_H + p_M) i^2 \) and \( l_B^j = L_B \),

where \( X^* \) denotes the aggregate amount of investment in LTT\(^{14}\)

(ii) \( X^* \) satisfies:

\[
X^* = \frac{S_2(i)ip_L}{i^2 - (p_H r^h + p_M r^m)},
\] (3.20)

i.e., \( p_H r^h + p_M r^m = (p_H h + p_M m) f'(X^*) = i^2 - \frac{S_2(i)ip_L}{X^*} \).

The proof of Lemma 3.4 is given in Appendix A. Note that \( (p_H h + p_M m) f'(X^*) > (p_H + p_M) i^2 \) implies \( X^* < (f')^{-1} \left( \frac{(p_H h + p_M m)^2}{p_H h + p_M m} \right) = X^{max} \). If investment in LTT is equal or greater than \( X^{max} \) the expected return on equity becomes strictly smaller than \( i^2 \) and investors are better off if they invest the entire wealth in STT. Moreover, according to Assumption 1 we have \( W + S_2(i) > X^{max} \), which is equivalent to \( W + S_1(i) > X^{max} + S_1(i) - \frac{S_2(i)}{i} = X^{max} + L_B \). Hence, Assumption 1 and Lemma 3.4 imply that the initial resources of consumers and investors are sufficiently high to invest at least \( X^* \) in LTT, whereas we allow for \( X^* > X \) since \( X^{max} > X \) and \( X^* < X^{max} \).

\(^{14}\)Note that \( (p_H h + p_M m) f'(X^*) > (p_H + p_M) i^2 \) implies \( X^* < (f')^{-1} \left( \frac{(p_H h + p_M m)^2}{p_H h + p_M m} \right) = X^{max} \). Hence under Assumption 1 we have \( W + S_2(i) > X^* \).
The aggregate amount of equity is

\[ E_1 = X^* - \frac{S_2(i)}{i}. \]  

(3.21)

Lemma 3.4 characterizes equilibria with banking default in state \( \lambda = l \) in \( t = 2 \). Let us next examine under which conditions (in terms of shock sizes) banks equity as defined by (3.21) is indeed not sufficient to absorb the losses in the bad state such that banks default.

**Lemma 3.5**

If \( l < l_{\text{crit}} \) and \( X^* \) as defined by (18) satisfies \( X^* > \overline{X} \) there exists an equilibrium with banking default in \( t = 2 \) in state \( \lambda = l \).

The proof is given in Appendix A. First, Lemma 3.5 states that in an equilibrium with banking defaults the macroeconomic shocks are larger than in an equilibrium in which banks do not default: \( l < l_{\text{crit}} \) and \( h > h_{\text{crit}} \). This implies that for any given amount of aggregate investment in LTT the gains in state \( \lambda = h \) are higher, while the losses in the bad state are limited to zero. As a consequence for any particular amount of funds banks can generate a higher expected return on equity than in an economy with small macroeconomic shocks. Second, in an equilibrium with banking default \( X^* > \overline{X} \), i.e. banks’ aggregate investment amount in LTT exceeds the one that is socially optimal. This is inefficient as the expected aggregate output falls below the first-best level. We formulate our results in the following proposition.

**Proposition 3.3**

Suppose \( l < l_{\text{crit}} \) (and \( h > h_{\text{crit}} \))
3. Liquidity Risk – Basic Model

Then there exists a unique equilibrium with

\( (i) \quad X = X^* \) where \( X^* \) is given by

\[ X^* = \frac{S_2(i)p_L}{i^2 - (p_Hr^h + p_Mr^m)}, \]

\( (ii) \quad E_1 = X^* - \frac{S_2(i)}{i} \)

\( (iii) \quad L_B = L_B = S_1(i) - \frac{S_2(i)}{i} \)

\( (iv) \quad 0 < L^I < W - X^* + \frac{S_2(i)}{i} \)

where banks default in \( t = 2 \) if \( \lambda = l \).

Moreover, we can prove the following:

**Claim 1**

*Under Assumption 4, there is no equilibrium in which banks default in state \( \lambda = m \).*

The Proof of Claim 1 is given in Appendix A.

### 3.5.3. Summary of the Main Insights

It is useful to summarize our main findings so far in the following proposition.

**Proposition 3.4**

*There exists a critical level of returns on LTT in state \( \lambda = l \) (\( \lambda = h \)), given by

\[ l^\text{crit} = \frac{iS_2(i)}{f'(X)X} \]

\[ h^\text{crit} = \frac{i^2X(1 - p_M) - p_LiS_2(i)}{f'(X)Xp_H} \]

such that*
3. Liquidity Risk – Basic Model

(i) If \( l \geq l^{\text{crit}} \) \((h \leq h^{\text{crit}})\), the unique equilibrium is characterized by \( X = \overline{X}, f'(X)(p_Hh + p_Mm + p_Ll) = i^2 \), \( E_1 = \overline{X} - \frac{S_1(i)}{i} \) and \( L_B = S_1(i) - \frac{S_2(i)}{i} \). Banks do not default. The allocation is first-best.

(ii) If \( l < l^{\text{crit}} \) \((h > h^{\text{crit}})\), the unique equilibrium is characterized by \( X^* > \overline{X} \) with \( X^* \) defined by (18), \( f'(X^*)(p_Hh + p_Mm + p_Ll) < i^2 \), \( E_1 = X^* - \frac{S_2(i)}{i} \) and \( L_B = S_1(i) - \frac{S_2(i)}{i} \). Banks attract a higher amount of equity and make an excessive investment in long-term risky technology. They default in state \( \lambda = l \).

Proposition 3.4 identifies the types of equilibria and illustrates the inefficiency occurring in case \( l < l^{\text{crit}} \). The intuition is as follows. If the negative macroeconomic shock is not severe \((l \geq l^{\text{crit}})\) banks invest the socially optimal amount of funds into LTT. Their equity is sufficiently high to absorb the consequences of the negative shock and their investments in liquid assets are high enough to refinance in \( t = 2 \). If the macroeconomic shocks are larger, i.e., when \( l < l^{\text{crit}} \) and \( h > h^{\text{crit}} \) banks can generate higher returns on equity for any given amount of funds as, on the one hand, the gains in the good state become larger, while, on the other hand, the downside risk is limited to zero due to the limited liability of equity holders. Or differently put: rising macroeconomic volatility increases the attractiveness of investment into bank equity. Thus, since banks generate a higher return for any particular amount of investment into equity than in no default scenario (where macroeconomic shocks are smaller), they receive a higher amount of equity\(^{15}\) and invest excessively in LTT causing the expected return on investment in LTT to fall below the return of short-term technology. This is inefficient from the social perspective as expected aggregate output in \( t = 3 \) declines compared to the socially optimal amount. Moreover, the amount of bank equity attracted is not sufficient to buffer the more severe negative macroeconomic shock.

The next corollary illustrates the inefficiency occurring in case \( l < l^{\text{crit}} \).

---

\(^{15}\)Recall that in any equilibrium the return on equity must be equal to the return on the risk-free investment.
Corollary 3.1

If $l < l_{\text{crit}}$, too many resources are invested by banks in LTT. They attract more equity capital, but it is insufficient to absorb the losses caused by a severe negative macroeconomic shock.

In the remainder of this thesis we assume that macroeconomic shocks are large, i.e., $l < l_{\text{crit}}$. Hence, the banking system cannot survive without regulatory intervention in state $\lambda = l$. 
4. Liquidity Risk – Regulation

In this chapter, we analyze and compare three different types of interference in the economy: liquidity requirements, liquidity insurance and liquidity risk taxes. Moreover, we will provide an example, which illustrates our model and the impact of different types of regulation on our economy.

4.1. Liquidity Requirements

We observed that an unregulated economy leads to a banking crisis if the macroeconomic shocks are large ($l < l^{crit}$ and $h > h^{crit}$) and the bad state occurs. Moreover, since banks can exploit their limited liability by deferring losses in case of a failure to the others (government providing deposit insurance), they attract relatively high amounts of equity and make excessive investment in the risky technology, which is inefficient from the social perspective as the expected return on investment in the risky technology falls below the risk-free return on investment of the short-term technology. However, equity cushions are insufficient to absorb the losses of excessive risky investments in the bad state.

One of the possible crisis prevention measures that we will examine is the imposition of liquidity requirements. A bank can be required to hold a fraction of its assets in cash or near-cash assets. In our model this amounts to a requirement on banks to invest a particular minimum
amount of funds in liquidity (STT). This regulatory measure, which we will also refer to as mandatory liquidity, increases banks’ loss absorption capacity. Let $L_B^{\text{reg}}$ denote the aggregate amount of mandatory liquidity. Bank $j$ is allowed to operate if it receives a positive amount of equity in $t = 1$ and fulfills $t_B^j \geq \frac{L_B^{\text{reg}}}{n}$.

To examine the impact of liquidity requirements on our economy we make the following assumptions.

(i) First, let us assume for the moment that banks do not default under liquidity requirements. That is, given $t_B^j \geq \frac{L_B^{\text{reg}}}{n}$ for all $j = 1, \ldots, n$, banks do not default in state $\lambda = l$ (and hence in states $\lambda = m, h$).

(ii) Second, let

$$W + S_1(i) > \bar{X} + L_B^{\text{reg}}. \quad (4.1)$$

We assume that the aggregate wealth of investors and the savings of the households are high enough to provide banks with an amount of funds sufficient to invest at least $\bar{X}$ in LTT and $L_B^{\text{reg}}$ in liquidity.

Now we are in a position to proceed with our analysis. Banks do not default by assumption, hence the expected equity of bank $j$ is given by

$$\mathbb{E}(e^j_i) = r^e x^j + \left( l_B^j i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} i - \frac{S_2(i)}{n} i \right) = r^e x^j + \left( l_B^j i - \frac{S_1(i)}{n} i \right) i^2 \quad (4.2)$$

with $l_B^j = \frac{E_1 + S_1(i)}{n} - x^j \geq \frac{L_B^{\text{reg}}}{n}$.
Using $l_B^j = \frac{E_1 + S_1(i)}{n} - x^j$ we formulate the maximization problem of bank $j$ as follows.

$$\max_{x^j} \mathbb{E}(e_3^j) = \max_{x^j} \left\{ r^e x^j + \left( \frac{E_1}{n} - x^j \right) \lambda^2 \right\}$$

(4.3)

subject to $\frac{E_1 + S_1(i)}{n} - x^j \geq \frac{L_{B_{reg}}}{n}$.

Bank $j$ acts competitively and chooses its optimal investment amount $x^j$ given $r^e = f'(X)(p_H h + p_M m + p_L l)$ and $L_{B_{reg}}$. Note that bank $j$ faces the same optimization problem as in the unregulated economy with small macroeconomic shocks. However, it is subject to a different budget constraint, i.e. the minimum investment in liquidity is prescribed by the regulator. We obtain the following result.

**Lemma 4.1**

In any equilibrium with liquidity requirement $L_{B_{reg}}$ in which no banking defaults occur in state $l$ (and hence in states $m$ and $h$) $r^e = \lambda^2$ and $l_B^j = \frac{L_{B_{reg}}}{n}$.

The proof of Lemma 4.1 is given in Appendix B. We observe that the aggregate amount of investment in LTT is $\overline{X}$ which is the first-best amount. Investment in liquidity is equal to the minimum requirement.

In Lemma 4.1 we characterize equilibria in which banks do not default. Hence, the next step is to determine $L_{B_{reg}}$ such that, given $L_{B_{reg}}$, the situation described in Lemma 4.1 indeed constitutes an equilibrium, i.e. banks’ investments in LTT and liquidity are $x^j = \frac{\overline{X}}{n}$ and $l_B^j = \frac{L_{B_{reg}}}{n}$, respectively, and banks do not default. The condition for no bank going bankrupt is that $e_3^j \geq 0$ if $\lambda = l$ for all $j = 1, ..., n$, which implies

$$e_3^j = \lambda f'(X) \frac{\overline{X}}{n} + \left( \frac{L_{B_{reg}}}{n} - \frac{S_1(i)}{n} \right) \lambda^2 \geq 0.$$
be denoted by \( L_B^{reg} \). \( L_B^{reg} \) is determined by

\[
e^3_j = l f'(X) \frac{X}{n} + \left( \frac{L_B^{reg}}{n} - \frac{S_1(i)}{n} \right) i^2 = 0, \tag{4.4}
\]

which yields

\[
L_B^{reg} = S_1(i) - \frac{l f'(X) X}{i^2}. \tag{4.5}
\]

From now on suppose that \( L_B^{reg} = L_B^{reg} \) as defined by (4.5). We observe that the liquidity requirement varies with the size of the negative shock: \( \frac{\partial L_B^{reg}}{\partial l} < 0 \). The more severe the negative shock, the greater is the amount of liquidity the banking system is required to hold. Note that \( \lim_{l \to 0} L_B^{reg} = S_1(i) \), i.e., if the return on investment in LTT in case of a negative shock approaches zero, the regulator requires banks to invest the entire deposits in liquidity. In this case banks can only invest equity into risky long-term technology, which makes a default on obligations impossible.

Note that substituting \( l = l^{crit} \) into the right-hand side of (4.5) yields \( L_B^{reg} = S_1(i) - \frac{S_2(i)}{i} = L_B \). Consequently, if \( l < l^{crit} \), it follows that \( L_B^{reg} > L_B \). Hence under liquidity requirement the banking system (as well as each individual bank) has a higher buffer for loss absorption in state \( \lambda = l \) compared to the unregulated economy. Moreover, the more severe the shock, the higher is the buffer. Note that the aggregate bank equity in \( t = 1 \) is given by

\[
E_1 = X - \frac{l f'(X) X}{i^2}.
\]

Obviously \( E_1 \) is increasing with declining \( l \). The more severe the negative shock, the greater is the liquidity cushion required to absorb the losses and thus the higher is the amount of first period equity banks have to attract to be able to fulfill the liquidity requirement.

We conclude that under liquidity requirement \( L_B^{reg} \) there exists an equilibrium in which banks
do not default and banks’ investment amounts are given according to Lemma 4.1.

So far we have been working under the assumption that banks do not default. Now we drop this assumption. Our next goal is to examine whether there exist equilibria with banking default under $L_{B}^{\text{reg}}$. For this purpose let

**Assumption 5**

$$W > X^{\text{max}} - \frac{lf'(X)X}{i^2} \quad \text{with} \quad X^{\text{max}} = (f')^{-1} \left( \frac{(p_{H} + p_{M})i^2}{p_{H}h + p_{M}m} \right).$$

Assumption 5 is stronger than Assumption 1, i.e., the minimum level of initial endowments of the households is required to be greater than under Assumption 1. Assumption 5 allows to analyze the economically interesting case, where the aggregate wealth of investors and the aggregate savings of consumers are high enough to provide banks with the amount of funds sufficient for excessive investment in the risky technology, specifically, sufficient to invest $X^{\text{max}}$ in LTT. Analysis similar to that in Section 3.5.2 yields the following result.

**Lemma 4.2**

Under liquidity requirement $L_{B}^{\text{reg}} = S_{1}(i) - \frac{lf'(X)X}{i^2}$ there exists no equilibrium with banking default.

The proof of Lemma 4.2 is given in Appendix B. Liquidity requirement $L_{B}^{\text{reg}}$ increases banks’ loss absorption capacity. We can show that under this policy measure the aggregate amount of investment in LTT, which would lead to banking defaults in state $\lambda = l$ must be so large that the expected return on equity would fall below the short-term risk-free return on STT. Hence, there is no equilibrium in which banks are able to generate a return on equity sufficiently large to attract such equity amounts.

1Note that Assumption 5 implies (4.1) (as $X^{\text{max}} > \bar{X}$).

2We show this as follows. Substituting $l = l_{\text{crit}}$ into the right-hand side of $W > X^{\text{max}} - \frac{lf'(X)X}{i^2}$ yields

$$W > X^{\text{max}} - \frac{S_{2}(i)}{p_{H}h} \quad \text{which is exactly equivalent to Assumption 1. As} \quad \frac{\partial lf'(X)X}{\partial l} > 0 \quad \text{for} \quad l < l_{\text{crit}}, \quad \text{it follows that} \quad W > X^{\text{max}} - \frac{lf'(X)X}{i^2} > X^{\text{max}} - \frac{S_{2}(i)}{p_{H}h}, \quad \text{which proves that Assumption 5 is stronger than Assumption 1.}

3Recall that the expected return on investment in LTT and hence also the expected return on equity decline with increasing amount of investment in LTT.
4. Liquidity Risk – Regulation

4.1.1. Summary of the Main Insights

We summarize the findings of the preceding section.

**Proposition 4.1**

Suppose that the regulator imposes liquidity requirement \( L_B^{\text{reg}} = S_1(i) - \frac{f'(X)X}{i^2} \). Then, there exists a unique equilibrium with

\[
\begin{align*}
(i) & \quad X = \bar{X} \quad \text{with} \quad f'(X)(p_H h + p_M m + p_L l) = i^2, \\
(ii) & \quad L_B = L_B^{\text{reg}}, \\
(iii) & \quad E_1 = \bar{X} - \frac{lf'(X)X}{i^2}, \\
(iv) & \quad L^f = W - \bar{X} + \frac{lf'(X)X}{i^2},
\end{align*}
\]

in which no banking defaults occur.

Using Proposition 4.1 we calculate the expected aggregate output in \( t = 3 \), denoted by \( \mathbb{E}(Y^{\text{req}}) \). It is given as follows

\[
\begin{align*}
\mathbb{E}(Y^{\text{req}}) &= (p_l l + p_M m + p_H h)f(X) + (L_B^{\text{reg}}i - S_1(i)i + S_2(i)) + L^f i^2 \\
&= (p_l l + p_M m + p_H h)f(X) + \left( S_1(i) - \frac{lf'(X)X}{i^2} \right)i - S_1(i)i + S_2(i)i \\
&\quad + \left( W - \bar{X} + \frac{lf'(X)X}{i^2} \right)i^2 \\
&= (p_l l + p_M m + p_H h)f(X) + (W - \bar{X})i^2 + S_2(i)i \\
&= \mathbb{E}(Y^{FB}).
\end{align*}
\]

If banks are subject to minimum liquidity requirements \( L_B^{\text{reg}} \) there exists a unique equilibrium in which banks do not default. Moreover, we obtain the first-best allocation regarding the investments in LTT and STT and regarding the expected utility of consumers, investors and of the third agent. The equity of banks is sufficiently high to absorb the losses in the bad state.
and no banking defaults occur. The minimum liquidity requirement \( \frac{L^{reg}}{B} \) increases banks’ loss absorption capacity in the bad state. The more severe the negative shock, the greater is the required liquidity buffer. Note that the liquidity requirement lowers the return on equity banks can generate for any particular amount of bank equity, since banks are not able to exploit their limited liability as in the unregulated economy.

### 4.2. Liquidity Insurance

Let us next examine an alternative crisis prevention measure: mandatory private liquidity insurance. Suppose that the regulator requires each individual bank to buy a certain amount of insurance contracts issued by investors. If a crisis is about to occur, i.e., \( \lambda = l \) investors are supposed to recapitalize the failing banking sector. Let \( \Omega \) denote the aggregate amount of insurance contracts necessary to recapitalize the banks. An individual bank is allowed to operate if it obtains a positive amount of equity and buys at least \( \frac{\Omega}{n} \) insurance contracts. The pay-off structure of an insurance contract is as follows.

**Definition 2**

One unit of insurance contracts issued by investors in \( t = 1 \) costs \( \$1 \). The payment of the contract issuer to the contract buyer in \( t = 2 \), denoted by \( r^I \), is conditioned on the realization of the macroeconomic shock and given by

\[
r^I = \begin{cases} 
0 & \text{if } \lambda = m \text{ or } \lambda = h \\
q & \text{if } \lambda = l 
\end{cases}
\]

with \( q > 0 \).
4. Liquidity Risk – Regulation

We observe that, in any equilibrium, repayment $q$ in the bad state is determined by

$$i = \mathbb{E}(r^I).$$

(4.6)

Equation (4.6) represents equilibrium in the insurance market. If expected payment on insurance contracts were lower than $i$, investors would be willing to sell as many insurance contracts as possible (excess supply of insurance). If expected payment to the banking sector were higher than $i$, no investor would be willing to provide insurance for banks. Hence (4.6) has to hold with equality.

Substituting $\mathbb{E}(r^I) = p_L q$ into (4.6) yields

$$q = \frac{i}{p_L}.$$  

(4.7)

To proceed with our analysis we make the following preliminary assumptions.

(1) First, we assume momentarily that insurance policy $\Omega$ is designed such that banks do not default in state $\lambda = l$ as well as in states $\lambda = m, h$.

(2) Second, we assume that the initial endowments of the households are high enough to provide banks with the amount of funds that is at least sufficient to invest $X$ in LTT, $L_B$ in liquidity and to recapitalize the banking system in case $\lambda = l$. That is

$$(W + S_1(i) + \Omega - (X + L_B + \Omega))i > q\Omega = \frac{i}{p_L} \Omega,$$

which yields

$$W + S_1(i) > X + L_B + \frac{\Omega}{p_L}.$$  

(4.8)

143
4. Liquidity Risk – Regulation

Note that since $E_1 = X + L_B + \Omega - S_1(i)$, (4.8) yields the following requirement on the aggregate wealth of investors

$$W > E_1 + \Omega \left( \frac{1 - p_L}{p_L} \right)$$

(4.9)

with $E_1 = \overline{X} + L_B + \Omega - S_1(i)$. (4.9) gives the minimum amount of investors’ wealth that is necessary to implement $\Omega$. The insurance capacity of investors is limited by their initial endowments and for the implementation of $\Omega$ it is crucial that investors’ wealth is large enough to recapitalize the banks in state $\lambda = l$.

Given the above assumptions we proceed to examine the impact of mandatory liquidity insurance on our economy.

As under insurance policy $\Omega$ banks do not default by assumption, the expected equity of bank $j$ in $t = 3$ is given by

$$\mathbb{E}(e^*_j) = r^e x^j + \left( \frac{p^*_j i - S_1(i)}{n} i + \frac{S_2(i)}{n} + p_L i \frac{\Omega}{p_L n} i - \frac{S_2(i)}{n} i \right)$$

(4.10)

This yields the following optimization problem

$$\max_{x^j} \mathbb{E}(e^*_j) = \max_{x^j} \left\{ r^e x^j + \left( \frac{p^*_j i - S_1(i)}{n} i + \frac{\Omega}{n} i \right) i \right\}$$

subject to $p^*_j \geq \frac{L_B}{n}$.
Using \( l_B^j = \frac{E_1 + S_1(i)}{n} - \frac{\Omega}{n} - x^j \) we rewrite (4.10) as follows:

\[
\mathbb{E}(e^j_3) = r^e x^j + \left( E_1 \frac{n}{n} - x^j + \frac{\Omega}{n} \right) i^2
= r^e x^j + \left( \frac{E_1}{n} - x^j \right) i^2,
\]

(4.11)

where \( E_1 = X + \Omega + L_B - S_1(i) \) and \( L_B \geq L_B^i = S_1(i) - \frac{S_2(i)}{i} \).

Bank \( j \) acts competitively and chooses its optimal investment amount \( x^j \) given

\( r^e = f'(X)(p_H h + p_M m + p_L l) \) and \( \Omega \). Note that bank \( j \)'s optimization problem is similar to those in Sections 3.5.1 and 4.1. We obtain the following result.

**Lemma 4.3**

*In any equilibrium with mandatory liquidity insurance \( \Omega \) in which no banking defaults occur in state \( l \) (and in states \( m \) and \( h \)) \( r^e = i^2 \) and \( l_B^j = L_B^i \).*

The proof of Lemma 4.3 is given in Appendix B. Note that the aggregate investment in LTT is \( \bar{X} \) which is the first-best amount. Investment in liquidity corresponds to the minimal amount. The aggregate first period equity is given by

\[ E_1 = \bar{X} + \Omega - \frac{S_2(i)}{i}. \]

Lemma 4.3 characterizes equilibria in which banks do not default. Hence, our next goal is to determine the minimum amount of insurance contracts, denoted by \( \Omega \), which is sufficient to recapitalize banks in state \( \lambda = l \) such that they indeed do not default and \( x^j = \bar{X} \) and \( l_B^j = L_B^i \) constitute an equilibrium. We determine \( \Omega \) by the following equality

\[
e^j_3 = l f'(X) \frac{\bar{X}}{n} + \left( \frac{L_B}{n} i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} i + \frac{\Omega}{p_L n} i \right) i - \frac{S_2(i)}{n} i
= l f'(X) \frac{\bar{X}}{n} - \frac{S_2(i)}{n} i + \frac{i^2}{p_L n} \Omega = 0,
\]
4. Liquidity Risk – Regulation

which yields

\[ \Omega = \frac{S_2(i)i - lf'(\bar{X})\bar{X}}{i^2}p_L. \]  \hspace{1cm} (4.12)

From now on we assume that in \( t = 1 \) the regulator chooses \( \Omega = \Omega \) as defined by (4.12). Moreover, we assume that Assumption 5 is satisfied. Let us next make some observations regarding \( \Omega \). First, we observe that \( \Omega \) satisfies (4.8) and (4.9). We show this as follows. Inserting (4.12) and \( L_B = S_1(i) - \frac{S_2(i)}{i} \) in (4.8) yields the following condition on investors’ wealth

\[ W > \bar{X} - \frac{lf'(\bar{X})\bar{X}}{i^2}, \]  \hspace{1cm} (4.13)

which is satisfied due to Assumption 5. This justifies our preliminary assumption that \( \Omega \) is implementable and that the initial endowments of the households are sufficiently large for investment amounts \( \bar{X} \) and \( L_B \) under insurance policy \( \Omega \). Moreover, Assumption 5 implies that under \( \Omega \) banks could be provided with the amount of resources that is large enough to invest \( X^{\max} > \bar{X} \) in LTT. Next we observe that \( \frac{\partial \Omega}{\partial l} < 0 \). Hence, the more severe the negative shock, i.e., the smaller \( l \), the greater is the amount of insurance contracts the banking system is required to hold and the higher is the requirement on the minimum aggregate wealth of investors. Note that \( \lim_{l \to 0} \Omega = \frac{S_2(i)}{i}p_L \) implying that \( q\Omega = S_2(i) \) for \( l \to 0 \). It follows that

\[ \lim_{l \to 0} c_d^i = \left( \frac{L_B}{n} \right) i + 2S_2(i) - S_1(i)i - S_2(i)i = 0. \]

That is, even if the return on investment in LTT in the bad state goes to zero banks still survive under insurance policy \( \Omega \).

We conclude that if the regulator introduces liquidity insurance \( \Omega \) in \( t = 1 \) there exists an equilibrium in which banks do not default and banks’ investment amounts are given according
to Lemma 4.3.

Next we drop the assumption that banks cannot default under insurance policy $\Omega$. Let us proceed to show that there is no equilibrium in which banks default under $\Omega$. We will prove this by contradiction. For this purpose we assume momentarily that there exists an equilibrium with banking default in $t = 2$ in state $\lambda = l$. Given banking default if $\lambda = l$, the expected equity of bank $j$ in $t = 3$ is given by

$$E(e_j^3) = (p_Hh + p_Mm)f'(X)x^j + (p_H + p_M)\left(\left(p_B^i - \frac{S_1(i)}{n}i + \frac{S_2(i)}{n}i\right)i - \frac{S_2(i)}{n}i\right).$$

Inserting $l_B^i = \frac{E_1 + S_1(i)}{n} - x^j - \frac{\Omega}{n}$ in the right-hand side of the above equality we obtain

$$E(e_j^3) = (p_Hh + p_Mm)f'(X)x^j + (p_H + p_M)\left(\frac{E_1}{n} - x^j - \frac{\Omega}{n}\right)i^2$$

(4.14)

s.t. $\frac{E_1 + S_1(i)}{n} - x^j - \frac{\Omega}{n} \geq \frac{L_B}{n}$.

Bank $j$ acts competitively and chooses its optimal investment amount $x^j$ given $r^e = f'(X)(p_Hh + p_Mm + p_LL)$ and $\Omega$.

Analysis similar to that in Section 4.1 yields the following result.

**Lemma 4.4**

*Under insurance policy $\Omega$ there exists no equilibrium in which banks default in state $\lambda = l$.***

The proof of Lemma 4.4 is given in Appendix B. In the same manner as under liquidity requirements we can show that if liquidity insurance is in place, banks default only if they overinvest in LTT so excessively that the expected return on equity falls below the risk-free return on STT. Hence, banks cannot attract equity amounts that are necessary for such excessive investments.
4. Liquidity Risk – Regulation

4.2.1. Summary of the Main Insights

We summarize the results of the preceding section.

Proposition 4.2

Suppose that the regulator imposes the insurance policy $\Omega = \frac{S_2(i) - lf'(X)X}{i^2}p_L$. Then, there exists a unique equilibrium with

\begin{align*}
(i) & \quad X = \overline{X} \quad \text{with} \quad f'(X)(p_H h + p_M m + p_L l) = i^2, \\
(ii) & \quad L_B = L_B = S_1(i) - \frac{S_2(i)}{i}, \\
(iii) & \quad E_1 = \overline{X} - \frac{S_2(i)}{i} (1 - p_L) - \frac{lf'(X)X}{i^2}p_L, \\
(iv) & \quad L^I = W - \overline{X} + \frac{S_2(i)}{i} (1 - p_L) + \frac{lf'(X)X}{i^2}p_L,
\end{align*}

in which no banking defaults occur.

Using Proposition 4.2, we calculate the expected aggregate output in $t = 3$, denoted by $\mathbb{E}(Y^{ins})$. It is given by

\[
\mathbb{E}(Y^{ins}) = (p_L l + p_M m + p_H h)f(\overline{X}) + (L_B i - S_1(i)i + S_2(i)i) + L^I i^2 + p_L q \Omega i \\
= (p_L l + p_M m + p_H h)f(\overline{X}) + (W - \overline{X})i^2 + S_2(i)i(1 - p_L) + \frac{lf'(X)X p_L}{i^2} + p_L (S_2(i)i - lf'(X)X) \\
= (p_L l + p_M m + p_H h)f(\overline{X}) + (W - \overline{X})i^2 + S_2(i)i \\
= \mathbb{E}(Y^{FB}).
\]

If liquidity insurance $\Omega$ is in place, there exists a unique equilibrium in which banks do not default. Moreover, as with liquidity requirements, we obtain the equilibrium allocation, which is first-best regarding investment amounts and the expected welfare of all market participants, while the risk-averse agents are fully insured against losses. Crucial thereby is the assumption
that investors’ wealth is sufficiently high to recapitalize banks in state $\lambda = l$. The more severe the negative shock, the higher is the amount of insurance contracts the banking system is required to buy from investors. Investors, in turn, have more funds available and invest more in bank equity. However, the additionally acquired funds have to be spent on mandatory insurance. Note that the expected repayment per unit of insurance contracts is $i$ and hence equal to the (expected) return on one unit of investment in liquidity. Similar as with liquidity requirements banks do not generate expected returns on equity that suffice to attract equity amounts allowing to overinvest in LTT so excessively that banks would default. Hence, under liquidity insurance, there is no equilibrium in which banks default.

### 4.3. Liquidity Risk Taxes

Finally, we examine the imposition of liquidity risk taxes as banking crisis prevention measure. By taxing investment in the risky technology the regulator makes this investment opportunity less profitable. This, in turn, counteracts the incentive to overinvest in LTT. However, as opposed to regulatory intervention via liquidity insurance and liquidity requirements, banks neither obtain additional funds for loss absorption in state $\lambda = l$ in $t = 2$ nor are directly forced to invest more in liquidity in $t = 1$.\(^4\) It will turn out that keeping banks from excessive investments in LTT by imposition of liquidity risk taxes is sufficient to prevent banking crises only if $l$ is not too low and if $f(X)$ satisfies certain additional criteria.\(^5\)

Suppose that in $t = 1$ the regulator charges bank $j$ a flat tax $\rho$ with $0 \leq \rho \leq 1$ for each unit of investment in LTT. Then if bank $j$ invests $x^j$ in LTT it has to pay taxes amounting to $\rho x^j$.

To analyze the impact of liquidity risk taxes on our economy, we make the following assumptions:

\(^4\)We assume that the regulator uses collected taxes for provision of public goods.
\(^5\)In the following, we will show which properties $f(X)$ has to satisfy and derive the lower bound of $l$. 

149
4. Liquidity Risk – Regulation

(i) First, we assume that under regulatory taxation \( \rho \), banks do not default in state \( \lambda = l \) in \( t = 2 \) (and hence in states \( \lambda = m, h \)).

(ii) Second, we assume that the initial endowments of the households are high enough to provide banks with the amount of funds that is sufficient to invest at least \( \overline{X} \) in LTT and \( L_B \) in liquidity for all \( \rho \) with \( 0 \leq \rho \leq 1 \). That is:

\[
W + S_1(i) \geq 2\overline{X} + L_B. \tag{4.15}
\]

(iii) Third, we make the following requirement on \( l \):

\[
l > \frac{S_2(i)i}{2f'(\overline{X})(f')^{-1}(2f'(\overline{X}))}. \tag{4.16}
\]

We will observe in the following that if \( l \) is too low, namely if (4.16) is not satisfied, banking defaults in the bad state cannot be prevented.

Given assumptions (i)-(iii) we proceed with the analysis. As banks do not default by assumption, the expected equity of bank \( j \) in \( t = 3 \) is given by

\[
\mathbb{E}(e^j_3) = r^e x^j + \left( l_B^j i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} \right) i - \frac{S_2(i)}{n} i. \tag{4.17}
\]

This yields the following optimization problem

\[
\max_{x^j} \mathbb{E}(e^j_3) = \max_{x^j} \left\{ r^e x^j + \left( l_B^j i - \frac{S_1(i)}{n} i + \frac{S_2(i)}{n} \right) i - \frac{S_2(i)}{n} i \right\}
\]

subject to the budget constraint \( l_B^j = \frac{E_1 + S_1(i)}{n} - (1 + \rho)x^j \geq \frac{L_B}{n} \).
4. Liquidity Risk – Regulation

Using \( l_B^j = \frac{E_1 + S_1(i)}{n} - (1 + \rho)x^j \) we rewrite (4.17) as follows

\[
\mathbb{E}(e^j) = r^e x^j + \left( \frac{E_1}{n} - (1 + \rho)x^j \right) i^2, \tag{4.18}
\]

where \( E_1 = (1 + \rho)X + L_B - S_1(i) \), \( L_B \geq L_B^* \).

Let \( X^{\text{tax}} \) denote the aggregate amount of investment in LTT. Applying similar arguments as in Sections 4.1 and 4.2 we obtain the following result.

**Lemma 4.5**

In any equilibrium under liquidity risk taxes \( \rho \) \((0 \leq \rho \leq 1)\) in which no banking defaults occur in state \( l \) (and hence in states \( m \) and \( h \)) \( r^e = (1 + \rho)i^2 \), \( l_B^j = \frac{L_B}{n} \).

The proof of Lemma 4.5 is given in Appendix B. Note that \( r^e = (1 + \rho)i^2 \) is equivalent to \( f'(X^{\text{tax}}) = (1 + \rho)f'(\overline{X}) \) and \( X^{\text{tax}} = (f')^{-1}((1 + \rho)f'(\overline{X})) \). Hence, we observe that under liquidity risk taxes, in any equilibrium in which banks do not default \( X^{\text{tax}} \leq \overline{X} \) as \( \rho \geq 0 \), meaning that the aggregate investment amount in LTT falls below the first-best level. This is socially inefficient, since the expected aggregate output declines accordingly.

Note that \( f'(X^{\text{tax}}) = (1 + \rho)f'(\overline{X}) \) implies that \( f''(X^{\text{tax}}) \frac{dX^{\text{tax}}}{d\rho} = f'(\overline{X}) \) and hence \( \frac{dX^{\text{tax}}}{d\rho} = \frac{f'(\overline{X})}{f''(X^{\text{tax}})} < 0 \). The greater \( \rho \), the smaller is the investment in LTT. The intuition is as follows.

The higher is the tax per unit of investment in LTT, the less attractive is this investment opportunity compared to the risk-free investment. Hence, the aggregate amount of investment in LTT has to decline, such that the return per unit of investment \( f'(X^{\text{tax}}) \) rises and investment in LTT remains at least as profitable as investment in STT.

Given Lemma 4.5, the equilibrium aggregate equity in \( t = 1 \) is

\[
E_1 = (1 + \rho)X^{\text{tax}} - \frac{S_2(i)}{i}.
\]
Lemma 4.5 characterizes equilibria without banking default. Our next goal is to find \( \rho \), denoted by \( \rho^* \) (\( 0 \leq \rho \leq 1 \)), such that banks just do not default in state \( \lambda = l \), i.e., \( e^l_j = 0 \), and the investment amounts in Lemma 4.5 indeed constitute an equilibrium. We observe that \( \rho^* \) has to satisfy the following equality

\[
e^l_j = l f'(X^{tax}(\rho^*)) \frac{X^{tax}(\rho^*)}{n} + \left( \frac{L_B}{n} - \frac{S_1(i)}{n} \right) i^2,
\]

\[
= l(1 + \rho^*) f'(X^{tax}(\rho^*)) \frac{X^{tax}(\rho^*)}{n} - \frac{S_2(i)}{n} i
\]

\[
= 0,
\]

which is equivalent to

\[
l(1 + \rho^*) f'(X^{tax}(\rho^*)) = S_2(i). \tag{4.19}
\]

Next we make the following observation. Since \( l < l^{crit} = \frac{i S_2(i)}{f'(X)} \) by assumption, we have

\[
l f'(X) < S_2(i), \tag{4.20}
\]

which implies that (4.19) can only hold if the left-hand side of (4.19) is greater than the left-hand side of (4.20). That is:

\[
(1 + \rho^*) X^{tax}(\rho^*) > X. \tag{4.21}
\]

Suppose first that \( \rho^* = 0 \). Then the left-hand side of (4.21) becomes \( 1 \cdot X^{tax}(0) = (f')^{-1}(f'(X)) = X \), which means that for \( \rho^* = 0 \) inequality (4.21) is violated. Hence (4.21) can only hold if the left-hand side of (4.21) is increasing in \( \rho \). This requires:

\[
\frac{\partial}{\partial \rho} \left( (1 + \rho) X^{tax}(\rho) \right) = X^{tax}(\rho) + (1 + \rho) \frac{\partial X^{tax}(\rho)}{\partial \rho} > 0. \tag{4.22}
\]
The intuition is straightforward. We have already observed that in the unregulated economy for \( l < l^{crit} \) we have
\[
lf'(X) \frac{\sum_{n} - S_{2}(i)}{n} i < 0,
\]
i.e., the equity of bank \( j \) is not sufficient to absorb the losses in the bad state. In order to survive under liquidity risk taxes the output realized by bank \( j \) in \( t = 3 \) must be greater than in the unregulated economy with investment amount \( \overline{X} \) for the same size of the macroeconomic shocks, i.e.,
\[
e_{j}^{3} = l(1 + \rho^{*}) f'(\overline{X}) \frac{X^{tax}(\rho^{*})}{n} \sum_{n} - \frac{S_{2}(i)}{n} i \geq 0
\]
can only hold if \( l(1 + \rho^{*}) f'(\overline{X}) \frac{X^{tax}(\rho^{*})}{n} > lf'(\overline{X}) \frac{\sum_{n} - \frac{S_{2}(i)}{n} i}{n} \) or equivalently \( (1 + \rho^{*}) X^{tax}(\rho^{*}) > \overline{X} \), which is exactly condition (4.21). Given \( X^{tax}(\rho^{*}) < \overline{X} \) and \( \frac{\partial X^{tax}(\rho)}{\partial \rho} < 0 \), condition (4.21) can only hold if (4.22) is satisfied. We interpret (4.22) as follows. Since \( \frac{\partial X^{tax}(\rho)}{\partial \rho} < 0 \), condition (4.22) is a requirement on LTT that when the tax rate \( \rho \) increases, the expected return on aggregate investment in LTT rises faster than the investment amount declines. In the remainder of this section we assume that LTT satisfies (4.22).

**Lemma 4.6**

Given (4.16) and (4.22), there exists a \( \rho^{*} \) with \( 0 \leq \rho^{*} \leq 1 \) that satisfies (4.19), i.e. \( \rho^{*} \) is implicitly determined by
\[
1 + \rho^{*} = \frac{S_{2}(i) i}{lf'(\overline{X})(f')^{-1} \left( (1 + \rho^{*}) f'(\overline{X}) \right)}.
\]

The proof of Lemma 4.6 is given in Appendix B. Lemma 4.6 states that if LTT satisfies the requirement (4.22) and if \( l \) is not too low and satisfies (4.16) there exists a tax rate \( \rho^{*} \) such that banks just survive in state \( \lambda = l \). This implies that if liquidity risk taxes \( \rho^{*} \) as defined by (4.23) are in place and conditions (4.16) and (4.22) hold, there exists an equilibrium in which banks do not default and investment allocations are given according to Lemma 4.5.

Suppose now that the regulator imposes \( \rho^{*} \) implicitly determined by (4.23). So far we have been operating under the assumption that banks do not default under liquidity risk taxation. Now we drop this assumption and examine whether there exist equilibria in which banks...
default in the bad state (given that (4.16) and (4.22) hold). For this purpose let us assume

**Assumption 6**

\[
W > (1 + \rho^*) (f')^{-1} \left( \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m} \right) - \frac{S_2(i)}{i}.
\]

Assumption 6 implies that the aggregate resources of households suffice to provide banks with the amount of funds that is large enough to invest at least \( X^{tax} = (f')^{-1} \left( \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m} \right) \) in LTT and \( L_B \) in liquidity.\(^6\)

Suppose momentarily that there exists an equilibrium with banking default in state \( \lambda = l \). In this case the expected equity of bank \( j \) in \( t = 3 \) is

\[
\mathbb{E}(e_j^3) = (p_H h + p_M m) f'(X^{tax}) x^j + (p_H + p_M) \left( l_B^j - \frac{S_1(i)}{n} \right) i^2 \tag{4.24}
\]

s.t. \( l_B^j = \frac{E_1 + S_1(i)}{n} - (1 + \rho^*) x^j \geq \frac{L_B}{n} \).

Inserting \( l_B^j = \frac{E_1 + S_1(i)}{n} - (1 + \rho^*) x^j \) into (4.24) yields

\[
\mathbb{E}(e_j^3) = (p_H h + p_M m) f'(X^{tax}) x^j + (p_H + p_M) \left( \frac{E_1}{n} - (1 + \rho^*) x^j \right) i^2. \tag{4.25}
\]

Bank \( j \) acts competitively and chooses its optimal investment amount \( x^j \) given \( r^e \) and \( \rho^* \).

We draw the same conclusion as under regulation via liquidity requirements and liquidity insurance:

**Lemma 4.7**

*Under liquidity risk taxes \( \rho^* \) there exists no equilibrium in which banks default in state \( \lambda = l \) (and hence states \( \lambda = m, h \)).*

---

\(^6\)We see this immediately if we add \( S_1(i) \) to both sides of the inequality. We obtain \( W + S_1(i) > (1 + \rho^*) (f')^{-1} \left( \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m} \right) + \left( S_1(i) - \frac{S_2(i)}{i} \right) = (1 + \rho^*) (f')^{-1} \left( \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m} \right) + \frac{L_B}{n}. \)
The proof of Lemma 4.7 is given in Appendix B. We show that there is no $X^{tax}$ such that the necessary conditions for banking default are simultaneously satisfied.

### 4.3.1. Summary of the Main Insights

Let us summarize the results in the following proposition:

**Proposition 4.3**

Suppose the regulator imposes $\rho^*$ defined by

$$\rho^* = \frac{S_2(i)}{i f'(X)(f'(X') - 1)},$$

and suppose (4.16) are satisfied. Then, there exists a unique equilibrium with

1. $X^{tax} = (f')^{-1}((1 + \rho^*) f'(X))$ with $f'(X^{tax})(p_H h + p_M m + p_L l) > i^2$, (4.22)
2. $L_B = L_B = S_1(i) - \frac{S_2(i)}{i}$,
3. $E_1 = (1 + \rho^*) (f')^{-1}((1 + \rho^*) f'(X)) - \frac{S_2(i)}{i}$,
4. $L' = W - (1 + \rho^*) X^{tax} + \frac{S_2(i)}{i}$,

in which no banking defaults occur.

The expected aggregate output in $t = 3$, denoted by $\mathbb{E}(Y^{tax})$, is given by

$$\mathbb{E}(Y^{tax}) = (p_L l + p_M m + p_H h) f(X^{tax}) + \left((S_1(i) - \frac{S_2(i)}{i}) i - S_1(i)i + S_2(i)i\right)i$$

$$+ (W - (1 + \rho^*) X^{tax})i^2 + S_2(i)i$$

$$= (p_L l + p_M m + p_H h) f(X^{tax}) + (W - \frac{S_2(i)i}{f'(X)})i^2.$$

Since $l < \frac{S_2(i)}{f'(X)}$, we have $\frac{S_2(i)i}{f'(X)} > X$. Using the latter inequality and $X^{tax} < X$ we obtain

$$\mathbb{E}(Y^{tax}) < (p_L l + p_M m + p_H h) f(X) + (W - X)i^2 + S_2(i)i$$

$$= \mathbb{E}(Y^{FB}).$$
4. Liquidity Risk – Regulation

If the regulator taxes liquidity risk, banking crises can be prevented given that the return on investment in LTT in the bad state is not too low and that the return on investment in LTT satisfies (4.22). As opposed to the regulation via liquidity requirements and liquidity insurance, under liquidity risk taxes, banks are just prevented from overinvestment in LTT by making LTT less profitable, they do not obtain additional funding in case of a negative shock. Hence, they can only survive if the shock is not too severe and if the aggregate output \( f'(X^{\text{tax}}(\rho))X^{\text{tax}}(\rho) \) realized in \( t = 3 \) increases as \( \rho \) rises such that the negative impact of taxes on investment amount \( X^{\text{tax}} \) in LTT is outweighed by increasing return on one unit of investment in LTT. Moreover, the equilibrium allocation that we obtain is not first-best. Banks aggregate investment amount in LTT is smaller than the socially optimal amount.

4.4. Main Result

If macroeconomic shocks are severe, the unregulated economy may lead to a banking crisis. Moreover, the limited liability of bank equity holders combined with governmental guarantee of deposits induce banks to invest excessively in the risky technology. This way banks can exploit their limited liability by deferring losses in case of a default to the government. Such excessive overinvestments make losses in case of an economic downturn particularly severe and cause the expected return on investment in LTT to fall below the risk-free return on investment in STT. However, the regulator has various options to intervene and to prevent large-scale banking defaults. If the regulator knows the size of the macroeconomic shocks and the wealth of investors is sufficiently large, it is possible within our model framework to guarantee the avoidance of banking defaults with both liquidity requirements and liquidity insurance. Moreover, these two policy measures induce equilibria characterized by allocations that are first-best regarding the expected utility of all market participants (investors, consumers and the third agent) and aggregate investment amounts in the short-term and the long-term techno-
4. Liquidity Risk – Regulation

ology. The third regulatory approach, examined in this thesis, is the imposition of liquidity risk taxes. This policy measure prevents overinvestment in LTT by making LTT less profitable, but it can guarantee the avoidance of banking crises only if (i) the bad macroeconomic shock is not too severe and if (ii) the risky technology fulfills certain additional criteria regarding marginal expected return on investment. Moreover, even if banking defaults can be prevented, the resulting equilibrium allocation is not first-best. Banks’ aggregate amount of investment in the long-term technology falls below the socially optimal level, which is inefficient as this lowers the expected aggregate output of the economy. We conclude that in our model the regulator should prefer liquidity requirements and liquidity insurance to liquidity risk taxes. Furthermore, the regulator is indifferent between applying liquidity requirements and liquidity insurance.

4.5. Example

In what follows we provide an example to illustrate our model and the impact of regulatory intervention.

Suppose \( f(X) = A + \frac{X^{1-\mu}}{1-\mu} \). Then, \( f'(X) = \frac{1}{X^\mu} \). Let \( A = 10, \mu = 2 \). We obtain \( f(X) = 10 - \frac{1}{X} \), \( f'(X) = \frac{1}{X^2} \). Note that \( f(X) > 0 \) for all \( X > \frac{1}{10} \); \( f'(X) > 0 \), \( f''(X) = -\frac{2}{X^3} < 0 \) for all \( X > 0 \); \( \lim_{X \to 0} f'(X) = \infty \) and \( \lim_{X \to \infty} f'(X) = 0 \). Hence, \( f(X) \) exhibits decreasing returns to scale and satisfies Inada Conditions.

No Banking Default

Suppose \( l \geq l_{crit} \). Then in any equilibrium \( r^e_L = (p_H h + p_M m + p_L l) f'(\bar{X}) = i^2 \), implying \( f'(\bar{X}) = \frac{1}{\bar{X}^\mu} = \frac{i^2}{p_H h + p_M m + p_L l} \). The unique equilibrium without regulatory intervention is
4. Liquidity Risk – Regulation

defined by

(i) \( X^{\text{nodef}} = \overline{X} = \sqrt{\frac{p_H h + p_M m + p_L l}{i}} \),

(ii) \( L_B^{\text{nodef}} = \overline{L_B} = S_1 - \frac{S_2}{i} \),

(iii) \( E_1^{\text{nodef}} = \sqrt{\frac{p_H h + p_M m + p_L l}{i}} - \frac{S_2}{i} \),

(iv) \( L_I^{\text{nodef}} = W - \frac{\sqrt{p_H h + p_M m + p_L l}}{i} + \frac{S_2}{i} \).

Note that \( l^{\text{crit}} = \frac{iS_2}{f'(\overline{X}/X)} = \frac{p_L S_2^2}{2i} + \sqrt{\frac{p_H h}{i}} + S_2 (p_H h^{\text{crit}} + p_M m). \)

**Banking default**

Suppose banks default in state \( \lambda = l \), i.e. \( l < l^{\text{crit}} \). Hence, in any equilibrium \( p_H r^h + p_M r^m = (p_H h + p_M m) f'(X^*) = i^2 - \frac{S_2 p_L}{S_X^*} \). Then, the unique equilibrium without regulatory intervention is defined as follows

(i) \( X^{\text{def}} = X^* = \frac{S_2 p_L}{2i} + \frac{1}{2i} \sqrt{\frac{S_2^2 p_L^2}{4} + 4(p_H h + p_M m)} \),

(ii) \( L_B^{\text{def}} = \overline{L_B} = S_1 - \frac{S_2}{i} \),

(iii) \( E_1^{\text{def}} = \frac{S_2 p_L}{2i} + \frac{1}{2i} \sqrt{\frac{S_2^2 p_L^2}{4} + 4(p_H h + p_M m)} - \frac{S_2}{i} \),

(iv) \( L_I^{\text{def}} = W - \frac{S_2 p_L}{2i} - \frac{1}{2i} \sqrt{\frac{S_2^2 p_L^2}{4} + 4(p_H h + p_M m)} + \frac{S_2}{i} \).

We can easily show that \( X^* > X \).

Suppose first that \( l = l^{\text{crit}} \) in the no default case. Then

\[
\overline{X} = \frac{1}{i} \sqrt{p_H h^{\text{crit}} + p_M m + \frac{p_L S_2^2}{2} + p_L \sqrt{\frac{p_H h^{\text{crit}} + p_M m}{4} + S_2 (p_H h^{\text{crit}} + p_M m)}}.
\]
After some simplifications and rearranging terms we have

$$X^2 = \frac{p_H h \text{crit} + p_M m}{i^2} + \frac{p_L S^2}{2i^2} + \frac{p_L S^2}{2i^2} \sqrt{\frac{p^2 L^2 S^2}{2i^2} + 4(p_H h \text{crit} + p_M m)},$$

We denote the size of the positive shock in the banking default case by $h^*$. Then $X^*^2$ is given by

$$X^*^2 = \frac{p_H h^* + p_M m}{i^2} + \frac{p_L S^2}{2i^2} + \frac{p_L S^2}{2i^2} \sqrt{\frac{p^2 L^2 S^2}{2i^2} + 4(p_H h^* + p_M m)}.$$

We immediately see that $X^2 < X^*^2$, as in the no banking default case we have $h \leq h \text{crit}$, and furthermore $h^* > h \text{crit}$ for the positive shock. Hence $X < X^*$. Moreover, banks obtain a higher amount of equity than in case without banking default, since $E_1^{\text{def}} = X^* - \frac{S_2}{i} > X - \frac{S_2}{i} = E_1^{\text{nodef}}$.

According to Lemma 3.2 and Lemma 3.5 bank $j$ defaults in $t = 2$ in state $\lambda = l$ if and only if $l f'(X^*) \frac{X^*}{\pi} < \frac{S_2}{\pi} i$. Hence a sufficient condition for banking default is the following

$$l < \frac{S^2 i}{f'(X^*)X^*} = \frac{S_2 i (S_2 p_L + \sqrt{S_2^2 p^2 L + 4(p_H h + p_M m)})}{2i} = \frac{S_2^2 p_L}{2} + \frac{S_2}{2} \sqrt{S_2^2 p^2 L + 4(p_H h + p_M m)} = l \text{crit}.$$

Hence, if $l < l \text{crit}$ banks indeed default.

**Liquidity Requirements**

Suppose $l < l \text{crit}$ and the regulator imposes liquidity requirements

$$L_B^{\text{reg}} = S_1 - \frac{l f'(X)X}{\pi} = S_1 - \frac{l}{i \sqrt{p_H h + p_M m + p_L L}}.$$
The unique equilibrium under regulatory intervention is defined as follows

\begin{align*}
(i) & \quad X^{liq} = \bar{X} = \frac{\sqrt{p_H h + p_M m + p_L l}}{i}, \\
(iii) & \quad L_B^{liq} = L_B^{reg} = S_1 - \frac{l}{i\sqrt{p_H h + p_M m + p_L l}}, \\
(ii) & \quad E_1^{liq} = \bar{X} - \frac{l}{i\sqrt{p_H h + p_M m + p_L l}}, \\
(iv) & \quad L^{liq} = W - \frac{l}{i\sqrt{p_H h + p_M m + p_L l}}.
\end{align*}

Note that $L_B^{reg} > L_B$. We can show this as follows:

\begin{align*}
L_B^{reg} &= S_1 - \frac{l}{i\sqrt{p_H h + p_M m + p_L l}} > S_1 - \frac{l^{crit}}{i\sqrt{p_H h + p_M m + p_L l}} \\
&= S_1 - \frac{S_2 i}{i\sqrt{p_H h + p_M m + p_L l}} \\
&= S_1 - \frac{S_2}{i} = L_B.
\end{align*}

**Liquidity Insurance**

Suppose $l < l^{crit}$ and the regulator imposes liquidity insurance

$\Omega = \frac{S_2 - l f'(\bar{X}) \bar{X} p_L}{i^2} = \frac{S_2 - \frac{l}{i\sqrt{p_H h + p_M m + p_L l}} p_L}{i^2} p_L$.

The unique equilibrium under regulatory intervention is defined as follows

\begin{align*}
(i) & \quad X^{ins} = \bar{X} = \frac{\sqrt{p_H h + p_M m + p_L l}}{i}, \\
(iii) & \quad L_B^{ins} = S_1 - \frac{S_2}{i}, \\
(ii) & \quad E_1^{ins} = \frac{\sqrt{p_H h + p_M m + p_L l}}{i} - \frac{l p_L}{i\sqrt{p_H h + p_M m + p_L l}} - \frac{S_2(1 - p_L)}{i}, \\
(iv) & \quad L^{ins} = W - \frac{\sqrt{p_H h + p_M m + p_L l}}{i} + \frac{l p_L}{i\sqrt{p_H h + p_M m + p_L l}} + \frac{S_2(1 - p_L)}{i}.
\end{align*}
Liquidity Risk – Regulation

**Liquidity Risk Taxes**

Suppose \( l < l^{crit} \) and the regulator charges per unit of investment in LTT liquidity risk tax \( \rho^* \) \((0 < \rho^* < 1)\), determined by \( \rho^* = \frac{S_2i}{i f'(X)(f')^{-1}(1+\rho^*)f'(X)} \).

Then in any equilibrium

\[
 f'(X^{tax}) = (1 + \rho^*) f'(X) = \frac{1}{X^{tax2}}.
\]

If Assumption 4 is satisfied\(^7\), the unique equilibrium under regulatory intervention is defined as follows

1. \( \rho^* = \frac{1}{2} \left( \frac{S_2^2}{t^2} (p_H h + p_L l + p_M m) + S_2 \sqrt{p_H h + p_M m + p_L l} \right) \frac{\sqrt{S_2^2 (p_H h + p_M m + p_L l) + 4}}{i} \),
2. \( X^{tax} = \sqrt[p_H h + p_M m + p_L l]{i } \),
3. \( L_B^{tax} = L_B = S_1 - \frac{S_2}{i} \),
4. \( E_1^{tax} = (1 + \rho^*) X^{tax} - \frac{S_2}{i} = \sqrt[p_H h + p_M m + p_L l]{i } - \frac{S_2}{i} \),
5. \( L_1^{tax} = W - \frac{\sqrt[p_H h + p_M m + p_L l]{i }}{i} + \frac{S_2}{i} \).

Note that \( X^{tax}(\rho) \) satisfies (4.22), which is the necessary condition to prevent banking default.

---

\(^7\) According to Assumption 4 there must be a lower bound on \( l \), given by

\[
l > \frac{S_2i}{i f'(X)(f')^{-1}(1+\rho^*)f'(X)}.
\]
4. Liquidity Risk – Regulation

in state $\lambda = l$. We show this as follows

$$X^{tax}(\rho) + (1 + \rho) \frac{\partial X^{tax}(\rho)}{\partial \rho} = \frac{\sqrt{p_H h + p_{Mm} + p_{Ll}}}{i \sqrt{1 + \rho}} - (1 + \rho) \frac{\sqrt{p_H h + p_{Mm} + p_{Ll}}}{2i(1 + \rho)^{\frac{3}{2}}}$$

$$= \frac{\sqrt{p_H h + p_{Mm} + p_{Ll}}}{2i \sqrt{1 + \rho}}$$

$$> 0.$$
A. Appendix to Chapter 3

A.1. Proof of Lemma 3.3

(i) Suppose that $r^e < i^2$. Then, all banks would choose $x^j = 0$ and thus

$$r^e = f'(X)(p_H h + p_M m + p_L l)$$

would be infinite, which is a contradiction.

(ii) Suppose that $r^e > i^2$, which is equivalent to $X < \overline{X}$. Then, using (12) we obtain

$$E(e^j_3) = r^e x^j + \left(\frac{E_1}{n} - x^j\right) i^2 > \frac{E_1}{n} i^2 \quad \forall j.$$

A.) Suppose that $l^j_B > l_B$. Then, bank $j$ can invest $l^j_B - l_B$ additional units of funds in LTT and $E(e^j_3)$ would increase by the amount $(r^e - i^2)(l^j_B - l_B)$. Hence, if $r^e > i^2$ bank $j$ will optimally choose $l^j_B = l_B$.

B.) From A.) we have $l^j_B = l_B$. Next we make the observation that Assumption 1 implies $W + S_1(i) > \overline{X} + L_B$.\(^1\) Hence, given $X < \overline{X}$, we conclude that investors must be investing some of their resources in STT and not into bank equity. This is a contradiction as the return on equity is strictly higher than the return on investment in STT. Hence $r^e > i^2$ cannot occur in an equilibrium.

\(^1\)Assumption 1 can be written as $W > X_{max} - \frac{S_2(i)}{i}$. Adding $S_1(i)$ to the both sides of the inequality gives $W + S_1(i) > X_{max} - \frac{S_2(i)}{i} + S_1(i)$. As $X_{max} > \overline{X}$ and $S_1(i) - \frac{S_2(i)}{i} = L_B$. Assumption 1 guarantees $W + S_1(i) > \overline{X} + L_B$.\(^1\)
We conclude that $r^e = i^2$ has to hold in any equilibrium without default.

Finally, for $r^e = i^2$ we observe that $l_B^j = l_B$ according to Tie-breaking rule 2, which proves Lemma 3.3.

A.2. Proof of Lemma 3.4

(i) Suppose $p_H r^h + p_M r^m \leq (p_H + p_M) i^2$.

Then using (3.19) we obtain

$$
\mathbb{E} (e_3^j) = (p_H r^h + p_M r^m) x^j + (p_H + p_M) \left( \frac{E_1}{n} - x^j \right) i^2 < \frac{E_1}{n} i^2.
$$

Investors would not invest in bank equity as the return on investment in STT is higher. Hence, $E_1 > 0$ only if

$$
p_H r^h + p_M r^m > (p_H + p_M) i^2.
$$

Given $p_H r^h + p_M r^m > (p_H + p_M) i^2$, suppose that $l_B^j > l_B$. Then, bank $j$ could invest $l_B^j - l_B$ additional units of funds in LTT and $\mathbb{E}(e_3^j)$ would increase by an amount

$$
(p_H (r^h - i^2) + p_M (r^m - i^2)) (l_B^j - l_B).
$$

Hence, bank $j$ will invest the maximal possible amount in LTT and choose $l_B^j = l_B$. Note that $l_B = l_B$ implies $L_B = L_B$ and $E_1 = X^* - \frac{S_2(i)}{i}$.

(ii) A.) First suppose

$$
p_H r^h + p_M r^m > i^2 - \frac{S_2(i) p_L}{X^*} \left( \text{i.e. } X^* < \frac{S_2(i) p_L}{i^2 - (p_H h + p_M m) f'(X^*)} \right).
$$

165
Then using (3.19) and $E_1 = x^j - \frac{S_2(i)}{n_i}$ we obtain

$$
\mathbb{E} \left( e^j_3 \right) = \left( pHr^h + pM r^m \right) x^j + \left( pH + pM \right) \left( E_1 \frac{1}{n} - x^j \right) i^2
$$

$$
= \left( pHr^h + pM r^m \right) x^j - \left( pH + pM \right) \frac{S_2(i)}{n_i} i
$$

$$
> \left( x^j - \frac{S_2(i)}{n_i} \right) i^2
$$

$$
= \frac{E_1}{n} i^2.
$$

The return on equity is higher than the return on investment in STT. Given $L_B = L_B$ and $X^* < X^{max}$, Assumption 1 implies $W > X^* - \frac{S_2(i)}{i} = X^* - \frac{S_2(i)}{i} + S_1(i) - S_1(i) = X^* + L_B - S_1(i)$. From $W + S_1(i) > X^* + L_B$ it follows that investors must be investing some of their resources in STT, which cannot be optimal as bank equity yields a higher return. As long as bank equity generates a higher return, investors will shift their resources from STT into equity. Hence $pHr^h + pM r^m > i^2 - \frac{S_2(i) ip_L}{X^*}$ cannot hold in equilibrium.

B.) Suppose now

$$
pHr^h + pM r^m < i^2 - \frac{S_2(i) ip_L}{X^*} \quad \text{(i.e.} \quad X^* > \frac{S_2(i) ip_L}{i^2 - (pHr^h + pM r^m) f'(X^*)})
$$

Then using (3.19) we obtain

$$
\mathbb{E} \left( e^j_3 \right) = \left( pHr^h + pM r^m \right) x^j - \left( pH + pM \right) \frac{S_2(i)}{n_i}
$$

$$
< \frac{E_1}{n} i^2,
$$

which implies that investors would not invest in bank equity as the return on investment in STT is strictly higher. This is a contradiction to $E_1 > 0$. Hence, $X^* > \frac{S_2(i) ip_L}{i^2 - (pHr^h + pM r^m) f'(X^*)}$ cannot occur in an equilibrium.
We conclude that in any equilibrium

\[ p_H r^h + p_M r^m > (p_H + p_M)i^2, \quad l^i_B = l_B \quad \text{and} \]

\[ p_H r^h + p_M r^m = (p_H h + p_M m)f'(X^*) = i^2 - \frac{S_2(i)ip_L}{X^*}, \quad (A.1) \]

which proves Lemma 3.4.

**A.3. Proof of Lemma 3.5**

We divide the proof into two steps.

Step 1: We start by deriving the necessary and sufficient condition for banking default. According to Lemma 3.2 bank \( j \) defaults in \( t = 2 \) if and only if \( \lambda = l \) and \( lf'(X)x^j + \left( l_B^j - \frac{S_1(i)j}{n} \right) i < 0 \). Lemma 3.4 implies that in any equilibrium with banking default in \( t = 2 \) in state \( \lambda = l \) we have \( X = X^* \) as defined by (A.1) and \( L_B = L_B \). From combining these two Lemmas it follows that bank \( j \) defaults in \( t = 2 \) in state \( \lambda = l \), if and only if

\[ lf'(X^*)\frac{X^*}{n} - \frac{S_2(i)j}{n}i < 0, \]

which is equivalent to

\[ l < \frac{S_2(i)j}{f'(X^*)X^*}. \quad (A.2) \]

Step 2: In the second step we are looking for a threshold level of \( l \), denoted by \( l^* \), such that (A.2) is satisfied for \( l < l^* \). We make the following observations:
A. Appendix to Chapter 3

(i) Suppose first that \( l = l^{\text{crit}} = \frac{iS_2(i)}{f'(X)X} \) and banks default in \( t = 2 \) in state \( \lambda = l \). Then in any equilibrium (A.1) has to be satisfied. From (3.17) we have:

\[
h = h^{\text{crit}} = \frac{i^2X(p_H + p_L) - p_LiS_2(i)}{f'(X)Xp_H}.
\]

Substituting \( h^{\text{crit}} \) into (A.1) yields

\[
\frac{i^2X(1 - p_M) - p_LiS_2(i)}{f'(X)X} f'(X^*) + p_Mm f'(X^*) = i^2 - \frac{S_2(i)ip_L}{X^*}. \tag{A.3}
\]

Suppose \( X^* = \bar{X} \). Then equation (A.3) is satisfied. Thus, \( X^* = \bar{X} \) satisfies (A.1) and as the left-hand side of (A.3) is strictly monotonically decreasing in \( X^* \) while the right-hand side of (A.3) is strictly monotonically increasing in \( X^* \), uniqueness follows as well. Hence in case \( l = l^{\text{crit}} \), equation (A.1) can be satisfied if and only if \( X^* = \bar{X} \). However, substituting \( l = l^{\text{crit}} \) and \( X^* = \bar{X} \) into (A.2) yields a contradiction: On the left-hand side we obtain \( l = l^{\text{crit}} = \frac{S_2(i)i}{f'(X)X} \), which is obviously equal to the expression on the right-hand side, given \( X^* = \bar{X} \). Thus we have an equality instead of strict inequality. We conclude that if \( l = l^{\text{crit}} \) banks just do not default.

(ii) Suppose next that \( l > l^{\text{crit}} \) and then by definition \( h < h^{\text{crit}} \).

We distinguish two cases

A.) Suppose that \( X^* < \bar{X} \) and hence \( f'(X^*) > f'(\bar{X}) \). In this case banks do not default in state \( \lambda = l \) (and thus in states \( \lambda = m, h \)). We show this as follows. First, since \( f'(X^*) > f'(\bar{X}) \) and \( l > l^{\text{crit}} \) the return per one unit of investment in LTT in state \( \lambda = l \) increases compared to case (i) where banks just do not default. Second, the resources that are not invested in LTT go into voluntary liquidity which yields a risk-free return \( i \) per unit of investment and equals the

168
deposit rate per unit of borrowed funds. Hence banks generate in state \( \lambda = l \) returns that are at least as high as their obligations towards depositors and do not default.

B.) Suppose next that \( X^* > \bar{X} \) and hence \( f'(X^*) < f'(\bar{X}) \). In this case we obtain a contradiction to (A.1). This results from the following observations. First, in (i) we observed that (A.1) is satisfied if \( X^* = \bar{X} \) and \( h = h_{\text{crit}} \).

Second, the left-hand side of (A.1) is strictly monotonically increasing in \( h \) and strictly monotonically decreasing in \( X \) while the right-hand side is strictly monotonically increasing in \( X \). Hence if \( h < h_{\text{crit}} \) and \( X^* > \bar{X} \) the left-hand side of (A.1) becomes strictly smaller than the right-hand side:

\[
(p_H h + p_M m) f'(X^*) < i^2 - \frac{S_2(i) i p_L}{X^*},
\]

such that the necessary condition for banking default is violated.

We conclude that there is no equilibrium with banking default if \( l > l_{\text{crit}} \).

(iii) Suppose finally that \( l < l_{\text{crit}} \). We observed (Proposition 1B.) that if \( l < l_{\text{crit}} \) there is no equilibrium in which banks do not default. Next we will show that for \( l < l_{\text{crit}} \) there exists an equilibrium in which banks default if \( \lambda = l \) and the aggregate amount of investment in LTI is given by \( X^* > \bar{X} \).

Recall that (A.1) is satisfied if \( h = h_{\text{crit}} \) and \( X^* = \bar{X} \) and that the left-hand side of (A.1) is strictly increasing in \( h \). Hence inserting \( h > h_{\text{crit}} \) (which is equivalent to \( l < l_{\text{crit}} \)) and \( X^* = \bar{X} \) in (A.1) we obtain the following strict inequality:

\[
(p_H h + p_M m) f'(\bar{X}) > i^2 - \frac{S_2(i) i p_L}{\bar{X}}.
\]

The left-hand side of (A.4) is strictly monotonically decreasing in \( X \) with
\[
\lim_{X \to \infty} f'(X) = 0, \text{ while the right-hand side is strictly monotonically increasing in } X \text{ and approaches } i^2 \text{ for } X \to \infty. \text{ Hence, there must be a unique value } X^* \text{ with } X^* > \overline{X} \text{ which satisfies (A.1). Finally we show that } X^* > \overline{X} \text{ and } l < l^{crit} \text{ also satisfy (A.2). As } f'(\overline{X})(pHh + pMm + pLl) = i^2, \text{ we have}
\]
\[
l = \frac{i^2 - f'(\overline{X})(pMm + pHh)}{f'(\overline{X})pL}. \tag{A.5}
\]

Note that the right-hand side of (A.5) is increasing in \(X\). Therefore, using \(X^* > \overline{X}\) and substituting \(X^* = \frac{S_2(i)p_L}{i^2 - (pHh + pMm)}f'(\overline{X})\) into (A.5) yields:

\[
l < \frac{i^2 - f'(X^*)(pMm + pHh)}{f'(X^*)pL} = \frac{S_2(i)p_L}{f'(X^*)p_L X^*} < \frac{S_2(i)i}{f'(X^*)X^*},
\]

which is equivalent to (A.2). Hence, banks indeed default in state \(\lambda = l\) in \(t = 2\) if \(X^* > \overline{X}\) and \(l < l^{crit}\).

We conclude that \(l^* = l^{crit}\). That is if \(l < l^* = l^{crit}\) (and hence \(h > h^{crit}\)) banks default in state \(\lambda = l\) in \(t = 2\) and thus \(x^j = \frac{X^*}{n}, l_j^i = l_B\) and \(E_1^j = \frac{X^*}{n} - \frac{S_2(i)}{m}\) constitute an equilibrium.

### A.4. Proof of Claim 1

We claim that, given Assumption 4, i.e., if

\[
h < \overline{h} = \frac{m}{p_H} \left( \frac{\overline{X}i}{S_2(i)} - (1 - p_H) \right)
\]

there is no equilibrium with banking default in state \(\lambda = m\). We prove this by contradiction. The proof will be divided into 3 steps.

**Step 1:** In the first step we derive a necessary condition for banking default in state \(\lambda = m\).

For this purpose, suppose, contrary to our claim, that there exists an equilibrium with
banking default in state $\lambda = m$ (and hence in state $\lambda = l$). Then applying the same arguments as in Lemma 3.12 we must have

$$mf'(X)x^j + \left(l_B^i - \frac{S_1(i)}{n}\right)i < 0.$$  

By assumption $mf'(\overline{X}) = \overline{i}^2$. Substituting $m = \frac{\overline{i}^2}{f'(\overline{X})}$ into the above inequality we obtain

$$\frac{\overline{i}^2}{f'(\overline{X})}f'(X)x^j + \left(l_B^i - \frac{S_1(i)}{n}\right)i < 0. \quad (A.6)$$

Solving (A.6) for $f'(X)x^j$ yields the following necessary condition for banking default:

$$f'(X)x^j < \frac{\left(l_B^i - \frac{S_1(i)}{n}\right)}{\frac{\overline{i}^2}{f'(\overline{X})}} f'(\overline{X}) = \frac{S_1(i)}{n} - \frac{l_B^i}{f'(\overline{X})}, \quad (A.7)$$

where $l_B^i \geq l_B = \frac{S_1(i)}{n} - \frac{S_2(i)}{m}$ according to Lemma 3.10.

Step 2: Next we show that the aggregate amount of investment in LTT has to satisfy $X > \overline{X}$. For this purpose we make the following observations.

(i) First, suppose that $X = \overline{X}$. Then banks cannot default on their obligations in state $\lambda = m$ for the following reason. We have $mf'(\overline{X}) = \overline{i}^2$ by assumption. That is, the return per period on one unit of bank investment (in both LTT and STT) is $i$ and thus equal to the deposit rate per one unit of borrowed funds. Thus, given $l_B^i \geq l_B$, banks have enough liquidity to repay their obligations towards depositors in $t = 3$ as well as in $t = 2$.

(ii) Suppose next that $X < \overline{X}$. Then banks cannot default on their obligations in state $\lambda = m$. As the return on investment in LTT satisfies $mf'(X) > \overline{i}^2$ and thus the
return on bank investments in LTT and STT is at least \( i \) and hence greater or equal to the deposit rate. Given \( l_B^1 > l_B \), banks are able to fulfill their obligations in both periods.

\[ \rightarrow \text{we conclude that } X > \overline{X} \text{ must hold if banks default in state } \lambda = m \text{ in } t = 2. \]

Step 3: We complete the proof by showing that \( \mathbb{E}(e_j^1) < \frac{E_l i^2}{n} \) if \( X > \overline{X} \) and (A.7) are satisfied and Assumption 4 holds. That is, banks would not receive a positive amount of equity in \( t = 1 \). We show this as follows. Assuming banking default in states \( m \) and \( l \), the expected equity of bank \( j \) in \( t = 3 \) is

\[
\mathbb{E}(e_j^3) = p_H h f'(X) x^j + p_H \left( l_B^1 - \frac{S_1(i)}{n} \right) i^2.
\]

(A.8)

Next we observe that in any equilibrium \( h f'(X) > i^2 \), since otherwise we would have \( \mathbb{E}(e_j^1) < \frac{E_l i^2}{n} \) and banks would not obtain a positive amount of equity. From \( h f'(X) > i^2 \) it follows that \( l_B^1 = l_B \) as the return per unit of investment in LTT is strictly greater than the return per investment unit in liquidity. Inserting \( l_B = \frac{S_1(i)}{n} - \frac{S_2(i)}{m} \) in (A.7) we obtain the following necessary condition for banking default

\[
f'(X) x^j < \frac{S_2(i)}{m} f'(\overline{X}).
\]

Using the above inequality we replace \( f'(X) x^j \) by \( \frac{S_2(i)}{m} f'(\overline{X}) \) in (A.8), which yields

\[
\mathbb{E}(e_j^1) < p_H h \frac{S_2(i)}{m} f'(\overline{X}) - p_H \frac{S_2(i)}{n} i.
\]

(A.9)

Moreover the amount of investment in LTT must be very large, so that the return on investment in LTT, given by \( \frac{i^2}{f'(X)} f'(X) \), becomes very small and (A.7) is satisfied.
A. Appendix to Chapter 3

According to Assumption 4, we have \( h < \bar{h} = \frac{m}{p_H} \left( \frac{X_i}{S_2(i)} - (1 - p_H) \right) \). Hence

\[
\mathbb{E}(e^j_3) < m \left( \frac{X_i}{S_2(i)} - (1 - p_H) \right) \frac{S_2(i)}{in} f'(X) - p_H \frac{S_2(i)}{n} i \quad (A.10)
\]

Finally we are in a position to show that under above considerations \( \mathbb{E}(e^j_3) < \frac{E_1}{n} i^2 \).

Using \( x^j > \frac{X}{n} \) and inserting \( m = \frac{i^2}{f'(X)} \) in (A.10) we obtain

\[
\mathbb{E}(e^j_3) < \frac{X}{n} i^2 - \frac{S_2(i)}{n} i
\]
\[
< \left( x^j - \frac{S_2(i)}{in} \right) i^2 = x^j i^2 - \frac{S_2(i)}{n} i = \frac{E_1}{n} i^2.
\]

We conclude that, given Assumption 4, banks would not receive a positive amount of equity if they survive only in the good state \( \lambda = h \), which is the desired conclusion.
B. Appendix to Chapter 4

B.1. Proof of Lemma 4.1

Note that the proof is similar to the proof of Lemma 3.3.

(i) Suppose that \( r^e < i^2 \). Then, all banks would choose \( x^j = 0 \) and thus

\[ r^e = f'(X)(p_H h + p_M m + p_L l) \]

would be infinite, which is a contradiction.

(ii) Suppose that \( r^e > i^2 \), which is equivalent to \( X < \bar{X} \). Then, using (4.3) we obtain

\[ \mathbb{E}(e_j^3) = r^e x^j + \left( \frac{E_1}{n} - x^j \right) i^2 > \frac{E_1}{n} i^2 \quad \forall j. \]

A.) Suppose that \( l^j_B > \frac{L_{reg}}{n} \). Then, bank \( j \) can invest \( l^j_B - \frac{L_{reg}}{n} \) additional units of funds in LTT and \( \mathbb{E}(e_j^3) \) would increase by the amount \( (r^e - i^2) \left( l^j_B - \frac{L_{reg}}{n} \right) \). Hence, if \( r^e > i^2 \) bank \( j \) will optimally choose \( l^j_B = \frac{L_{reg}}{n} \).

B.) In A.) we observed \( l^j_B = \frac{L_{reg}}{n} \). According to (4.1) the initial endowments of households satisfy \( W + S_1(i) > \bar{X} + L_{reg} \). Hence if \( X < \bar{X} \) it follows that investors invest some of their resources in STT, despite the fact that bank equity yields a strictly higher return. This is a contradiction. Hence \( r^e > i^2 \) cannot occur in an equilibrium.
We conclude that $r^e = i^2$ has to hold in any equilibrium without default.

Finally, for $r^e = i^2$ we observe that $l_B^i = \frac{L_{reg}}{n}$ according to Tie-breaking rule 2, which finishes the proof of Lemma 4.1.

**B.2. Proof of Lemma 4.2**

We prove Lemma 4.2 by contradiction. For this purpose suppose that there exists an equilibrium in which banks default in state $\lambda = l$ in $t = 2$, given liquidity requirement $L_{reg}^B = S_1(i) - \frac{f'(X)x}{i^2}$. We proceed in several steps. We will start with some preliminary observations which will be needed to derive the necessary and sufficient condition for banking default. Then we will show that if this condition is satisfied, banks would not receive a positive amount of equity in $t = 1$, i.e. the expected return on equity would be strictly smaller than the return on investment in STT.

First, we observe that the expected equity of bank $j$ in $t = 3$ is given by

$$\mathbb{E}(e_j^3) = (p_Hh + p_Mm)f'(X)x^j + (p_H + p_M)\left(l_B^i - \frac{S_1(i)}{n}\right)i^2,$$  \hspace{1cm} (B.1)

where $l_B^i = \frac{E_1 + S_1(i)}{n} - x^j \geq \frac{L_{reg}}{n}$. Applying the same arguments as in the proof of Lemma 3.4, we state that in any equilibrium

$$p_Hh + p_Mm = (p_Hh + p_Mm)f'(X) > (p_H + p_M)i^2 \quad \text{and} \quad l_B^i = \frac{L_{reg}}{n}. \hspace{1cm} (B.2)$$

We prove (B.2) as follows. Suppose that $(p_Hh + p_Mm)f'(X) \leq (p_H + p_M)i^2$. Then using
(B.1) and $l_B^j = \frac{E_1 + S_1(i)}{n} - x^j$ we obtain

$$E(e_3^j) = (p_H h + p_M m) f'(X) \frac{X}{n} + (p_H + p_M) \left( \frac{E_1}{n} - \frac{X}{n} \right) i^2$$

If the above inequality holds, investors would not invest into bank equity as the return on investment in STT is higher. As a consequence banks receive a positive equity amount only if $p_H r^h + p_M r^m > (p_H + p_M) i^2$. Suppose next, given $p_H r^h + p_M r^m > (p_H + p_M) i^2$, that $l_B^j > \frac{L_{reg} B}{n}$. Then bank $j$ could invest $l_B^j - \frac{L_{reg} B}{n}$ additional units of funds in LTT and $E(e_3^j)$ would increase by an amount $(p_H (r^h - i^2) + p_M (r^m - i^2)) \left( l_B^j - \frac{L_{reg} B}{n} \right)$. Hence, bank $j$ will choose $l_B^j = \frac{L_{reg} B}{n}$. We conclude that (B.2) has to hold in any equilibrium. Given (B.2) we proceed to derive the necessary and sufficient condition for banking default. For this purpose let us distinguish three cases regarding the aggregate equilibrium investment amount in LTT:

1. Suppose first that $X = \overline{X}$. Then the equity of bank $j$ in $t = 3$ in state $\lambda = l$ is given by

$$e_3^j = l f'(\overline{X}) \frac{\overline{X}}{n} + \left( \frac{L_{reg} B}{n} \frac{i}{i} - \frac{S_1(i)}{n} \right) i = 0$$

and bank $j$ just does not default in state $\lambda = l$. Hence, there exists no equilibrium with banking default in which $X = \overline{X}$.

2. Suppose that $X < \overline{X}$. Then banks cannot default. As the return per one unit of investment in LTT increases compared to case 1. (note that $f'(X) > f'(\overline{X})$) and funds that are not invested into LTT go into liquidity which yields a risk-free return $i$ per unit of investment. Hence, given $l_B^j > \frac{L_{reg} B}{n}$, banks can always fulfill their obligations. It follows that there exists no equilibrium with banking default in which $X < \overline{X}$.

3. Finally suppose that $X > \overline{X}$. Applying Lemma 3.12, using $X > \overline{X}$ and $l_B^j = \frac{L_{reg} B}{n}$ yields the following necessary and sufficient condition for banking default:
Bank \( j \) defaults in \( t = 2 \) in state \( \lambda = l \) if and only if \( X > \bar{X} \) and

\[
lf'(X) \frac{X}{n} + \left( \frac{L_{\text{reg}}^{\text{reg}}}{n} + \frac{S_1(i)}{n} \right) i = l(f'(X) \frac{X}{n} - f'(\bar{X}) \frac{X}{n}) < 0.
\]

Thus banks default in \( t = 2 \) in state \( \lambda = l \) if and only if \( X > \bar{X} \) and

\[
f'(X)X < f'(\bar{X})\bar{X}.
\]  \( \text{(B.3)} \)

Finally we can show that if the necessary and sufficient condition for banking default is satisfied we have \( \mathbb{E}(e_j^3) < \frac{E_1}{n} \):  

Given \( X > \bar{X} \), (B.2) and (B.3) we obtain

\[
\mathbb{E}(e_j^3) = (p_Hh + p_Mm)f'(X) \frac{X}{n} - (p_H + p_M)f'(X) \frac{X}{n} < \frac{X}{n} - l f'(X)X \frac{X}{n} < \frac{X}{n} i^2 - l f'(X)X \frac{X}{n} = \frac{E_1}{n} i^2.
\]

Hence, if the necessary and sufficient condition for banking default is satisfied, the return on bank equity is strictly smaller than the return on investment in STT. In this case investors would not provide banks with equity.

We conclude that under regulatory liquidity requirement \( L_{\text{reg}}^{\text{reg}} \) there exists no equilibrium where banks default in state \( \lambda = l \), which proves Lemma 4.2.
B.3. Proof of Lemma 4.3

Note that the proof is similar to the proofs of Lemmas 3.3 and 4.1.

(i) Suppose first that $r^e < i^2$. Then, all banks would choose $x^j = 0$ and thus

$$r^e = f'(X)(p_H h + p_M m + p_L l)$$

would be infinite, which is a contradiction.

(ii) Suppose next that $r^e > i^2$, which is equivalent to $X < \bar{X}$. Then, using (4.11) we obtain

$$E(e^j_3) = r^e x^j + \left( \frac{E_1}{n} - x^j \right) i^2 > \frac{E_1}{n} i^2 \quad \forall j.$$ 

A.) Suppose that $l_B^j > \frac{L_B}{n}$. Then, bank $j$ can invest $l_B^j - \frac{L_B}{n}$ additional units of funds in LTT and $E(e^j_3)$ would increase by the amount $(r^e - i^2) \left( l_B^j - \frac{L_B}{n} \right)$. Hence, if $r^e > i^2$ bank $j$ will optimally choose $l_B^j = \frac{L_B}{n}$.

B.) In A.) we observed $l_B^j = \frac{L_B}{n}$. From (4.8) it follows that the initial endowments of households are high enough to provide banks with the amount of resources sufficient to invest at least $\bar{X}$ in LTT and $L_B$ in liquidity under insurance policy $\Omega$. Hence, given $X < \bar{X}$, we conclude that investors must be investing some of their resources in STT, although bank equity yields a strictly higher expected return. This is a contradiction as investors can increase their wealth by switching some of their resources from STT into equity (as long as $r^e > i^2$). Hence $r^e > i^2$ cannot occur in an equilibrium.

We conclude that $r^e = i^2$ has to hold in any equilibrium without banking default.

For $r^e = i^2$ we observe that $l_B^j = \frac{L_B}{n}$ according to Tie-breaking rule 2.

To sum up, in any equilibrium $l_B^j = \frac{L_B}{n}$ and $r^e = i^2$, which proves Lemma 4.3.
B. Appendix to Chapter 4

B.4. Proof of Lemma 4.4

Note that the proof is similar to the proof of Lemma 4.2.

The proof will involve the following steps. We begin by making several observations regarding some properties of equilibrium with banking default. Then using these observations we will derive the necessary and sufficient condition for banking default and show that if it is satisfied, banks would not receive a positive amount of equity in \( t = 1 \).

First, applying the same arguments as in the Proof of Lemma 3.4 we observe that in any equilibrium in which banks default in state \( \lambda = l \)

\[
p_{H}r^{h} + p_{M}r^{m} = (p_{h} + p_{M})f'(X) > (p_{H} + p_{M})i^{2} \quad \text{and} \quad l_{B}^{j} = \frac{L_{B}}{n}. \quad (B.4)
\]

We show this as follows. Suppose that \((p_{H}h + p_{M}m)f'(X) \leq (p_{H} + p_{M})i^{2}\). Then using (4.14) we obtain

\[
\mathbb{E}(c_{3}^{j}) = (p_{H}h + p_{M}m)f'(X)x^{j} + (p_{H} + p_{M})\left(\frac{E_{1}}{n} - x^{j} - \frac{\Omega}{n}\right)i^{2} < \frac{E_{1}}{n}i^{2}.
\]

In this case investors would not invest in bank equity as the return on investment in STT is higher. Hence \( E_{1} > 0 \) only if \( p_{H}r^{h} + p_{M}r^{m} > (p_{H} + p_{M})i^{2} \). Suppose now, given \( p_{H}r^{h} + p_{M}r^{m} > (p_{H} + p_{M})i^{2} \), that \( l_{B}^{j} > \frac{L_{B}}{n} \). Then, bank \( j \) could invest \( l_{B}^{j} - \frac{L_{B}}{n} \) additional units of funds in LTT and \( \mathbb{E}(c_{3}^{j}) \) would increase by an amount \((p_{H}(r^{h} - i^{2}) + p_{M}(r^{m} - i^{2}))(l_{B}^{j} - \frac{L_{B}}{n})\). Hence, bank \( j \) will optimally choose \( l_{B}^{j} = \frac{L_{B}}{n} \). Summing up, (B.4) has to hold in any equilibrium.

Under the above considerations we proceed to derive the necessary and sufficient condition for banking default. For this purpose let us distinguish three cases regarding the aggregate
equilibrium investment amount in LTT:

1. Suppose first that $X = \bar{X}$. Then the equity of bank $j$ in $t = 3$ in state $\lambda = l$ is given by

$$e_3^j = lf'(\bar{X})\frac{\bar{X}}{n} + \left(\frac{L_B n i - S_1(i)}{i n} i + \frac{i^2 \Omega}{p_L n}\right) i = 0.$$ 

and bank $j$ just does not default in state $\lambda = l$. Hence, there exists no equilibrium with banking default in which $X = \bar{X}$.

2. Suppose that $X < \bar{X}$. Then banks cannot default. As the return per one unit of investment in LTT increases compared to case 1. ($f'(X) > f'(\bar{X})$) and funds that are not invested in LTT go into liquidity which yields a risk-free return $i$ per unit of investment. Hence, given $l_B^j > L_B$, banks can always fulfill their obligations towards depositors. It follows that there exists no equilibrium with banking default in which $X < \bar{X}$.

3. Finally suppose that $X > \bar{X}$. Applying Lemma 3.12, using $X > \bar{X}$ and $l_B^j = \frac{L_B n}{i}$ yields the following necessary and sufficient condition for banking default:

Bank $j$ defaults in $t = 2$ in state $\lambda = l$ if and only if $X > \bar{X}$ and

$$l f'(X) \frac{X}{n} + \left(\frac{S_1(i) - S_2(i)}{i n} i - \frac{S_1(i)}{p_L} \frac{i}{i^2 n} + \frac{S_2(i) i - l f'(\bar{X}) \bar{X}}{p_L} \right) i = 0.$$

Thus banks default in $t = 2$ in state $\lambda = l$ if and only if $X > \bar{X}$ and

$$f'(X) X < f'(\bar{X}) \bar{X}. \quad (B.5)$$

Finally, we are in a position to show that if the necessary and sufficient conditions for banking default are satisfied we have $\mathbb{E}(e_3^j) < \frac{E_L i^2}{n}$.
B. Appendix to Chapter 4

Given $X > \bar{X}$, (B.4) and (B.5) we obtain

$$
\mathbb{E}(e_3^e) = (p_H h + p_M m) f'(X) \frac{X}{n} - (1 - p_L) \frac{S_2(i) n}{n}
$$

$$
< \frac{X}{n} i^2 - \frac{p_L l f'(X) \bar{X}}{n} - (1 - p_L) \frac{S_2(i) n}{n}
$$

$$
< \frac{X}{n} i^2 - \frac{p_L l f'(X) \bar{X}}{n} - (1 - p_L) \frac{S_2(i) n}{n}
$$

$$
= \frac{E_1}{n} i^2.
$$

Hence, if the necessary and sufficient condition for banking default is satisfied, the return on bank equity is strictly smaller than the return on investment in STT. In this case investors would not provide banks with equity.

We conclude that under insurance policy $\Omega$ there exists no equilibrium in which banks default in state $\lambda = l$, which proves Lemma 4.4.

B.5. Proof of Lemma 4.5

Note that the proof is similar to the proofs of Lemmas 3.3, 4.1 and 4.3.

(i) First suppose that $r^e < (1 + \rho)i^2$. Then using (4.18) we obtain

$$
\mathbb{E}(e_3^e) = r^e x^j + \left( \frac{E_1}{n} - (1 + \rho) x^j \right) i^2
$$

$$
< \frac{E_1}{n} i^2.
$$

In this case investors would not provide banks with equity as investment in STT yields a strictly higher return.

(ii) Suppose now that $r^e > (1 + \rho)i^2$, which is equivalent to $X^{tax} < (f')^{-1} \left( (1 + \rho) f'(\bar{X}) \right)$. 

181
B. Appendix to Chapter 4

Then using (4.18) we have

\[ E(e^j) = r^e x^j + \left( \frac{E_1}{n} - (1 + \rho)x^j \right) i^2 > \frac{E_1}{n} i^2. \]

A.) Suppose that \( l^j_B > \frac{L_B}{n} \). In this case bank \( j \) can invest \( \frac{l^j_B - \frac{L_B}{n}}{1 + \rho} \) additional units of funds in LTT and \( E(e^j) \) would increase by the amount \( (r^e - (1 + \rho)i^2) \frac{l^j_B - \frac{L_B}{n}}{1 + \rho} \). Hence, if \( r^e > (1 + \rho)i^2 \) bank \( j \) will optimally choose \( l^j_B = \frac{L_B}{n} \).

B.) In A.) we observed \( l^j_B = \frac{L_B}{n} \). From (4.15) it follows that the households can provide banks with the amount of equity sufficient for investment amounts \( X \) and \( L_B \). Hence, for \( X^{tax} < (f')^{-1}\left((1 + \rho) f'(\bar{X})\right) \leq \bar{X} \), we conclude that investors must be investing some of their resources in STT, despite the fact that bank equity yields a strictly higher return. This is a contradiction. Hence \( r^e > (1 + \rho)i^2 \) cannot occur in an equilibrium.

We conclude that \( r^e = (1 + \rho)i^2 \) has to hold in any equilibrium without default.

Since \( r^e = (1 + \rho)i^2 \) the return on one unit of investment in LTT is \( \frac{(1 + \rho)i^2}{1 + \rho} = i^2 \) and equal to the return on investment in STT. According to Tie-breaking rule 2 we observe that \( l^j_B = \frac{L_B}{n} \).

To sum up, in any equilibrium,

\[ l^j_B = \frac{L_B}{n} \quad \text{and} \quad r^e = (1 + \rho)i^2, \quad (B.6) \]

which proves Lemma 4.5.
B.6. Proof of Lemma 4.6

We prove Lemma 4.6 in three steps:

Step 1: Suppose first that $\rho^* = 0$. Substituting $\rho^* = 0$ into the left-hand side of (4.19) yields $lf'(X)X$. Then from (4.20) it follows that the left-hand side of (4.19) is strictly smaller than the right-hand side.

Step 2: Next, we observe that according to (4.22) the left-hand side of (4.19) is strictly increasing in $\rho$.

Step 3: Finally, suppose that $\rho^* = 1$. Inserting $\rho^* = 1$ in the left-hand side of (4.19) yields $2lf'(X)(f')^{-1}(2f'(X))$. Then according to (4.16), the right-hand side of (4.19) is strictly greater than the left-hand side.

From steps (1)-(3) we conclude that there must be a $\rho^*$ with $0 < \rho^* < 1$ such that (4.19) is satisfied, which proves Lemma 4.6.

B.7. Proof of Lemma 4.7

To simplify the presentation we denote $(f')^{-1}((1 + \rho^*)f'(X))$ briefly by $X^{\rho^*}$. Note that as $\rho^* \geq 0$, we have $X^{\rho^*} \leq X$.

We prove Lemma 4.7 by contradiction. For this purpose we assume momentarily that there exists an equilibrium with banking default in state $\lambda = l$ and that expected equity of bank $j$ in $t = 3$ is given by (4.25). We proceed as follows. We start by deriving some necessary conditions that have to hold in any equilibrium. Then we will show that under $\rho^*$ there is no $X^{tax}$ that satisfies these conditions and at the same time fulfills $lf'(X^{tax})X^{tax} < S_2(i)i$, which also must hold in any equilibrium in which banks default in state $\lambda = l$. 
First, applying the same logic as in the Proof of Lemma 3.4 we observe that in any equilibrium
\[ p_{Hr}^h + p_{Mr}^m = (p_H h + p_M m) f'(X^{\text{tax}}) > (p_H + p_M)(1 + \rho^*)i^2 \]
and \( l_B^j = \frac{L_B}{n}. \) (B.7)

We prove this as follows. Suppose first that
\[ p_{Hr}^h + p_{Mr}^m = (p_H h + p_M m) f'(X^{\text{tax}}) \leq (p_H + p_M)(1 + \rho^*)i^2. \]

Then using (4.25) we obtain
\[
\mathbb{E}(e_j^3) = (p_H h + p_M m) f'(X^{\text{tax}}) x^j + (p_H + p_M) \left( \frac{E_1}{n} - (1 + \rho^*) x^j \right) i^2 \\
= \left( (p_H h + p_M m) f'(X^{\text{tax}}) - (p_H + p_M)(1 + \rho^*)i^2 \right) x^j + (p_H + p_M) \frac{E_1}{n} i^2 \\
< \frac{E_1}{n} i^2.
\]

In this case investors would not provide banks with equity as the return on investment in STT is strictly higher than the return on equity. Hence \( E_1 > 0 \) only if
\[ p_{Hr}^h + p_{Mr}^m > (p_H + p_M)(1 + \rho^*)i^2. \]

Suppose next, given \( p_{Hr}^h + p_{Mr}^m > (p_H + p_M)(1 + \rho^*)i^2, \) that \( l_B^j > \frac{L_B}{n}. \) Then, bank \( j \) could invest \( \frac{l_B^j - \frac{L_B}{n}}{1 + \rho^*} \) additional units of funds in LTT and \( \mathbb{E}(e_j^3) \) would increase by an amount \(( (p_H h + p_M m) f'(X^{\text{tax}}) - (p_H + p_M)(1 + \rho^*)i^2 \) \( \frac{l_B^j - \frac{L_B}{n}}{1 + \rho^*} \). Hence, bank \( j \) will optimally choose \( l_B^j = \frac{L_B}{n}, \) which completes the proof of (B.7).

Note that (B.7) implies \( f'(X^{\text{tax}}) > \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m}, \) which yields the following upper threshold on \( X^{\text{tax}}. \)
\[ X^{\text{tax}} < (f')^{-1} \left( \frac{(p_H + p_M)(1 + \rho^*)i^2}{p_H h + p_M m} \right). \] (B.8)

184
Moreover, since \( L_B = L_B \) the first period equity \( E_1 \) is given by

\[
E_1 = L_B - S_1(i) + (1 + \rho^*)X^{tax} - \frac{S_2(i)}{i}.
\]

(B.9)

Next we observe that \( X^{tax} \) has to satisfy:

\[
X^{tax} = \frac{p_L S_2(i)i}{(1 + \rho^*)i^2 - (p_Hh + p_Mm)f'(X^{tax})}.
\]

(B.10)

We prove (B.10) as follows. Suppose first that

\[
X^{tax} < \frac{p_L S_2(i)i}{(1 + \rho^*)i^2 - (p_Hh + p_Mm)f'(X^{tax})}.
\]

Then given \( l_B^j = \frac{L_B}{n} \) and (B.9) we obtain

\[
E(e_3^j) = (p_Hh + p_Mm)f'(X^{tax})x^j - (p_H + p_M)\frac{S_2(i)}{n}i
\]

\[
> (1 + \rho^*)x^j i^2 - \frac{S_2(i)}{n}i
\]

\[
= \frac{E_1}{n} i^2,
\]

which implies that expected return on equity is strictly higher than \( i^2 \). Given \( L_B = L_B \) and (B.8), Assumption 6 implies \( W > (1 + \rho^*)X^{tax} - \frac{S_2(i)}{i} = (1 + \rho^*)X^{tax} - \frac{S_2(i)}{i} + S_1(i) - S_1(i) = (1 + \rho^*)X^{tax} + L_B - S_1(i) \). From \( W + S_1(i) > (1 + \rho^*)X^{tax} + L_B \) we can conclude that investors must be investing some of their resources in STT, which cannot be optimal as bank equity yields a higher return. As long as bank equity generates a higher return, investors will shift their resources from STT into equity. This is a contradiction.
Suppose next

\[ X^{\text{tax}} > \frac{p_L S_2(i) i}{(1 + \rho^*) i^2 - (p_H h + p_M m) f'(X^{\text{tax}})} \]

Then

\[ \mathbb{E}(e^j_3) < \frac{E_1}{n} i^2, \]

implying that investors would not provide banks with equity.

We conclude that (B.10) has to hold in any equilibrium with banking default. Next we proceed to look for the aggregate amount of investment in LTT such that (B.10) and (B.7) are satisfied and \( l f'(X^{\text{tax}}) X^{\text{tax}} < S_2(i) i \). We distinguish three cases regarding the investment amount \( X^{\text{tax}} \).

1. Suppose first that \( X^{\text{tax}} = \overline{X} \). Then since \( l < l^{\text{crit}} = \frac{i S_2(i)}{f'(X) X} \) bank \( j \) defaults in \( t = 2 \) in the bad state. However, \( X^{\text{tax}} = \overline{X} \) violates (B.10). We prove this as follows. Inserting \( \overline{X} \) in (B.10) and multiplying both sides of (B.10) by \( (1 + \rho^*) i^2 - (p_H h + p_M m) f'(\overline{X}) \) yields

\[ \overline{X}(1 + \rho^*) i^2 - \overline{X}(p_H h + p_M m) f'(\overline{X}) = p_L S_2(i) i \]

or equivalently

\[ \overline{X} \rho^* i^2 + p_L l f'(\overline{X}) \overline{X} = p_L S_2(i) i. \]  \hspace{1cm} (B.11)

Inserting \( \rho^* = \frac{S_2(i) i}{l f'(\overline{X}) X_{\rho^*}} - 1 \) in (B.11) and subtracting \( p_L l f'(\overline{X}) \overline{X} \) from both sides yields

\[ \overline{X} i^2 \left( \frac{S_2(i) i}{l f'(\overline{X}) X_{\rho^*}} - 1 \right) = p_L (S_2(i) i - l f'(\overline{X}) \overline{X}). \]  \hspace{1cm} (B.12)
B. Appendix to Chapter 4

Dividing both sides of (B.12) by \( \frac{S_2(i) - 1f'(X)X^\rho}{lf'(X)X^\rho} \) and using \( X^\rho \leq \bar{X} \) yields

\[
\bar{X}i^2 = \frac{p_L(S_2(i) - 1f'(X)X)}{S_2(i) - 1f'(X)X^\rho} \leq p_Lf'(X)X^\rho,
\]

which is a contradiction since by definition \( i^2 = f'(X)(p_Hh + p_MM + p_LL) \) and hence we must have:

\[
\bar{X}i^2 = \bar{X}f'(X)(p_Hh + p_MM + p_LL) > p_Lf'(X)X^\rho.
\]

We conclude that \( X^{tax} = \bar{X} \) violates the necessary condition for equilibrium with banking default.

2. Suppose next that \( X^{tax} > \bar{X} \) and hence \( f'(X^{tax}) < f'(\bar{X}) \). We can show that \( X^{tax} > \bar{X} \) violates (B.10). According to (B.10) \( X^{tax} \) has to satisfy

\[
X^{tax}(1 + \rho^*)i^2 - X^{tax}(p_Hh + p_MM) = p_LS_2(i)i.
\]

(B.13)

Substituting \( \rho^* = \frac{S_2(i)}{lf'(X)X^\rho} - 1 \) into (B.13) and rearranging terms yields

\[
X^{tax}(i^2 - f'(X^{tax})(p_Hh + p_MM)) + X^{tax}i\left(\frac{S_2(i) - 1f'(X)X^\rho}{lf'(X)X^\rho}\right) = p_LS_2(i)i,
\]

(B.14)

subtracting \( X^{tax}(i^2 - f'(X^{tax})(p_Hh + p_MM)) \) from both sides of (B.14) we obtain

\[
X^{tax}i\left(\frac{S_2(i) - 1f'(X)X^\rho}{lf'(X)X^\rho}\right) = p_LS_2(i)i - X^{tax}(i^2 - f'(X^{tax})(p_Hh + p_MM)).
\]

(B.15)
As \( f'(X^{tax}) < f'((X)) \), we have

\[
i^2 - f'(X^{tax})(p_H h + p_M m) > i^2 - f'(((X))(p_H h + p_M m) = p_L f'((X)).
\]

Hence, due to \( X^{tax} > ((X) \), the right-hand side of (B.15) is strictly smaller than

\[
p_L (S_2(i) - l f'((X))) (X^{tax}). \tag{B.16}
\]

Replacing the right-hand side of (B.15) by (B.16) yields the following inequality that has to hold in any equilibrium

\[
X^{tax} i^2 \left( \frac{S_2(i) - l f'((X)) X^{\rho^*}}{l f'((X)) X^{\rho^*}} \right) < p_L (S_2(i) - l f'((X))) \tag{B.17}
\]

Dividing both sides of (B.17) by \( \frac{S_2(i) - l f'((X)) X^{\rho^*}}{l f'((X)) X^{\rho^*}} \) yields

\[
X^{tax} i^2 < \frac{p_L (S_2(i) - l f'((X)))}{S_2(i) - l f'((X))} \leq p_L l f'((X)) X^{\rho^*},
\]

which is a contradiction, since \( X^{tax} i^2 > ((X)^2 = f'((X))(p_H h + p_M m + p_L l) \).

We conclude that \( X^{tax} > ((X) \) violates the necessary condition for equilibrium with banking default.

3. Suppose \( X^{tax} < ((X) \) and thus \( f'(X^{tax}) > f'((X)) \).

\( X^{tax} \) has to satisfy (B.10) which is equivalent to

\[
X^{tax} ((1 + \rho^*) i^2 - (p_H h + p_M m) f'(X^{tax})) = p_L S_2(i) i. \tag{B.18}
\]

Suppose \( X^{tax} = X^{\rho^*} \leq ((X)). Then using \( f'(X^{tax}) = (1 + \rho^*) f'((X)), (1 + \rho^*) = \frac{S_2(i)}{l f'((X)) X^{\rho^*}} \)
and $i^2 - (p_H h + p_M m) f'(\bar{X}) = p_L l f'(\bar{X})$ we rewrite the left-hand side of \eqref{eq:appendixB18} as

\[
X^{\rho^*}(1 + \rho^*) \left(i^2 - (p_H h + p_M m) f'(\bar{X})\right)
= X^{\rho^*} \frac{S_2(i)i}{lf'(\bar{X})X^{\rho^*}} p_L l f'(\bar{X})
= p_L S_2(i) i,
\]

which is equivalent to the right-hand side of \eqref{eq:appendixB18}. Obviously \eqref{eq:appendixB10} is satisfied for $X^{\text{tax}} = X^{\rho^*} < \bar{X}$. Moreover $X^{\text{tax}} = X^{\rho^*}$ is the unique solution of \eqref{eq:appendixB10} as the left-hand side of \eqref{eq:appendixB10} is strictly monotonically increasing in $X^{\text{tax}}$ and the right-hand side of \eqref{eq:appendixB10} is strictly monotonically decreasing in $X^{\text{tax}}$ due to $f''(X^{\text{tax}}) < 0$. However, we observed that under liquidity taxes $\rho^*$ banks do not default in state $\lambda = l$ if they invest $X^{\text{tax}} = X^{\rho^*}$ in LTT and $L_B$ in liquidity. Recall that

\[
e^3_j = l(1 + \rho^*) f'(\bar{X}) \frac{X^{\rho^*}}{n} - \frac{S_2(i)}{n} i
= l \frac{S_2(i) i}{lf'(\bar{X})X^{\rho^*}} \frac{f'(\bar{X})X^{\rho^*}}{n} - \frac{S_2(i)}{n} i = 0.
\]

Hence there is no $X^{\text{tax}} < \bar{X}$ that satisfies \eqref{eq:appendixB10} and $lf'(X^{\text{tax}})X^{\text{tax}} < S_2(i)i$.

We conclude that if liquidity taxes $\rho^*$ are in place, there exists no equilibrium in which banks default in state $\lambda = l$, which proves Lemma 4.7.
C. Appendix: List of Notations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v$</td>
<td>initial endowment of a household</td>
</tr>
<tr>
<td>LTT</td>
<td>risky long-term technology</td>
</tr>
<tr>
<td>STT</td>
<td>risk free short-term technology</td>
</tr>
<tr>
<td>$i$</td>
<td>constant (risk free) return on one unit of investment in STT</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>realization of the macroeconomic shock with $\lambda = h$: high returns, $\lambda = m$: moderate returns, $\lambda = l$: low returns</td>
</tr>
<tr>
<td>$p_s$</td>
<td>probability of realization of the macroeconomic shock with $s = H$: high returns, $s = M$: moderate returns, $s = L$: low returns</td>
</tr>
<tr>
<td>$X$</td>
<td>aggregate amount of investment in LTT</td>
</tr>
<tr>
<td>$f(X)$</td>
<td>production function</td>
</tr>
<tr>
<td>$\lambda f(X)$</td>
<td>aggregate output of investment in LTT</td>
</tr>
<tr>
<td>$\bar{h}$</td>
<td>upper threshold of $h$</td>
</tr>
<tr>
<td>$r^\lambda$</td>
<td>$\lambda f'(X)$ with $\lambda = h, m, l$</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Symbol</th>
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</tr>
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</table>
| $r^e$  | expected return to banks on one unit of investment in LTT  
  with $r^e = p_H r^h + p_M r^m + p_L r^l$  |
| $\eta$ | measure of a household continuum with $\eta \geq 1$  |
| $c_t, c_{t+1}$ | consumption of consumer born in $t$ in $t$ and in $t + 1$ with $t = 1, 2$  |
| $u(\cdot)$ | utility function  |
| $s_t$  | individual savings of a consumer in period $t$  |
| $S_t$  | aggregate savings of a generation of consumers in period $t$  |
| $D_t$  | aggregate amount of deposits in period $t$ with $D_t = D^C_t + D^I_t$  
  $D^C_t$: deposits held by consumers, $D^I_t$: deposits held by investors  |
| $W$    | initial aggregate wealth of investors  |
| $E_t$  | aggregate bank equity in period $t$  |
| $c^j_t$ | equity of bank $j$ in period $t$  |
| $L^I_t$ | aggregate amount of investment in STT by investors in period $t$  |
| $r^{D_t}$ | deposit rate in period $t$  |
| $d^j_t$ | amount of bank $j$’s deposits in period $t$ with $d^j_t = d^C_t + d^I_t$  
  $d^C_t$: deposits held by consumers, $d^I_t$: deposits held by investors  |
| $x^j$  | bank $j$’s amount of investment in LTT  |
| $v^j_B$ | bank $j$’s amount of investment in STT, also called voluntary liquidity  |
| $L_B$  | aggregate amount of investment in voluntary liquidity  |
| $L^B_B$ | minimum amount of aggregate investment in voluntary liquidity  |
C. Appendix: List of Notations

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>$\bar{X}$</td>
<td>aggregate amount of investment in LTT defined by $\bar{X} = (f')^{-1}\left(\frac{i^2}{p_H+h+p_M+m+l}\right)$</td>
</tr>
<tr>
<td>$X^{max}$</td>
<td>aggregate amount of investment in LTT defined by $X^{max} = (f')^{-1}\left(\frac{(p_H+p_M)i^2}{p_H+h+p_M+m}\right)$</td>
</tr>
<tr>
<td>$l^{crit}$</td>
<td>threshold level of $l$ defined by $l^{crit} = \frac{iS_2(i)}{f'(\bar{X})\bar{X}}$</td>
</tr>
<tr>
<td>$h^{crit}$</td>
<td>threshold level of $h$ defined by $h^{crit} = \frac{i^2X(p_M+p_L)-p_LiS_2(i)}{f'(\bar{X})Xp_H}$</td>
</tr>
<tr>
<td>$Y^\lambda$</td>
<td>aggregate output of the economy in $t = 3$ in state $\lambda$ with $\lambda = h, m, l$</td>
</tr>
<tr>
<td>$\mathbb{E}(Y^{FB})$</td>
<td>expected aggregate output of the economy in $t = 3$ in the first-best world</td>
</tr>
<tr>
<td>$L_B^{reg}$</td>
<td>aggregate amount of investment in STT by banks under liquidity regulation</td>
</tr>
<tr>
<td>$L_B^{reg}$</td>
<td>minimum amount of aggregate investment in STT by banks under liquidity regulation</td>
</tr>
<tr>
<td>$\Omega$</td>
<td>aggregate amount of insurance contracts</td>
</tr>
<tr>
<td>$\Omega$</td>
<td>minimum aggregate amount of insurance contracts</td>
</tr>
<tr>
<td>$r^l$</td>
<td>repayment of insurance contract with $r^l = 0$ if $\lambda = m, h$ and $r^l = q$ $(q &gt; 0)$ if $\lambda = l$</td>
</tr>
<tr>
<td>$\rho$</td>
<td>flat tax per one unit of investment in LTT with $0 \leq \rho \leq 1$</td>
</tr>
<tr>
<td>$X^{tax}$</td>
<td>aggregate amount of investment in LTT under liquidity risk taxes</td>
</tr>
<tr>
<td>$Y^{req}$</td>
<td>aggregate output of the economy in $t = 3$ under liquidity requirements</td>
</tr>
<tr>
<td>$Y^{ins}$</td>
<td>aggregate output of the economy in $t = 3$ under liquidity insurance</td>
</tr>
</tbody>
</table>
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<tbody>
<tr>
<td>$Y^{t_{ax}}$</td>
<td>aggregate output of the economy in $t = 3$ under liquidity risk taxes</td>
</tr>
<tr>
<td>$X^{\rho^*}$</td>
<td>aggregate amount of investment in LTT defined by</td>
</tr>
</tbody>
</table>

$$X^{\rho^*} = (f')^{-1}((1 + \rho^*)f'(X))$$


Bibliography


Bibliography


Bibliography


Bibliography


Bibliography


## Curriculum Vitae

Zurich, March 28, 2012

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<thead>
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