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Banking Regulation

Assessment and Simulation of Regulatory Measures

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed and properly cited resources and literature.

The author further declares that the thesis has not been used previously for obtaining any university degree.

Prague, May 18, 2011

Signature

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Garant studijního programu Vám dle zákona č. 111/1998 Sb. o vysokých školách a Studijního a zkušebního řádu UK v Praze určuje následující bakalářskou práci

Předpokládaný název BP:

Banking Regulation: Assessment and Simulation of the Prepared Regulatory Measures

Charakteristika tématu, současný stav poznání, případné zvláštní metody zpracování tématu:

After the 2008 collapse of the financial system, there is a growing alarm over its hidden vulnerabilities including overleverage and interconnectedness of the banks. These issues are addressed by increased regulatory activity, such as the prepared Basel III agreement.

Agent-based modelling is an alternative approach in economics and other sciences, which describes the reality as a system of interacting agents. In my thesis, I will use such method for studying the impact of prepared regulation on the financial system.

Struktura BP:

Abstrakt:

The thesis focuses on the modelling of the international banking system and possible impact of regulation prepared in the aftermath of the financial crisis. The main tool for our analysis will be agent-based modelling, which allows us to incorporate the network-based vulnerabilities of the banking system.

In the first part, we describe the current situation of the banking system and the proposed regulatory measures. We also introduce the framework of agent-based modelling along with its advantages, disadvantages and possibilities for financial system simulation.

In the second part, we build a model allowing us to study the system behaviour under specific parameter choice. After running the simulations, we interpret the results and possibly draw some policy implications.

Osnova:

I. Introduction

II. Theoretical background
- Basic concepts in banking
- Macroeconomic Conditions
- Regulation framework
- Agent-Based modelling

II. Empirical analysis
- The model (inspired by Gai, Kapadia 2010 or Hermsen 2010)
- Simulation runs of the model under different scenarios
- Interpretation of the Simulation Results and Policy Implications

IV. Conclusion

Seznam základních pramenů a odborné literatury:

Axelrod R., Tesfatsion L.: *On-Line Guide for Newcomers to Agent-Based Modelling in the Social Sciences,* Iowa State University, 2007, viewed 20 June 2010, http://www.econ.iastate.edu/tesfatsi/abmread.htm.

Mishkin, F. S.: *The Economics of Money, Banking, and Financial Markets*. Pearson Addison-Wesley, 2007.

Gai, P.,Kapadia, S.: *Contagion in financial networks,* Proc. R. Soc. A 466:2401-2423, 2010

Hermsen, O.: *Does Basel II destabilize financial markets? An agent-based financial market perspective,* Eur. Phys. J. B 73 (1) 29-40, 2010

IMF (International Monetary Fund): *Global Financial Stability Report: Responding to the Financial Crisis and Measuring Systemic Risks.*, Washington, DC: International Monetary Fund, 2009c.

Mejstřík M., Pečená M., Teplý P.: *Basic Principles of Banking,* Karolinum press, 2008

Schooner, H. M. and Taylor, M. W.: *Global Bank Regulation: Principles and Policies.* Elsevier, 2009.

Tesfatsion L., Judd K. L.: *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*, Elsevier/North Holland, 2006.

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Abstract

This thesis focuses on international banking regulation, particularly the capital adequacy requirements known as the Basel Accords. In the first part, we study the rationale for regulating the banks and describe the evolution of the Basel Accords, including the newly presented measures known as Basel III. The main conclusion of this part is that the regulation is heavily shaped by the banks themselves and does not always serve the best for protecting the financial system. In the second part dedicated to systemic risk modelling, we first introduce the used methodology and then build an agent-based model which enables us to simulate the impacts of various types of negative shocks given various settings of the banking system and the regulatory environment, including the capital and liquidity measures. Our simulations show firstly that sufficient capital buffers are crucial for systemic stability, secondly that the discretionary measures have little effect once a crisis breaks out and thirdly that liquidity measures are a relevant regulatory tool.

JEL Classification: **E61, G01, G21, G28**

Keywords: **agent-based modelling, banking regulation, Basel Accords, systemic risk**

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Abstrakt

Tato práce pojednává o mezinárodní bankovní regulaci, zejména pomocí požadavků na kapitálovou přiměřenost obsažených v Basilejských dohodách. V první části se zaměřujeme na důvody regulace bank a popisujeme vývoj mezinárodní bankovní regulace včetně aktuálně představených dokumentů známých jako Basel III. Hlavním závěrem této části je skutečnost, že regulace je z velké míry ovlivňována samotnými bankami a ne vždy slouží k zajištění stability finančního systému. Ve druhé části věnované modelování systémového rizika nejprve uvedeme použitou metodologii a následně zkonstruujeme multiagentní model, který umožňuje simulovat dopady negativních šoků při různých nastaveních parametrů bankovního systému a regulatorního prostředí. Naše simulace ukazují zaprvé, že dostatečná míra kapitálu je nezbytná pro zajištění systémové stability, zadruhé, že jakmile se systém octne v systémové krizi, diskreční zásahy mají jen velmi malý účinek a zatřetí poukazují na užitečnost regulace likvidity.

Klasifikace JEL: **E61, G01, G21, G28**

Klíčová slova: **bankovní regulace, Basilejské dohody, multiagentní modelování, systémové riziko**

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1 Introduction

The 2008/2009 financial crisis pointed at the vulnerabilities and close interlinkages of the financial system. It left the world economy paralysed and questioning the beliefs it had held for at least three decades. The main concept put to question was banking regulation. Since the current regulatory setting failed to prevent the financial crisis or mitigate the subsequent downturn, there came increased demand for its adjustment, and the regulation of banks became one of the most frequent topics in the financial as well as in the political world. Hence, it is a very important subject and since the new regulatory standards known as Basel III came out only very recently, it is also highly up-to-date.

The aim of this thesis is a thorough examination of banking regulation, connecting the dots that led to the recent financial crisis, provision of better understanding of how the mechanisms behind the regulatory measures work and drawing attention to the importance of capital regulation. The main contribution is that it provides a complex view on the Basel Accords and also tests the effect of individual regulatory measures on a simulated banking system.

The thesis is structured as follows: in the first chapter, after a short introduction of the basic concepts of banking, we will describe the changes that the banking business had gone through in the period since the collapse of Bretton Woods system and state the main reasons for banking regulation, such as depositor protection and systemic externalities. Subsequently, the second chapter focuses on the Basel Committee for Banking Supervision and the Basel Accords, which are the main regulatory documents. We will provide the description of the evolution from Basel I through Basel II to the newly proposed Basel III along with the assessment of these documents and finally, we will carry out an institutional analysis of the forces shaping the form of the banking regulation.

The last chapter will concentrate on modelling of systemic risk and impact of regulation on resilience of a banking system. First, we will shortly introduce the used methodological approaches, namely the network modelling and agent-based modelling, along with examples of their utilisation in modelling of banking systems. Second, we will construct a model of a banking system and provide comparative statics analysis under several stress scenarios. Finally, we will summarize the results and provide policy implications along with a short description of areas for further improvement.

2 Principles of Banking and the Banking Regulation

2.1 General Info

The first part of the first chapter defines the main concepts of banking for the purpose of further discussion. It provides general information on how a bank is defined, describes its key functions, names the main types of risks inherent to the banking business and outlines how a bank's stylized balance sheet looks like.

2.1.1 Definition of a Bank

The definition of a bank varies slightly across different countries.[1] However, most of the definitions reflect the core activities of banks, i.e. taking deposits and granting loans. A universal definition which is used by the regulators to decide whether a financial institution ought to be subject to banking regulation may be found in Freixas, et al. (2008):

[a] bank is an institution whose current operations consist in granting loans and receiving deposits from the public, [2]

2.1.2 Balance Sheet of a Bank

According to the bank definition, it seems obvious that the main parts of the bank's balance sheet are the deposits and other credit it collects to make a pool of funds and on the other side loans and advances it produces from this pool.

Capital forms the next important part of a bank's balance sheet. Since the losses covered by the net worth have to be written off by the bank's owners and not the bank's creditors, it works as a buffer against unexpected losses and its sufficient amount is also one of the main requirements by the regulatory bodies.

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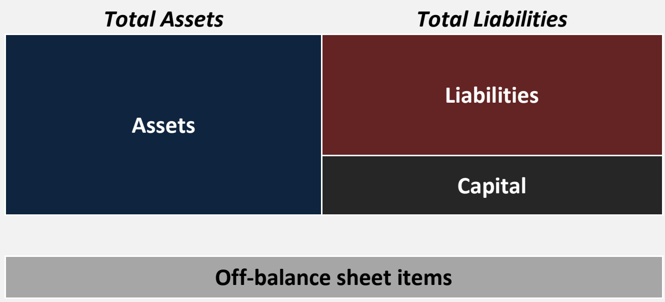
[1] EU definition may be found in *EU Directive 2006/48/EC*, Article 4. In the US law, banks are defined in *Auten v. United States National Bank of New York* (1899; p. 141-142). For more examples, refer to Schooner, et al. (2009).

[2] (Freixas, et al., 2008; p. 1).

Besides the bank's balance sheet, there are off-balance sheet items which represent sophisticated contracts such as credit lines, guarantees, swaps, hedging contracts or securities. Those operations do not constitute genuine assets or liabilities but only a conditional commitment to a bank and thus they are not reflected on the balance sheet. (Freixas, et al., 2008).

Figure 1: Stylized scheme of a bank's balance sheet



Source: (Mejstřík, et al., 2009), *author*

2.1.3 Functions of a Bank

The two main activities, granting loans and receiving deposits imply several functions the banks undertake. These are discussed i.a. in Freixas, et al. (2008) or Mejstřík, et al. (2009) and the key ones are asset transformation, provision of liquidity and payment services, and risk management.

2.1.3.1 Asset Transformation

Funds transformation lies between their collection and advancement. Such function of banks can be seen from three different aspects:

First, the banks transform the size of the individual products in a way that is suitable for the clients. This is called convenience of denomination. According to Gurley and Shaw (1960), banks change the financial products the firms want to issue into the ones the investors desire by aggregation of small deposits and investing them into large loans.

Second, the banks provide quality transformation of assets, i.e. they transform the deposits so that the final portfolio has better risk-return profile than the disaggregated individual investments. A bank can also help overcome the information asymmetry between debtors and creditors by taking the role of a delegated monitor, screening and monitoring the loan applicants (Diamond, 1984).

The third aspect of the asset conversion is maturity transformation, which is a process of change of short-maturity deposits convenient for the depositors into longer-maturity loans that are convenient for the borrowers. This entails potential liquidity issues when a larger portion of deposits is withdrawn and the bank cannot meet its obligations when they are due since its assets are blocked for a longer term. When this situation occurs on a large scale, it is called a *bank run*.

2.1.3.2 Liquidity and Payment Services

Since banks historically had large amounts of money in vaults, they started to offer the merchants a possibility to pay with bills of exchange to mitigate the risk of transporting large amounts of precious metals. Later on, banks started to issue notes for circulation from which the paper money emerged, checking and payment systems have been evolving and finally, the money became dematerialized and the payments started to take the form of movement of electronic funds among the bank accounts.

Nowadays, banks provide transfers of the demandable debt as the main means of payments. According to Schooner, et al. (2009), this fact is not surprising since deposits possess good characteristics to become the medium of exchange. Their face value is easy to determine, they are divisible, their ownership is easily transferable and there is a relative certainty about no losses during the payment. These factors make deposits a good substitute for material money as a medium of exchange and place banks into an important role of facilitating the payments.

2.1.3.3 Risk Management

The banks' main activity entails sale and purchase of imperfect, non-standard contracts that are not easily transferable to third parties and that remain unfinished until full repayment (Mejstřík, et al., 2009). These are sources of risk inherent in the banking business that needs to be taken into account and well managed. Among others, there are three basic types of risk connected to the banks' operation:

1. The banks have to face credit risk associated with the possibility of the debtors not repaying their loans. This can happen for several reasons, but mostly it is because of insolvency of the counterparty. According to Freixas, et al. (2008), lately, this risk has been increasing. Initially, the loans were fully collateralized and the loan advancing activity was similar to the one of a pawnbroker. However, mainly with the establishment of investment banking and providing money to industries, the banking business began to involve investments that are much more risky and require good appraisal done mostly by scoring and rating of the credit applicants and their investment projects.

2. The maturity transformation and the subsequent fact that the two sides of the balance sheet have different structure result in market risk, i.e. the potential for unfavourable movement of the market prices and in particular of interest rates. Moreover, because banks usually operate with high leverage, even a relatively small price change can have vast consequences on the banks' profit or even solvency. According to Freixas,

et al. (2008), with the end of the Bretton Woods system in the beginning of 1970s, the interest rates and market prices became more volatile and thus the market risk increased.

3. Since the deposits have a short-term character and the loans are fixed for longer periods, there can be an unexpected lack of funding or even mass deposit withdrawals. The concept of liquidity risk thus represents the possibility that a bank will not be able to repay its obligations when they are due. Also, when there is a lack of short-term funding, keeping the bank in operation may be extremely expensive, because it may need to sell some of its assets for much lower price or to borrow funds for high interest rates. Because the short-term funding is very expensive, liquidity problems may lead to large losses and eventually even to insolvency. Hence, they have to be avoided by the banks.

These basic risks in banking have increased in time and among other types of risk they materialized in the recent financial crisis.[3] The crisis also pointed to those risks that are not inherent to individual banks, but are system-wide, particularly the risk of contagion, or systemic risk, connected with the possibility of a shock spreading and amplifying from one bank to another.

2.2 The Regulation Framework

In this part, we will introduce the main reasons for bank regulation. Subsequently, a brief overview of the policies before the end of the Bretton Woods system will be presented as well as how the banking sector has evolved since. Finally, we close this subchapter by introducing the rationale for the regulation to be on the cross-border basis.

2.2.1 Rationale for Banking Regulation

According to Dewatripont, et al. (1994), the views on why the banks should be regulated differ. We agree that the answer does not lie in the individual functions such as asset transformation or payment system provision. Although these activities are vital to the economy, they are not more important than e.g. food supply, cars or pharmaceuticals, sectors where the prudential regulation does not exist.

Neither the sole existence of the deposit insurance programmes or state aid explains the case,[4] since the *a priori* banking regulation is caused by the same reasons as the *ex-post* bail-outs. The truth is that the anticipation of state help for banks in distress further amplifies the

[3] Complete list of types of risk materialized during the financial crisis can be found in Teplý, et al. (2010b).
[4] According to Dewatripont, et al. (1994; p. 30), it *"puts the cart before the horse"*.

need for the regulation, since it results in moral hazard and excessive risk-taking, and the same holds for the deposit insurance.[5] However, the core reasons lie in the key two types of market failure - asymmetric information and the existence of externalities.

2.2.1.1 Information Asymmetries and Representation Hypothesis

Several authors stress that the regulation should be targeted to protect the individual depositors, since there are differences in the information available to them and to the bank. Information asymmetry arises when one party to a contract possesses a significant informational advantage over the other party. Such situation is often linked with complex products where the costs of monitoring and understanding the situation are substantially high and especially for the financial products, their nature and intensity makes it a significant issue (Schooner, et al., 2009), (Mishkin, 2004).

The bank deposit is a financial contract when the bank promises to return the depositor's funds at any time she demands them or at some fixed future date. However, the bank has much more information for effective judgement on the probability of honouring such promise and it may happen that either the bank will take deposits without any intention to repay them[6] or that it will not be able to repay them because of financial problems. The depositors and creditors, on the other hand, have little knowledge of the bank's financial condition, mostly because they do not know the structure of the bank's assets and off-balance sheet items and cannot verify their value. Furthermore, even if the information is available, very few depositors possess the expertise to evaluate it and draw conclusions for their behaviour.

The existence of asymmetric information then leads to two issues: moral hazard and adverse selection. Moral hazard is a situation that arises when the counterparty has an incentive to behave in such a way that it increases the risk of not honouring the contract. For example, a bank may invest in excessively risky assets, because its management will be better off when the investment is successful but most of the risk is borne by the depositor when the investment becomes a failure.

Adverse selection arises when the most undesirable counterparty is selected, because it has the largest incentive to put effort in entering into a contract, for example a bank in financial distress will be more eager to collect deposits or take loans. Since this phenomenon makes

[5] An empirical study by Detragiache, et al. (2002) concludes that especially where the institutional environment is weak, explicit deposit insurance leads to bank instability.

[6] Major scandal of this type was connected with the fraudulent Bank of Credit and Commerce International in 1980s.

bad loans more likely to occur, it can happen that the lenders or depositors decide not to provide any loans to any banks, even to the financially sound ones.[7]

More on the asymmetric information and subsequent behaviour of banks and depositors as a rationale for the regulation of the banking system can be also found in Dewatripont, et al. (1994) where this phenomenon is presented as the *representation hypothesis.*

2.2.1.2 Externalities and Systemic Risk

Perhaps even more importantly, the regulation should be targeted to protect the entire system since there is a danger of severe external costs resulting from failures of individual banks.

Externalities are economic benefits or costs that are not compensated or charged for and thus they are transferred to the rest of system. The unique functions of the banking business, together with its importance and network character, make it vulnerable to such costs and it can happen that a failure of one bank triggers a process that results in huge losses either to other financial institutions or to the whole economy. Although there are a diverse variety of channels that can spread and amplify the losses, we will describe only the main ones.

The first type of externalities stems from the ever-rising interconnectedness of the financial system. This issue is linked to payment systems, over-the-counter derivatives contracts and extensive global interbank contracts, which result in very complex financial networks. Even though the growing interconnectedness leads to better risk diversification and smoother credit allocation, it also increases the potential of situations when a failure of one institution results in an adverse shock to its creditors, who may potentially spread it further in the next rounds when they fail themselves.

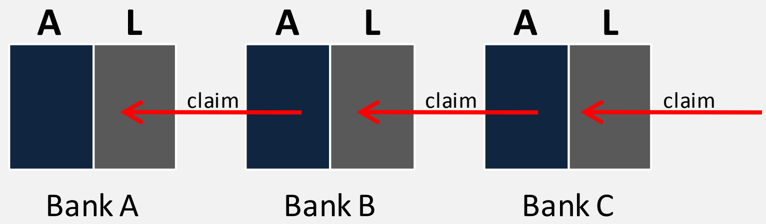
Such situation is described in Brunnermeier, et al. (2009b) with a basic, naive scheme of shock propagation which he calls a *"Domino"* effect. Here $Bank\ A$ has borrowed from $Bank\ B$ who has borrowed from $Bank\ C$. When $Bank\ A$ defaults, then $Bank\ B$ suffers a loss. If the loss is too large to be covered by the $Bank\ B$'s capital, the shock spreads further to $Bank\ C$.[8] Moreover, because of the financial innovation, the banks are able to hide significant portion of their contracts on the off-balance sheet and thus these risks are usually not known of until they materialise in a form of a systemic crisis.

---

[7] Classic case where the asymmetric information results in no trade is illustrated on the used car market in Akerlof (1970).

[8] More sophisticated methods of modelling of such shocks will be introduced in the last chapter of our thesis.

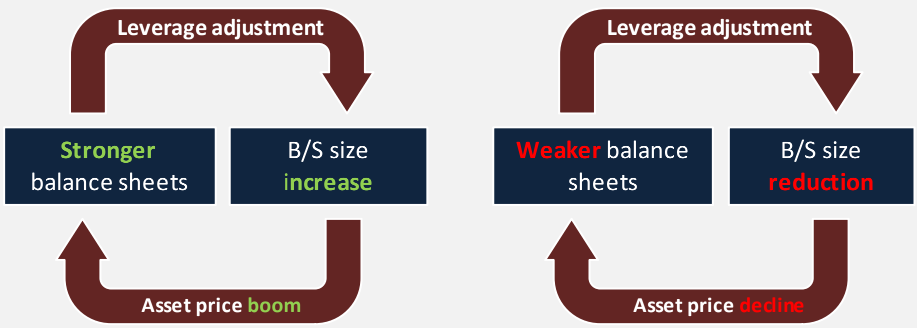
Figure 2: The "Domino" effect of financial contagion



Source: (Brunnermeier, et al., 2009b), *author*

Asset prices are another channel for the external costs to arise. Simulation studies show that externalities stemming from interconnectedness materialize only assuming very large shocks (Brunnermeier, et al., 2009b). However, if the asset prices are not fixed and banks are not passive in their distress behaviour, the situation further aggravates. Facing funding difficulties, in order to keep certain level of equity-to-loan ratio or because of sheer panic, banks begin to get rid of a portion of their assets. If, moreover, the balance sheet values are not fixed by the book prices of the assets and they are marked to market, there is a danger of asset price spirals.

Figure 3: The "asset price spiral" effect during the boom and bust periods



Source: (Brunnermeier, et al., 2009b), *author*

As we can see in the scheme above, due to marking to market, in times of economic boom, banks' balance sheets are expanding with the rising prices. Keeping the loan-to-equity ratio constant, the banks can purchase more assets, pushing their prices even higher. In an economic downturn, this mechanism gets reversed and the shrinking balance sheets with eroded equity force the banks to sell parts of their assets and use the funds to repay their obligations. As the price is declining, mainly with the whole financial sector acting in a synchronous manner, this leads to huge spill-over losses.

The systemic risk, represented mainly by the interconnectedness and spill-over externalities, does not pose danger only to banks and other financial institutions. Due to the vital importance of the financial system to the real economy, the costs are likely to spread to other businesses and individuals, and result in losses of economic output. This danger is also taken as a reason for state bail-outs which ultimately transfer the costs from the banks to the taxpayer.

2.2.2 Evolving Banking System Characteristics

From the end of World War II until the end of 1970s, the financial system was heavily regulated. This was caused partly by the regulatory responses to the Great Depression, and partly by the Bretton Woods system. There were e.g. Glass-Steagall Act in the US and several similar concepts in the rest of the world, which separated commercial banking and investment banking. Also, the cross-border capital flows were restricted by exchange controls, and banks were required to hold certain minimum reserves.

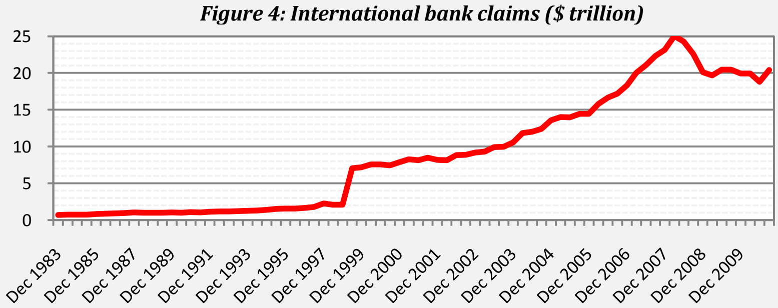
In addition, in order to ensure the stability of the banking system, the governments prescribed fixed interest rates for which the banks collected the deposits and provided loans and usually the spreads between these two rates were rather wide. For these reasons, the business model of the banks was said to be the 3-6-3 rule: The bankers collected deposits at 3% interest rate, lent them at 6% and were on the golf course by 3 in the afternoon (Schooner, et al., 2009). In other words, the banking business was relatively simple and safe.

However, with the collapse of the Bretton Woods system and the process of the European integration, the deregulation began and the restrictions were being removed. As we can see in the figure below, the character of the banking business was on its way to change.

Box 1: Trends in banking since the Bretton Woods collapse

Cross-border operations	Because of the deregulation of currency transfers, capital is allowed to flow freely across borders. The chart below illustrates the data of the Bank of International Settlements, which shows that consolidated international bank claims grew from $703 billion in 1983 to $20,409 billion in 2010.

Figure 4: International bank claims ($ trillion)



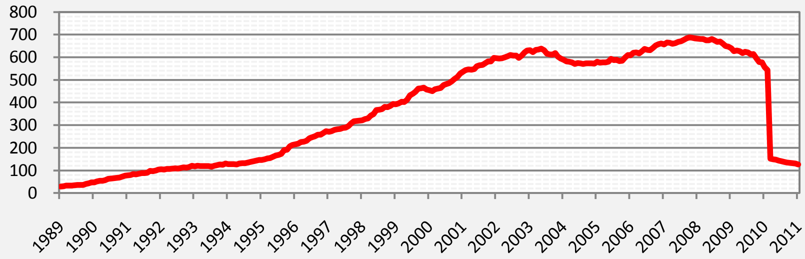
Consolidation	Along with globalization and competitive pressures resulting from the deregulation in 1980s, there came a period of banking consolidation. According to the 2001 Group of Ten report, there were large numbers of mergers and acquisitions in the banking sector, with the annual

number of deals increasing threefold during the 1990s, and this trend has continued onwards.[9]

Securitization

During the 1980s, the banks also started to transform the traditional banking products as loans or mortgages into marketable securities and the traditional model of banking business, where a bank grants a loan and holds it on its own balance sheet, changed into an originate-to-distribute model, where the banks produce loans only to repackage them and sell them on the secondary markets.

Figure 5: Pool of securitized consumer loans issued by US banks ($ trillion)



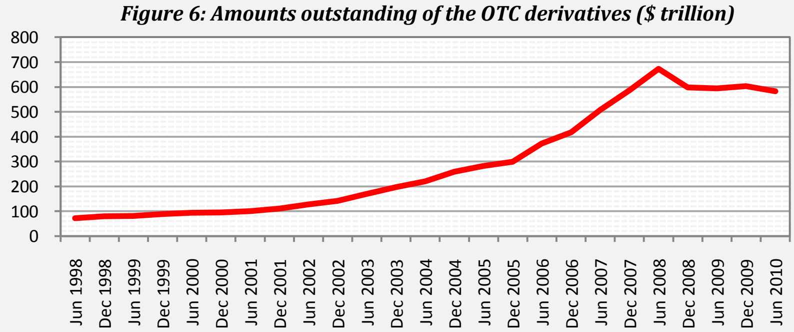
Note: the sharp decline in 2010 is caused by change in US accounting standards

The claims are then usually split into several classes, or tranches, according to the priority of repayment (seniority) and subsequent risk exposure. This allows for creation of multiple different investment instruments with different risk ratings, some of them having their credit quality increased above the value of the respective portion of collateral (Fabozzi, et al., 2008).[10]

Derivatives

New financial products appeared to satisfy the demand for managing increasing market and credit risks. Most of them are traded over-the-counter rather than on a centralized exchange. The chart below (BIS data) illustrates the steady growth of the OTC derivatives amount during the 2000s until the 2008 financial crisis.

Figure 6: Amounts outstanding of the OTC derivatives ($ trillion)



Source: (Group of Ten, 2001), (Schooner, et al., 2009), (BCBS, 2011a), (FED, 2011), *author's comments*

[9] For more recent data, see Davis (2007) or Mejstřík, et al. (2009).

[10] More information on the role of securitization in the recent financial crisis can be found in Teplý, et al. (2010a)

Such development has led to increased systemic risk. With the international capital flows and global financial products, the system became much more interconnected and complex. Banks' balance sheets grew with the new funding possibilities pushing their leverage to unsustainable values. Even though the small, more risky banks partly disappeared because of the competitive pressure, the remained ones pose much greater threat to the system should they fail. Finally, because of the opaque bilateral contracts, it became very hard for an outsider, even a regulator, to map the interlinkages in the financial sector. Even though many of these dangers came to the surface during the 2008 financial crisis, the banking system so far has remained very similar.

2.2.3 Case for International Regulation

Although until 1970s, the banks were subject to stringent regulation, it was exercised almost solely on the national level with each government setting its own rules. While this concept was possible during the Bretton Woods system, the increasing international operations of banks and the emergence of multinational banks with multiple subsidiaries across the world implied the need for worldwide coordination of the regulatory policies.

According to Dale (1994), there are three main reasons for the post-1970s banking system to be regulated internationally:

1. Because of the new international structures the banks can form, it is necessary to understand which authority should be responsible for regulation of which banks. Otherwise, a bank may manage to evade regulatory attempts of all countries of its operation.

2. Since the national banking sub-systems are closely linked together in the international interbank market, there is a risk that one country would be adversely affected by problems originating elsewhere.

3. The incentives to support domestic banks may lead to decreasing the regulatory burden in individual countries. This may put the other jurisdictions in danger and their banks in a competitive disadvantage, and it can even lead to a race to the bottom, when the competition of regulatory authorities would result in global under-regulation.

3 Basel Accords

3.1 Banking Regulation before the Crisis

In the first part of the second chapter, we will focus on the Basel Committee on Banking Supervision and its main prescriptions for the banking regulation before the 2008 crisis, namely the Basel I and Basel II accords. After a short description, we will examine the aspects of the first two Basel accords and their problems which surfaced in the recent financial crisis.

Figure 7: Timeline of the Basel accords

Source: author inspired by (Teplý, 2010c)

3.1.1 Basel Committee on Banking Supervision

After the Bretton Woods collapse, it did not take long time for the new types of international risks to manifest. On June 26, 1974, due to large losses on foreign exchange operations, German Bankhaus Herstatt was deprived of its banking license. Due to the time-zone difference between Germany and New York, when the Herstatt bank was closed by the German regulators, it was a middle of the trading day in New York. Since most of the Bankhaus Herstatt's counterparties were located in New York and these banks still had not settled the accounts with the German bank, they were exposed to losses accounting for a half-day trading. This regulatory failure caused panic and the prices for interbank credit and foreign exchange soared in the days to follow (BCBS, 2004a).

As a recognition of the new situation that arose in banking business and in response to the Bankhaus Herstatt failure, the central-bank governors of the Group of Ten countries established the Committee on Banking Regulations and Supervisory Practices, now known as the Basel Committee for Banking Supervision. Initially designed to "*close gaps in the supervisory net*",[11] it serves as a common forum for cooperation and coordination of its

[11] (BCBS, 2009; p. 1)

member countries regarding banking supervision, and is engaged in three main areas of action (BCBS, 2009):

1. Information exchange on national supervisory arrangements,
2. improvement of techniques for the international supervision,
3. setting minimum regulatory standards in areas when they are considered desirable.

According to the BIS Factsheet, there are 27 members of the Committee,[12] each represented by its central bank and also by the institution responsible for prudential banking regulation if this is not the central bank. The first meeting was scheduled in 1975 and since then the committee holds three or four meetings a year (BCBS, 2009).

The committee is not a formal international institution: it does not have permanent staff and the results of its activities do not automatically come into force as international laws. Nevertheless, it releases documents on recommendations, guidelines, and best practices for supervision of internationally active banks (Tarullo, 2008). These documents are then often transferred into the national laws and have become the regulatory standard for worldwide international banking.

The first document prepared by the committee was the 1975 Basel Concordat that establishes joint responsibility of home and host authorities for regulation of international banks. The committee also developed the Core Principles for Effective Banking Supervision,[13] which is a set of best practices providing a comprehensive description of standards that can be used for implementation or assessment of banking regulation in the individual countries. Nonetheless, the most important documents published by the Committee are the Basel Capital Accords, which will be discussed further in this text.

3.1.2 Bank Capital

As already mentioned, the bank capital serves as a cushion that absorbs the expected and unexpected losses and prevents them from being transferred to the rest of the system. Although under the assumption of perfect markets, it does not matter whether the banks are funded by equity or debt (Modigliani, et al., 1958); in reality it is profitable for them to hold much lower capital levels than would be socially desirable. The reasons are twofold:

[12] The list includes Argentina, Australia, Belgium, Brazil, Canada, China, France, Germany, Hong Kong SAR, India, Indonesia, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, Russia, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. (BCBS, 2011b)

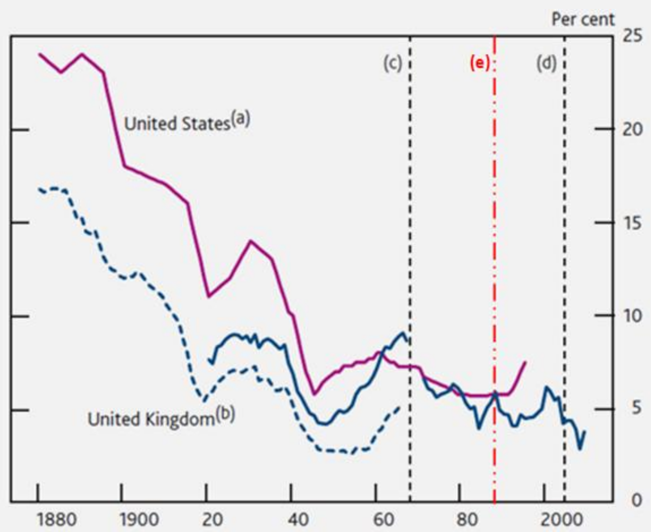
[13] (BCBS, 2006a)

1. Debt has significant tax advantages because the interest paid to the creditors is tax-deductible, while the dividends paid for the stakeholders are not (Sinkey, 2002). Even though higher levels of debt are linked with higher bankruptcy costs, which may balance the advantages of debt financing to some point, the banks' shareholders have limited liability and its managers even more so (John, et al., 1991). The capital structure optimization thus usually results in severe undercapitalization.

2. In most countries, there exists a certain form of deposit insurance, an institute of lender of last resort and high probability of bail-outs for banks that are too big to fail. Because of such safety nets, the risk perceived by the depositors and creditors is lower than would be in the case of no intervention. Since the confidence in a bank is positively affected by its net worth as well as by the government guarantees (Mejstřík, et al., 2009), the higher the guarantees, the less capital the banks need to hold for not losing the trust of their counterparties and the public.

When we look into the past, we see that on average, the capital ratios had been declining until the end of the Second World War and then, under heavy regulation and the Bretton Woods system, they started to rise again.

Figure 8: Declining capital ratios: a long-term view



(a) US data show equity as a percentage of assets.

(b) UK data on the capital ratio show equity and reserves over total assets on a time-varying sample of banks, representing the majority of the UK banking system, in terms of assets. Prior to 1970 published accounts understated the true level of banks' capital because they did not include hidden reserves. The solid line adjusts for this.

(c) Change in UK accounting standards.

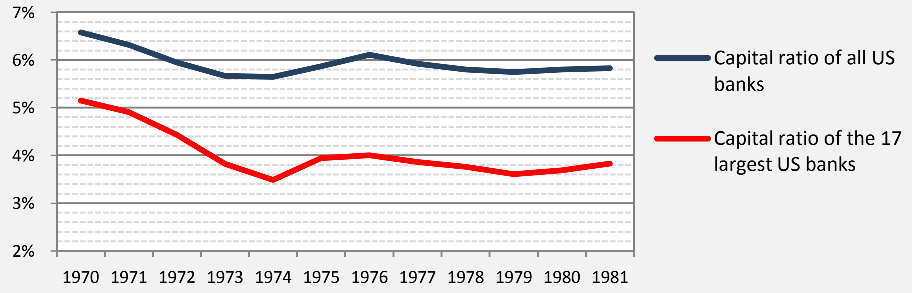
(d) International Financial Reporting Standards (IFRS) were adopted for the end-2005 accounts.

(e) Introduction of Basel I capital requirements.

Source: (BOE, 2009), *author*

Nevertheless, with mounting competitive pressures resulting from the 1970s and 1980s deregulation, the banks' margins started to decrease. Subsequently, the banks were trying to raise revenues by lending more while the level of capital on their balance sheets remained fixed or even declined (Tarullo, 2008). Therefore, the capital ratios of the main international banks were deteriorating and as we can see in the figure below, the largest, internationally active banks were leading the way.

Figure 9: Declining capital ratios: example for the US banks



Source: author, (Talley, 1983 in Tarullo, 2008)

3.1.3 Basel I

In response, around 1980s, the individual BCBS member countries started to introduce measures to keep a certain level of capital ratios of their domestic banks. Also, these usually were not simple leverage ratios, but their computation involved assigning weights to assets according to the risks they featured. In 1988, these efforts were put together in a form of a common framework for capital regulation, which was introduced by the Committee as the Basel I Accord which was to be implemented until the end of 1992.

3.1.3.1 Basel I Capital Requirements

The central concept of Basel I (BCBS, 1988) is the capital adequacy ratio, which all internationally active banks should have been required to maintain, and which can be summarized into a simple formula:

$$\left(CAD_{Total} = \frac{Tier\ 1\ Capital + Tier\ 2\ Capital}{RWA} \geq 8\%\right) \ \wedge \ \left(CAD_{Tier1} = \frac{Tier\ 1\ Capital}{RWA} \geq 4\%\right),$$

There, CAD_{Total} and CAD_{Tier1} stand for the capital adequacy ratios prescribed by the regulation, $Tier$ 1 and $Tier$ 2 are two different types of capital and RWA stands for the sum of risk-weighted assets. It holds that

$$RWA = \sum_{i=1}^{n} w_i A_i,$$

where w_i stands for the weight of i-th asset A_i in the total portfolio of n assets. The weights are assigned according to the credit risk of the borrower by fixed rules. For example, government bonds or cash have zero weight. On the other hand, claims on the private sector are weighted by 100%.

As to the capital classification, Tier 1 consists mostly of equity and disclosed reserves and it is used as the main measure by the regulators, while Tier 2 describes less reliable items such as undisclosed reserves, loan-loss provisions or subordinated term debt. A closer definition of the two categories of capital and also a list of types of assets and their respective risk weights can be found in the original document (BCBS, 1988).

3.1.3.2 Basel I Shortcomings

From the outset, this relatively simple rule was criticised for several deficiencies, e.g.:

1. The capital ratio is too simplistic and it is not an outcome of too much scientific analysis but rather of a political discourse. Also, the risk weights are set by intuition in the best case; or even according to the pressure of politically powerful groups in the worst case (Benston, 1998 in Schooner, et al., 2009).

2. The risk weighting categories are too broad, which incentivizes the banks to perform regulatory arbitrage, i.e. replacing the assets that have relatively overvalued risk weights with the ones that are in the same category but are relatively more risky (Schooner, et al., 2009). Because of this risk-shift, the level of capital in the banking system was again beginning to decline.

3. Basel I also did not address other types of risk. Although historically, credit risk is the main type of risk in banking, mostly with the fluctuating interest rates and the banks' involvement in market activities, it was necessary to regulate the area of market risk as well. This was partly addressed in 1996, when the Basel I was amended with measures for market risk measurement and regulation. For market risk calculation, the banks should have used models using value-at-risk (VaR), which is the maximum expected loss on a portfolio at a specified confidence level over a given holding period (Mejstřík, et al., 2009).

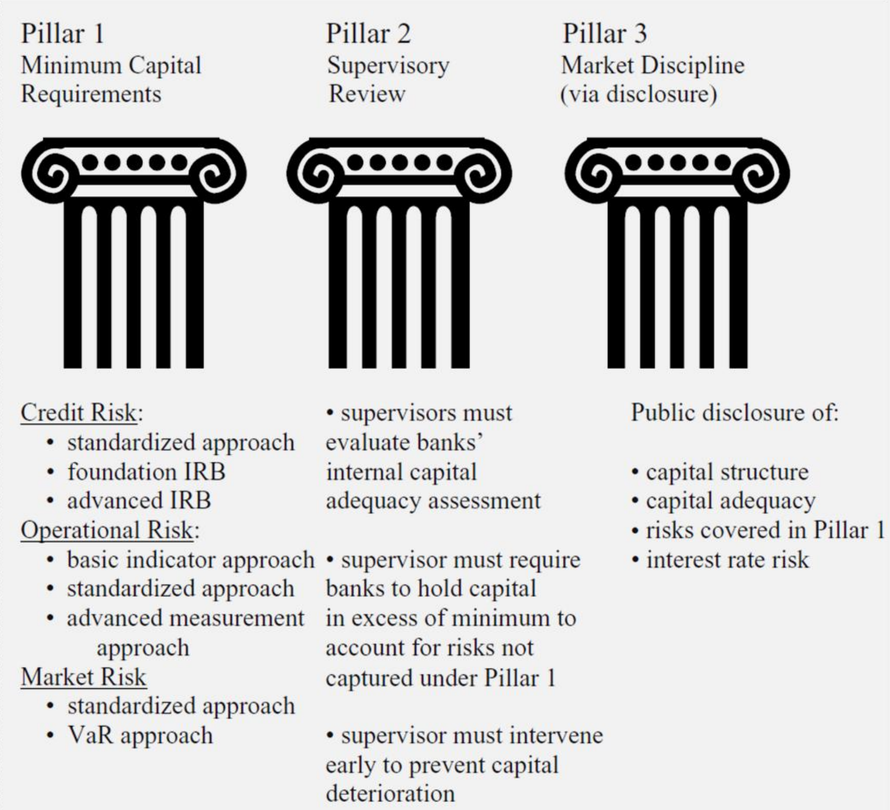
Moreover, in the late 1990s, the banks themselves commenced their lobby for change. The bankers were complaining about the differences between the assigned risk weights and the actual risks and arguing that the risk management techniques had improved significantly since the introduction of Basel I.

3.1.4 Basel II Measures

The revision process of the Basel Accord started in 1999 and lasted five years. Finally, in 2004 it resulted in the new Basel II (BCBS, 2004b), which was to be implemented by 2007. In contrast to Basel I which is about 25 pages long, the new document accounts for full 239 pages and thus its detailed description is out of scope of this thesis. We will illustrate only the basic facts, full description can be found either in the Accord itself (BCBS, 2004b) or in Schooner, et al. (2009) or Tarullo (2008).

Basel II is based on three "pillars" as we can see in the fig. 10:

Figure 10: Three pillars of Basel II



Source: (Schooner, et al., 2009), *author*

3.1.4.1 First Pillar of Basel II

The first pillar, which contains the capital requirements, is the most similar one to Basel I. The Tier 1 and Tier 2 capital definitions remain the same, as well as the minimum ratios of 4% and 8%. What changes significantly is the definition of risk weighted assets, i.e. the denominator of the ratio, which now involves credit risk, market risk and newly also operational risk measures.

$$CAD_{Total} = \frac{Tier\ 1\ Capital + Tier\ 2\ Capital}{Credit\ risk + Market\ risk + Operational\ risk} \geq 8\%\ ,$$

As has been mentioned, the market risk measures have been amended to Basel I in 1996 and do not change in Basel II. The credit risk measures, on the other hand, were modified significantly to allow for better risk sensitivity and the operational risk measure is a completely new concept.

As to the credit risk regulation, instead of five broad categories of assets which were assigned fixed risk weights under Basel I, the new accord allows for two basic options (BCBS, 2001).

1. "standardized approach" assigns the risk weights according to the external ratings provided by rating agencies

2. "internal rating based" (IRB) approach allows for usage of internal credit assessment models, subject to strict supervision of methodological and disclosure standards. This approach further allows for two options according to the extent of the banks' participation on determining the value of risk-weighted assets:

    a. the "foundation" IRB approach, where the banks determine the probabilities of default and the other inputs are provided by the regulator,

    b. the "advanced" IRB approach, where the risk calculation is solely the banks' responsibility and the regulator only validates the calculation process.

Regarding the measures for operational risk, the banks can again choose among more options, varying from the most standardized Basic Indicator Approach where the capital requirement is calculated as a 15% fixed percentage of gross income, to Advanced Measurement Approach, where the capital charge is calculated by the bank itself. However, as with the credit risk measures, the methods used for calculation need to meet certain standards and are reviewed by the regulator (Mejstřík, et al., 2009).

3.1.4.2 Second Pillar of Basel II

The extended involvement of banks' internal processes demanded the regulators to change the approach to banks supervision. Instead of simply prescribing the rules and checking the capital levels, it is necessary to examine how well the banks assess risks. The second pillar defines the process of dialogue between the banks and the regulators and comprises of four main principles[14]:

1. Banks should have a process for assessing their capital adequacy in relation to their risk profile.

2. Supervisors should review and evaluate banks' internal capital adequacy assessments and strategies, as well as their ability to monitor and ensure their compliance.

3. Supervisors should be able to intervene if they are not satisfied with the result of this process, they should expect banks to operate above the minimum regulatory capital ratios and they should have the ability to require banks to hold capital in excess of the minimum.

4. Supervisors should seek to intervene at an early stage to prevent capital from falling below the minimum levels.

[14] (BCBS, 2004b; pp. 159-165)

3.1.4.3 Third Pillar of Basel II

Providing enough information is necessary to ensure that the market participants can better understand the risk profiles of individual banks and adequacy of their capital positions. Therefore, the third pillar aims to strengthen the market discipline through enhanced disclosure by banks which is required in several areas, mostly comprising the banks' methods for risk assessment and capital adequacy calculation (BCBS, 2001).

Although the core set of requirements in the second and third pillars apply to all banks, it is clear that the rules ought to be more demanding for the banks using the internal approaches for risk assessment.

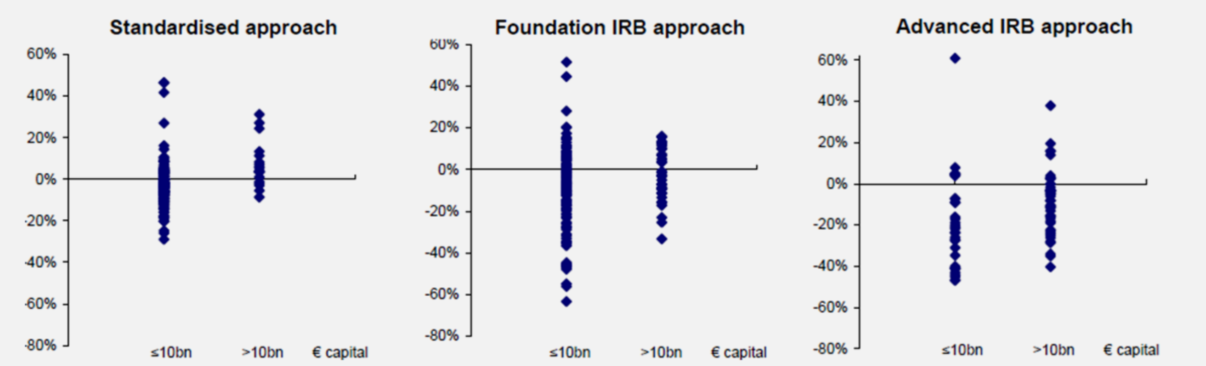
3.1.5 The Failure of Basel II

Despite its complexity, Basel II did not succeed in fulfilling its main proclaimed goal: ensuring stability of the banking system. On the contrary, in some aspects it can be even thought of as one of the reasons of the financial crisis of 2008. On the following lines, we will introduce the main aspects in which Basel II was, and still is, criticised.

3.1.5.1 IRB Approach as a Risky Benefit for the Large Banks

Firstly, the existence of several possible approaches to calculation of capital requirements means that there is no common ground on which the capital requirements may be compared among banks. While the standardised approach does not differ too much from Basel I, the IRB approach involves processes that are more complex and more difficult to control by the regulators, and that provide more space for the large banks to shape their capital requirements according to their needs.

Figure 11: QIS-5 results for Basel II



Note: The figure depicts the change in the required capital after the new accord is implemented. In each chart, the banks are divided into two groups according to their size (size of their capital). Note that the IRB approaches result in relative undercapitalization.

Source: (BCBS, 2006b), *author*

Nevertheless, even without choosing the models that are explicitly bad, for some institutions, Basel II meant looser regulation. According to QIS-5 (BCBS, 2006b)[15], for the large banks using the advanced IRB approach, the capital requirements would fall on average by more than 26%, while the smaller ones using the standardized approach would experience an increase of 1.7%.

Second, the eligibility criteria for using the IRB models are designed so that only a small number of the largest banks were able to meet them. Since the IRB approach enables banks to lower their capital requirements, it puts the smaller banks into competitive disadvantage, deforms the market and further increases the market share of the large banks (Lall, 2010). Because the large banks are the ones who hold comparatively lower capital ratio levels, the circle closes and leaves the system vulnerable and severely undercapitalized.

3.1.5.2 Naive Risk Assessment Models

The events of 2008 showed that the models used for the assessment of credit and market risk are flawed in their very assumptions. Firstly, the calculation of risks relies to a large extent on historical data. However, given the pace of financial innovation and introduction of new products, the data samples were often too small and the historical information on these products' performance was a poor indicator of the losses to come. Secondly, most of the models for market and credit risk calculation assume that the losses on individual assets are independent events. However, during the recent financial downturn, assets among which no correlations were anticipated became correlated, which resulted in much larger losses than expected by the models (Lall, 2010). As the Chief executive of Goldman Sachs put it after the crisis, *"[i]n the past several months, we have heard the phrase "multiple standard deviation events" more than a few times. If events that were calculated to occur once in 20 years in fact occurred more regularly, it does not take a mathematician to figure out that risk management assumptions did not reflect the distribution of the actual outcomes. Our industry must do more to enhance and improve the scenario analysis and stress testing"* (Blankfein, 2008).

Partly, these problems might have been anticipated. Particularly the utilization of VaR models, which has been a part of the Basel accords since the introduction of market risk measures into Basel I, could have been well tested on the data from e.g. the Asian Crisis of 1997 or the Brazilian Crisis of 1994-98. The fact that was left unchanged in Basel II is rather an outcome of interest groups pressure, as we can see further in table 7.

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[15] The abbreviation stands for "Quantitative Impact Study". These documents are prepared by the Basel Committee usually for assessment of the impact of newly proposed measures on the banks' capital adequacy.

3.1.5.3 *Procyclicality*

Basel II is also often criticized for its procyclicality, i.e. reducing capital requirements during boom times and raising them during a downturn. In recession, as the perceived quality of the held assets is declining, the need for regulatory capital increases. This holds for credit risk as well as market risk.

1. Rising probabilities of default calculated by the internal models and declining ratings used by the standardised approach result in decline in the banks' credit willingness. As the banks begin to deleverage, the liquidity in the system suddenly falls and the sources of funding that were previously taken for granted drain out, which further worsens the economic conditions. Moreover, this mechanism may be amplified by liquidity spirals as modelled in Brunnermeier, et al. (2009a).

2. When the banks reach the limit of minimum capital requirements, they face two possibilities: seek additional sources of funding or sell certain part of their portfolio, usually the more risky one. In adverse financial conditions when the funding possibilities are scarce, the banks choose the latter option, which results in asset fire sales. Not only does this push the asset prices down but it also leads to destabilization of financial markets, as modelled in Hermsen (2010).

3.1.5.4 *Low Capital Requirements Related to Certain Assets*

One of the priorities of Basel II was to stop the regulatory arbitrage that the banks performed via moving their assets to off-balance sheets by securitization. For this reason, the Committee proposed to assign the capital requirements linked to individual securitization tranches according to external ratings. However, after an intense lobby, in the final version of the accord, for the banks using the IRB approach, the most of the requirements were dramatically reduced as can be seen in the table below.

Table 1: Proposed and final risk weights for individual tranches of asset-backed securities

Originally proposed in 1999

External rating	*Risk weight*
AAA to AA-	20%
A+ to A-	50%
BBB+ to BBB-	100%
BB+ to BB-	150%
B+ or below	deducted from capital

Finally appeared in Basel II in 2004

External rating	*Risk weight*
AAA	7%
A+	12%
BBB+	35%
BB+	250%
below BB-	deducted from capital

Note: The risk weights were lowered for the IRB banks only. Banks using the standardized approach had to follow the risk weights as originally proposed. The ratings are according to Standard & Poor's methodology.

Source: author according to (BCBS, 1999), (BCBS, 2004b)

Because of these tiny risk weights, after 2004, the banks began to use the off-balance sheet instruments in large quantities to lower the required capital. Asset-backed securities rose from 7% of US GDP in March 2004 to an 18% in June 2007, which was a larger increase in the three years after the publication of Basel II than in the entire previous twenty years. When the related risks began to materialize in 2007/2008, it became clear that this measure had created incentives for the banks to securitize the exposures and distribute them into the market rather than keeping them on their balance sheets, where the related risks would be much easier to observe and control (Lall, 2009).

Similar fate met the trading book regulation. Initially, Basel Committee planned for an additional capital charge to cover the various risks associated with credit derivatives. However, the industry pressure again resulted in severe undercapitalization of this area (Lall, 2010).

3.2 After the Crisis and Beyond

In this part, we will introduce the new capital framework known as Basel III. After the description of its contents, we will analyze the institutional background of the Basel processes, and what impact it has on Basel III. Finally, we assess the outcomes of the new measure and provide certain alternative approaches.

3.2.1 Basel III Measures

As mentioned above, the deficiencies of Basel II surfaced during the financial turmoil which was triggered by the American sub-prime mortgage market, and which led to several bank bankruptcies and billions of dollars of world-wide state aid to the banks. The Global Financial Crisis shook the foundations of the regulatory system when it showed that the prudential requirements, which were supposed to protect the financial system against a catastrophic meltdown, spectacularly failed (Schooner, et al., 2009).

In response, after several adjustments of the Basel II framework concerning securitization and the trading book and after several Consultative documents[16] on the new capital accord, on December 16, 2010, the Basel Committee published the final version of Basel III. Comprising two key documents, (BCBS, 2010a), which states the capital requirements and (BCBS, 2010b), which describes the new measures regarding the banks' liquidity, the accord aims to *"improve the banking sector's ability to absorb shocks arising from financial and economic stress, whatever the source, thus reducing the risk of spillover from the financial sector to the real economy"* (BCBS, 2010a).

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[16] The consultative documents are proposals published by the BCBS in order to receive comments from the local authorities, banks and other companies in the industry. These comments are then taken into account in preparation of the final accord.

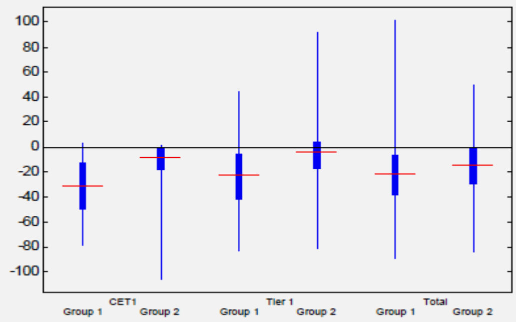
Basel III brings new measures in several key areas, which will be examined more closely below. These are:

1. capital quality,
2. capital quantity,
3. restriction of leverage,
4. liquidity requirements.

3.2.1.1 Capital Quality

The new regulatory framework introduces changes in the structure of the required capital base in order to improve its quality, consistency and transparency (BCBS, 2010a). As an answer to the crisis which demonstrated that the most important capital reserves are the retained earnings and common shares, the banks will have to deduct goodwill, general intangibles and some investments in other financial institutions from common equity. This will increase the amount of common equity they will be required to hold. In addition, there is a requirement for deduction of deferred tax assets from the capital base, which is a convenient measure since the banks in crisis with no or extremely low incomes do not have to pay the income tax and thus they have nothing to subtract the DTAs from.

Figure 12: Changes in capital levels according to QIS



Note: On y-axis, there is a percentage change in the capital levels after full introduction of Basel III.
Group 1 banks are those that have Tier 1 capital in excess of €3 billion, are well diversified, and are internationally active.
All other banks are considered Group 2 banks.

Source: (BCBS, 2010c), *author*

According to the recent Basel III Quantitative Impact Study, these changes in capital definition will affect all types of capital across all banks, but the impact on internationally active banks from Group 1 will be much stronger. The main drivers of the capital levels decline are deductions of goodwill and deferred tax assets (BCBS, 2010c).

3.2.1.2 Capital Quantity

As to the basic capital requirements as we know them from the previous accords, the Tier 1 capital ratios have also been increased. Common Equity Tier 1 capital requirement was raised from 2% to 4.5% and Tier 1 capital requirement from 4% to 6% of risk-weighted assets, while the total capital requirement stayed at 8%.

In addition to the adjustment of these standard requirements, there are two buffers further increasing the banks' need to raise capital, and also there is a proposal of additional requirement for systematically important financial institutions (SIFIs).

- The banks will need to hold a Capital Conservation buffer of 2.5% of risk-weighted assets, which is a "softer" requirement that does not have to be met at all times. However, when the banks do not hold this capital reserve, their ability to spend their retained earnings by paying off bonuses to the management and dividends will be limited until the banks return to full compliance.
- The countercyclical buffer goes even further and addresses the criticism of pro-cyclicality of Basel II by building up an additional capital reserve in times when the risks of system-wide stress are growing. In periods of excess credit growth, the national authorities can introduce a capital requirement which will vary between zero and 2.5% of risk-weighted assets. This reserve may then be used in the periods of stress (BCBS, 2010a).
- The requirements for SIFIs are an attempt to internalize the externality of a possible failure of large, systematically important banks by enhancing their loss-absorbing capacity beyond Basel III requirements. Although the form of this new regulation is yet to be introduced, it is expected that this measure will entail further capital charges (Hannoun, 2010).

Table 2: Individual capital requirements of Basel III

Measure	*Core Tier 1*	*Total Tier 1*	*Total Capital*	*Notes*
Basic capital requirements	4.5% (2%)	6% (4%)	8% (8%)	*Core Tier 1 represents the highest form of loss absorbing capital (share capital and retained earnings).*
Capital Conservation buffer	2.5% (0%)			*Must comprise common equity, bringing total common equity requirement to 7%.*
Countercyclical capital buffer	0%-2.5% (0%)			*Determined by national supervisors depending on local circumstances.*
Additional requirement for SIFIs	To be determined by the BCBS (0%)			*Still under consideration at the global level. Expected to be set in the region of an additional minimum possibly 5% for global SIFIs and 2-3% for domestic SIFIs, as a combination of common equity and contingent capital.*

Note: The ratios required under Basel II are in the brackets

Source: (KPMG, 2010b), *author*

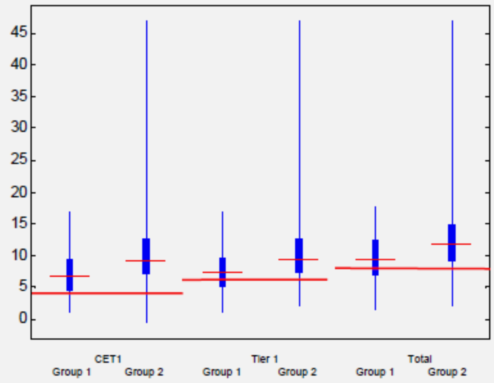
The new accord also addresses the issues of low risk weights, especially for securitizations and OTC derivatives, i.a.:

- The models will be required to use stressed inputs, i.e. calculate the capital requirements according to historical data of a 12-month period of stress situation. This period (i.e. 2008 would be a good example) must be approved by the regulator.

- The capital requirements for the risks connected to securitization will be increased, with certain lower-rated securitization exposures obtaining an overwhelming 1250% risk weight. Also, higher collateral haircuts will be introduced (BCBS, 2010a).
- Basel III also introduces measures for mitigating counterparty credit risk, i.a. higher charges for bilateral OTC exposures and zero charge for the derivatives traded through the central counterparty.

When we add up all those requirements, we arrive at a significant amount of capital that will be needed compared to Basel II. A question arises: What will be the cost of the new regulation? The answers differ across the industry; some stress the negative impact on economic recovery and economic growth due to higher credit costs, others are expressing concern whether the new rules are stringent enough. We will examine the differing views in the next chapter.

Figure 13: Capital ratios according to QIS



Note: Group 1 banks are those that have Tier 1 capital in excess of €3 billion, are well diversified, and are internationally active. All other banks are considered Group 2 banks.

Source: (BCBS, 2010c), *author*

The figure above depicts banks' compliance with the Basel III basic capital requirements according to QIS. As we can see in the table below, after introducing the new capital definition and asset risk-weighting, all the basic current capital ratios decline. When we add the Capital conservation buffer, a median Group 1 bank will find itself under the minimum required level of CET1.

Table 3: Comparison of basic Basel II and Basel III capital ratios according to QIS

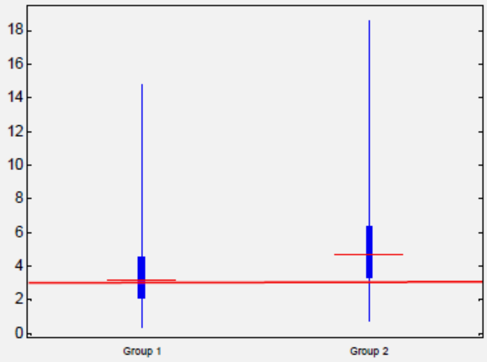
	CET1		**Tier 1**		**Total**	
	Basel II	***Basel III***	***Basel II***	***Basel III***	***Basel II***	***Basel III***
Group 1	11.1	5.7	10.5	6.3	14.0	8.4
Group 2	10.7	7.8	9.8	8.1	12.8	10.3

Source: (BCBS, 2010c), *author*

3.2.1.3 Leverage Ratio

Another issue revealed by the past two years is that for some assets, in recession, the risk weights can become irrelevant. That is why there is a new requirement for a simple non-risk-based leverage ratio of 3%, calculated as Tier 1 capital over the bank's total assets, off-balance sheet exposures and derivatives (Hannoun, 2010). Such simple rule ensures that even when the risk weights on individual assets fail, the impact is not as disastrous.

Figure 14: Leverage ratio according to QIS



Source: (BCBS, 2010c), *author*

According to QIS, approximately 42% of the Group 1 banks and 20% of the Group 2 banks in the sample would have been constrained by this measure as of December 31, 2009, assuming the new definition of Tier 1 capital. On average, the large banks' ratio in 2009 was 2.8% with some of them even deeper below (BCBS, 2010c).

3.2.1.4 Liquidity Measures

As a response to the recent crisis, Basel III adds into its portfolio of regulatory measures also liquidity requirements. The banks will have to maintain certain amount of assets that can be quickly transformed into cash to cover sudden cash outflows when there is a need for source of financing quicker and cheaper than can be found in the inter-bank market.

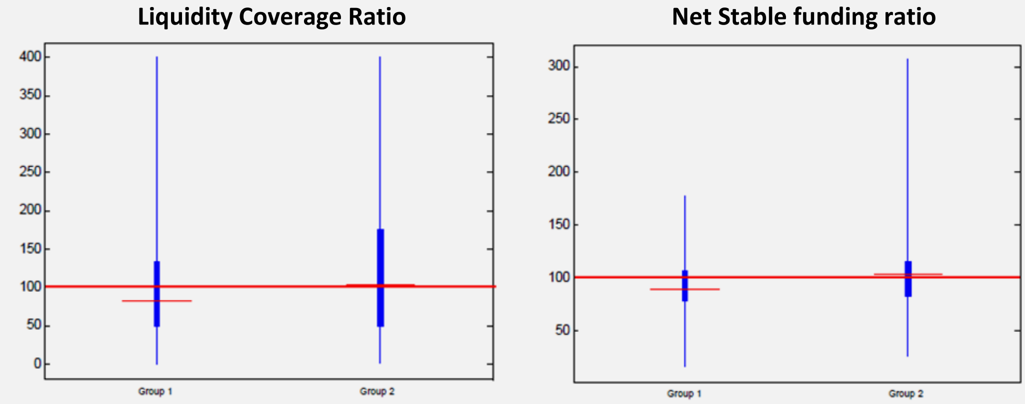
Table 4: Liquidity requirements under Basel III

Measure	Formula	Notes
Liquidity Coverage Ratio	$LCR = \frac{High\ quality\ assets}{30\ day\ net\ cash\ outflows} \geq 100\%$	***"High-quality liquid assets"*** *are those assets that can be easily and immediately converted into cash at little or no loss of value.*
Net Stable funding ratio	$NSFR = \frac{Available\ stable\ funding}{Required\ stable\ funding} \geq 100\%$	***"Stable funding"*** *is defined as the portion of those types and amounts of equity and liability financing expected to be reliable over a one-year time horizon under conditions of extended stress.* *The amount of such funding* ***"required"*** *is a function of the liquidity characteristics of various types of assets held, on or off the balance sheet.*

Source: author according to (BCBS, 2010b)

Basel III regulates the liquidity risk by two measures, the Liquidity Coverage Ratio and the Net Stable funding ratio. While the first one is a requirement to keep cash reserves that could finance at least the first 30 days of a liquidity crisis, the second one requires having stable refinancing options available for the assets that cannot be turned quickly into cash.

Figure 15: LCR and NSF ratios according to QIS



Source: (BCBS, 2010c), *author*

When we look at the QIS, we see that in 2009, the large banks' ratios for both the liquidity measures were on average under the required 100%.

Particularly the Net Stable Funding ratio is highly controversial and has often been the target of the industry's complaints. From the regulatory point of view, this measure tackles the banks' overreliance on wholesale markets, which can turn into a serious problem in the periods of liquidity stress. The banks, on the other hand, believe that the little gain in systemic safety cannot outweigh the cost of changes to their business models (Elliott, 2010). That is why there is a rather long period of observation (the rules will be fully implemented in 2018) and the parameters can be subject to further calibration.

3.2.1.5 Basel III Implementation

Table 5: Implementation dates of individual Basel III measures

Group	Measure	Implementation begins	Implementation ends
Capital quality	*Capital deductions*	2013	2022
Capital quantity	*Core Tier 1 ratios*	2013	2015
	Market risk and securitization	2012	2012
	Counterparty credit risk	2013	2013
	Conservation buffer	2016	2019
Leverage	*Leverage ratio**	2013	2018
Liquidity	*Liquidity coverage ratio**	2013	2015
	*Net stable funding ratio**	2014	2018

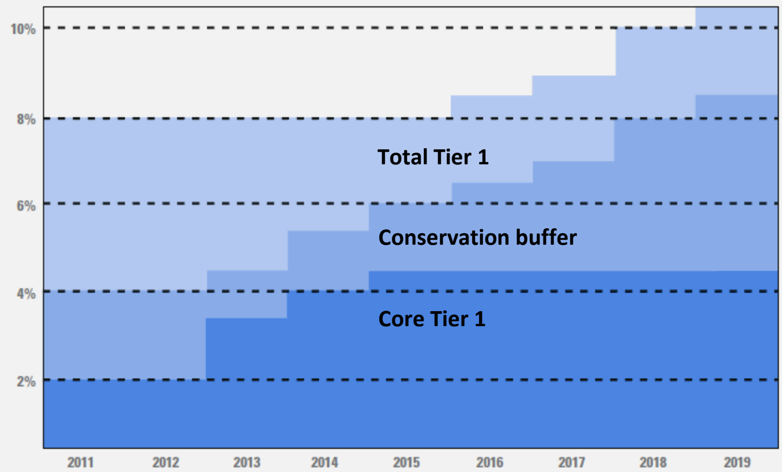
** The measures with asterisk are subject to observation period and may be recalibrated. Top priority measures are coloured in blue.*

Source: author according to (McKinsey&Company, 2010), (BCBS, 2010a)

None of the aforementioned measures will come into force immediately - the Basel III requirements will be phased in over a period at least until 2019. There is an implementation plan for the individual parts of Basel III to be put into force by the national regulators and also there will be observation periods dedicated to potential recalibration of certain parameters.

As we can see in table 5, the implementation schedule is rather loose. Although the risks related to securitization will be reassessed with higher risk weights already in 2012, most of the measures will be introduced no sooner than January 2013. The capital ratio timeline shows that the adjustments for CET1 ratio will be in full force in 2015, whereas the one for Tier 1 capital will not reach its target level even until 2019.

Figure 16: Implementation timeline of individual capital ratios



Source: (KPMG, 2010a), *author*

Moreover, since the Basel Accords are only sets of standards and principles, it is not certain whether Basel III will be transposed into national law of all the individual Basel Committee member states within the planned deadline and some countries may even choose not to implement it at all. On the other hand, the Declarations of G20 summits indicate that the proposed regulation still has its full support[17] and also the EU will implement Basel III in its new Capital Requirements Directive (Clifford Chance, 2010).

3.2.2 Institutional Background and Implications for Basel III

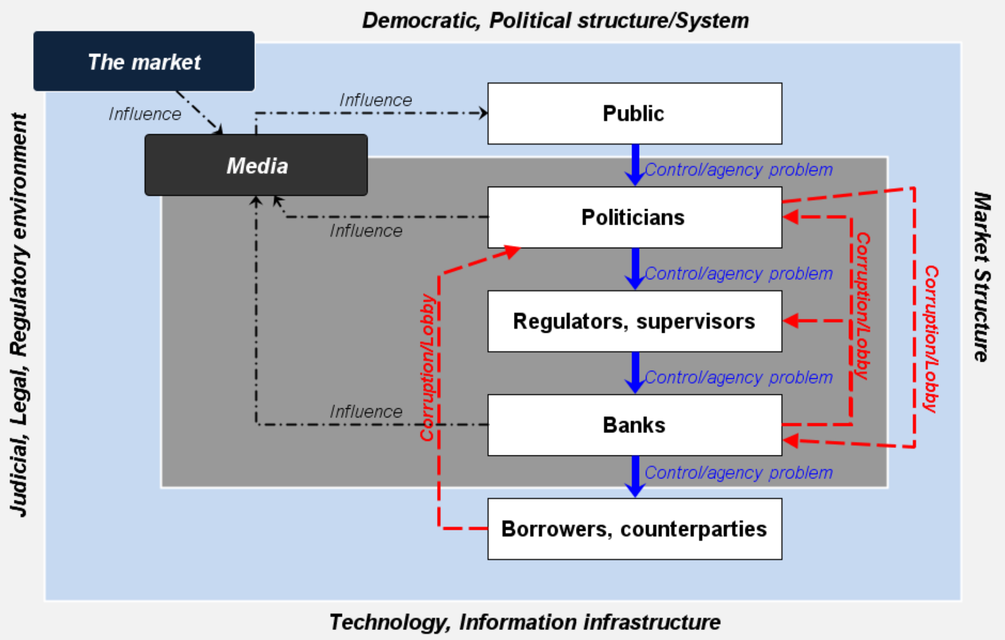
Not only may the regulation fail in its outcomes as we have seen in the case of Basel II; it may even be the underlying incentives and processes that are flawed. On the following lines, we first provide insight into the negotiations and lobby behind the creation of the first two Basel accords and we describe the process behind Basel III.

[17] See the declarations of G20 Summits in Seoul (G20, 2010a; p. 8) or Toronto (G20, 2010b; pp. 4, 15-17).

3.2.2.1 *Role of Lobby in the International Banking Regulation Framework*

We have indicated several times before that the international regulation is rather a political issue than a technical one. According to Barth, et al. (2005), in a broader context, it is performed in an environment of political, legal, cultural and technological forces, and it involves a sequence of agency problems and interest group pressures. Although this scheme is rather simplified, the crucial point is that it is not possible to study banking regulation without considering the motivation of those who set and implement the policies.

Figure 17: Banking regulation framework



Source: author inspired by (Barth, et al., 2005)

The figure above depicts several interest groups connected together in a chain of agency relationships. At the heart of the problem, there are three subjects, each with very different objectives:

- The banks seek to maximize profits while managing risks, notably the credit risk arising from the selection of borrowers, and control whether they behave responsibly. The banks are also trying to shape the regulatory environment by lobby, corruption, and also by influencing the public opinion via the channel of media.
- Regulators' main objective is to create standards, rules and enforcement measures that ensure that the banks behave in a way that does not threaten the stability of the system and lead to external costs. However, their decisions are being influenced not only by the incomplete information the banks provide but also with personal connections, offers of jobs and other benefits (Barth, et al., 2005). Moreover, although

the regulators are not politically accountable, they may try to expand their power by increasing complexity and extent of the regulation.[18]

- In order for the politicians to meet their objective of getting re-elected, they need to respond to potential public demand for regulation via controlling and influencing the work of the regulators and supervisors. Clearly, politicians not always pursue the public interest. They are also often dependent on donations and financing by the banks so they have to listen to their needs. Moreover, the politicians can be influenced by the borrowers who lobby for favourable regulatory policies. Whom the politicians listen to the most depends largely on the current stage of the political cycle.

Because of the strong lobby by the banks, the processes behind the Basel accords creation and implementation are sometimes regarded as regulatory capture whereby the large banks with enough influence seize the procedure and turn it into their advantage. The best description of such situation can be found in Lall, (2009), Lall (2010) or Tarullo (2008) and the following analysis draws mainly on these works.

The examples of the regulatory capture begin right with Basel I. In 1983, the US Congress imposed capital requirements on US banks in order to prevent future needs for expensive state aid. The American banks complained that it would put them into competitive disadvantage, mostly compared to Japanese banks, whose market share grew rapidly and who were not required to hold such high capital levels. In response to fierce lobby, American regulators put lots of effort into international negotiations which resulted in a common framework for capital regulation and which increased US banks' competitiveness.

Also, we have already mentioned that the negotiations on Basel II commenced mainly because of the large international banks' complaints about the relevance of the specified risk categories of assets. The changes in regulation originally seemed well-intended, with set of strong objectives, as we can see in table 6.

However, after the six years of preparations and pressure of the interest groups, the initial objectives could be found only partly in the final version of Basel II. Instead, the Basel Committee came out with even looser regulation of the internationally active banks, which proved deadly in 2008. In the light of the recent situation, it is almost comical to read in the

[18] The incentive for the regulators to increase their control via increasing the extent of the regulation and disregarding the costs it brings to the economy has a parallel in the "Hubris motive" used for the explanation of corporate takeovers. According to the Hubris hypothesis, the managers of the bidding firms are acting against their shareholders' interests by paying too much for their targets. (Roll, 1986)

final version of Basel II that *"the Committee has benefited greatly from its frequent interactions with industry participants and looks forward to enhanced opportunities for dialogue."*[19]

Table 6: Shift in the proclaimed objectives of Basel II

Original consultative document[20]	*Final version of Basel II*[21]
"continue to promote safety and soundness in the financial system and, as such, also at least maintain the current overall level of capital in the system"	*"develop a framework that would further strengthen the soundness and stability of the international banking system while maintaining sufficient consistency that capital adequacy regulation will not be a significant source of competitive inequality* ***among internationally active banks****"*
"continue to enhance competitive equality"	
"constitute a more comprehensive approach to addressing risks"	*"maintain the aggregate level of [capital] requirements, while also providing incentives to adopt the more advanced risk-sensitive approaches of the revised Framework"*
"focus on internationally active banks, although its underlying principles should be suitable for application to banks of varying levels of complexity and sophistication"	*"arrive at significantly more risk-sensitive capital requirements that are conceptually sound and at the same time pay due regard to particular features of the present supervisory and accounting systems in individual member countries"*

Source: author according to (BCBS, 1999), (BCBS, 2004b)

Table 7 briefly summarises the particular successes of lobby during negotiations on Basel II.

Table 7: The effect of lobby on Basel II

Area of interest	*Initial aim*	*Lobby*	*Recommendation*	*Final proposal*
Internal ratings	Incorporate external credit ratings into new framework	IIF	Recognize internal credit risk models of "sophisticated" banks	Recognition of internal ratings for A-IRB banks
Trading book / derivatives	Introduce charge for derivatives risk ("w factor")	ISDA	Drop "w factor"; do not apply credit risk capital requirements to trading book	"W factor" abolished in 2001; minimal regulation of the trading book
Market risk	Standardized methodology based on fixed risk parameters	IIF	Substitute standardized methodology for market risk (VaR) models	Recognition of VaR models in 1996
Securitization	Link risk weight categories to external credit ratings	ESF, ASF	Lower risk weights for rated tranches; greater use of internal ratings	Reduced weights for rated tranches; internal ratings for unrated tranches, liquidity facilities

IIF: *Institute of International Finance – consultative group of major US and EU banks representing the financial industry's interests*
ISDA: *International Swaps and Derivatives Association – the largest global financial trade association, representing over 860 institutions in the privately negotiated derivatives industry*
ESF: *European Securitization Forum,* ***ASF:*** *American Securitization Forum*

Source: (Lall, 2010), *author*

3.2.2.2 *The Case of Basel III*

The process that led to Basel III can again be explained on the basis of fig. 17. In contrast to Basel II, the recent change in regulation was not inhibited by the banks. The major hallmark of the economic crisis was the failure of Lehman Brothers in September 2008, when the losses

[19] (BCBS, 2004b; p. 4)
[20] (BCBS, 1999; p. 5)
[21] (BCBS, 2004b; pp. 2-4)

of the financial system finally spread into the real economy.[22] First, it was the public anger and pressure for change of the banking regulation which induced the politicians, in our analysis represented by the G-20, to call for capital adequacy reform. At the summit in Pittsburgh a year after Lehman collapse, the G-20 introduced its requirements for banking regulation including the leverage ratio, countercyclical measures, liquidity standards and systemic charge for banks which are too-connected-to-fail (G20, 2009).

With due complaints of the banking industry, the Basel Committee started negotiations on the new regulatory framework known as Basel III. However, in the second phase of the process, the pressure of the disorganized public ceased as the economic situation in advanced economies improved. From this point, the process has been again gradually taken over by the well-organized international banks. As we know from fig. 17, these institutions have two options for shaping the regulatory environment: direct influence through personal connections, lobby and corruption, and indirect influence through the media.

- There are evident personal connections between the two opposing sides, with IIF members getting jobs at the Basel Committee and otherwise. Lall (2010) provides an overview of opinion shifts of the ex-Basel Committee members who joined the IIF. The banking industry even managed to recruit Jacques de Larosière, author of the Larosière report, which was one of the first to point at the necessity of a regulatory reform. Because of these links, the banking industry managed to get closer to the Basel Committee and organize confidential discussions with its members.
- The banks were also directly influencing the public by predicting severe costs the new regulation would bring, and they had been doing so even before the Basel Committee came out with specific figures in its proposals. Again, Lall (2010) provides examples of the industry's estimates of the new measures' impact on loan prices or GDP growth. These forecasts which the bankers were threatening the public with *"were based on pure guesswork"*[23] and they were becoming increasingly extreme as the consultation period was approaching its closing date.

To these two tactics we must also add the constant pressure for implementation delays, which resulted in the aforementioned situation of extended timescales for the new accord's full operation. Moreover, the phase-in period is long enough for the banks to succeed in watering down the measures that are yet to be calibrated or even devised, such as the systemic surcharge, liquidity ratios and the leverage ratio.

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[22] According to the IMF World Economic Outlook Database, the GDP growth in the US practically stopped in 2008 and fell to -2.6% in 2009. In the Euro area in 2008 it fell to 0.5% in 2008 and -4.1 in 2009 (IMF, 2011)

[23] (Lall, 2010; p. 30)

3.2.3 Outcomes of Basel III

Although the core documents of the new accord have already been published in December 2010, there is still a lot to do: the measures need to be calibrated and implemented in the individual countries, and the regulators need to prepare themselves for monitoring the banks' compliance with the new ratios.

The banks, on the other hand, ought to start planning their capital and liquidity needs and changes in their internal processes. It is clear that the new accord will incur some additional costs to the banks, be it for raising more capital or for the implementation of the new risk-management and reporting procedures, and these costs are even likely to transfer to the economy in the form of higher interest rates or transaction fees.

One such example will presumably be the trade finance, products of transaction banking such as letter of credit, which are of vital importance for promoting economic activity.[24] In contrast to other off-balance sheet products, these usually entail relatively low levels of risk - according to ICC (2010), the empirical data show that there are only 1,140 defaults in the full sample of 5,223,357 trade finance transactions provided by observed nine international banks over a period from 2005 to 2009, which accounts for only 0.02% rate of default. However, mainly because of the leverage ratio which will not take into account the risk profiles of individual assets, the banks will be required to hold capital against the whole value of their trade finance asset portfolio. According to Standard Chartered in Beck (2010), Basel III will bring a $270 billion cut in international trade flows, which would increase the price by 40% and result in 0.5% decrease of global GDP.

On the other hand, from several aspects, Basel III is a step in the right direction and the benefits are likely to outweigh the costs. The increase in capital requirements, tighter capital definition and the new liquidity charges will ensure that the financial system is again at least a little bit safer. A question remains whether that is enough.

3.2.4 Alternative solutions

Many experts call for even tighter regulation,[25] some for an entirely different concept. We agree with Dewatripont, et al. (2010), that the capital requirements need to be simplified. It does not matter how sophisticated the capital ratios are, they can never capture all aspects of risk the major financial institutions are facing. Moreover, the current setting of various buffers is rather opaque and difficult to monitor by the regulators and also by the investors

[24] In contrast to e.g. investment banking, transaction banking is one of the areas where the Czech banks can feel the pressure of the new regulation as well.

[25] See e.g. the letter sent to FT on November 9, 2010, where 20 leading banking experts suggest capital ratios of at least 15% (Admati, et al., 2010).

and the public. Instead, simple and easily verifiable indicators are needed that quickly point to problematic banks and allow for a quick discretionary reaction. Only in this setting the regulation will not be designed only to *"fight the previous crisis"*.[26]

We suppose that as to the capital requirements, much more attention should be given to the leverage ratio, which is the ultimate measure of how a bank is able to cover its own losses. The leverage ratio also tackles the Basel II problem with procyclicality, since it automatically requires more capital if the credit pool is expanding.[27] A simple leverage requirement will be further modelled in the next part of our thesis.

[26] (Dewatripont, et al., 2010; p. 8)

[27] However, since this measure alone would incentivize the banks to seek more risky assets with higher yield, there ought to be also a measure that uses some simplified version of risk-weighted approach, presumably the simple capital ratio of Basel I (Pakravan, 2010).

4 Modelling of the Banking System

4.1 Modelling Framework

In order to be able to better understand how the individual measures affect the behaviour of the banking system, in the rest of our thesis, we will focus on simulation of different regulatory environments. However, before constructing the model itself, we will briefly introduce the basic modelling framework. Firstly, we begin with the two basic methodological approaches and second, we provide examples of applications of these in different models of banking systems.

4.1.1 Used methodology

For our model, we chose a framework building on two main approaches, both of them connected to complex systems modelling and computational economics – these are network theory and agent-based modelling, Since we use them as tools, the description we provide is rather illustrative than exhaustive. Interested reader is encouraged to follow the links to further sources, which provide the information on the subject in much more detail.

4.1.1.1 Network modelling

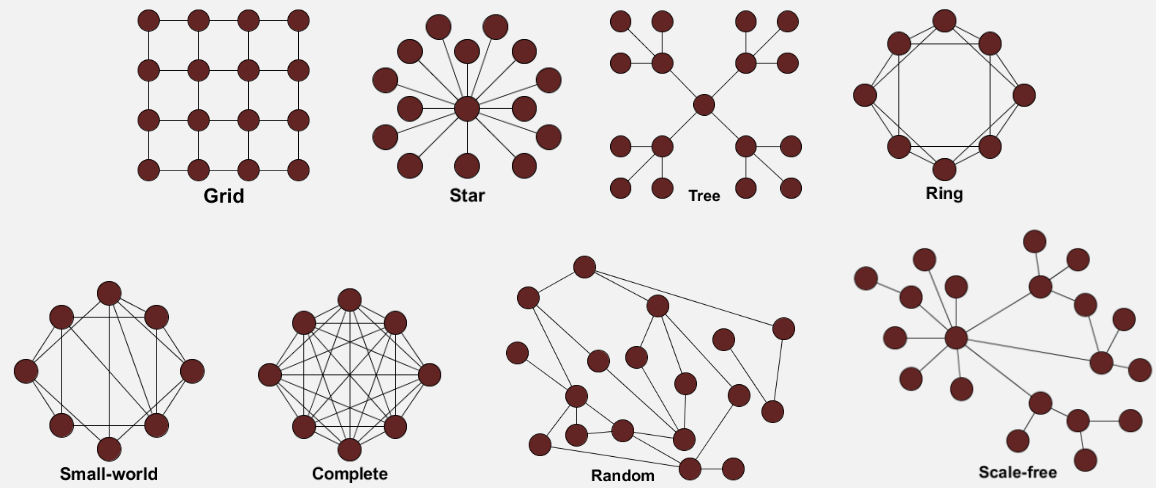
The network theory can be used in any situation when one needs to describe interconnected structures, whether these are terrorist organizations, the Internet or financial systems. Generally, a network is a collection of nodes interconnected with edges. Mathematically, it is a graph defined as $G = (N, E, f)$, where N is a set of nodes (or vertices), E is a set of edges (or links) and $f: E \rightarrow N \times N$ is the function that maps the edges onto individual pairs of nodes (Lewis, 2009).

Nodes may represent individual agents, depending on the field we use the network approach in, i.a. servers and websites when we study computer networks or people in case of social networks. In the framework of finance, they may represent banks, traders, depositors, companies or whatever else entity which constitutes a part of a financial system.

Generally, edges can bear more information than just whether two nodes are linked or not. They can be oriented, which means that they are linking an ordered pair of nodes and hence there are two possible directions in which two nodes can be joined. The edges may also have different weights which represent the strength of the connections. In financial systems modelling, such properties allow us to describe the creditor/debtor relationships as well as the amounts owed by particular banks.

Finally, different mapping functions result in different network topologies, as we can see in the picture below. Comprehensive description of these types of networks and links to the original research can be found i.a. in Wilhite (2006) or Lewis (2009).

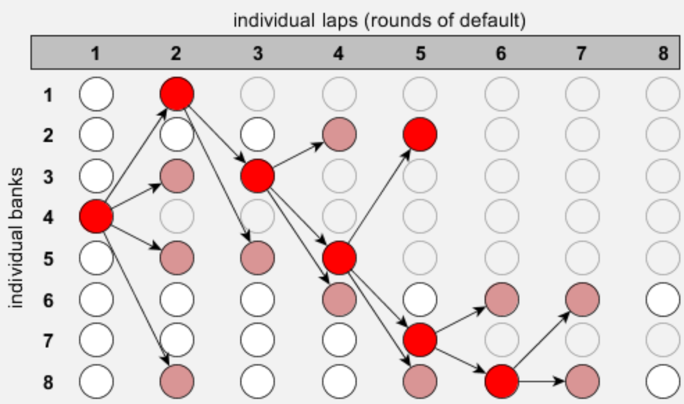
Figure 18: Examples of network topologies



Source: author inspired by (Wilhite, 2006)

A set of problems that have been extensively studied on different network structures is the transmission of shocks. One example is the spread of contagious diseases through a network of people from a small set of infected ones as modelled in epidemiology research.[28] Clearly, this approach may be used directly for banking systems modelling as well. As introduced in the second chapter, when one bank fails, the losses are transmitted to its creditors. In the next lap, some of these fail as well and they spread the losses even further. In the figure below, the failed banks are represented by the bright red.

Figure 19: Knock-on "Domino" effects in a banking system



Source: author inspired by (Sell, 2001)

[28] See e.g. Meyers (2007).

4.1.1.2 *Agent-Based Modelling*

Generally, agent based modelling is a bottom-up approach in which multiple agents, each with its own instructions, interact in a virtual environment. According to Tesfatsion (2006a), *"[an agent] refers broadly to bundled data and behavioural methods representing an entity constituting part of a computationally constructed world."* [29] The actions of the individual agents then result in certain aggregate behaviour of the entire system which is subject to the modeller's examination.

For example, in his famous paper, Schelling (1969) observed that very simple instructions for an agent's preference of neighbourhood may lead to total segregation on a macro level. Also, there are the heterogeneous agent models of financial markets, which are able to replicate the stylized facts of the real-world financial markets, see e.g. Lux, et al. (2000). A very comprehensive guide to agent-based economics may be found in Tesfatsion, et al. (2006b), and lately, this approach is gaining even more recognition as may be illustrated by The Economist (2010) and Farmer, et al. (2009).

Modelling of banking systems fits well into this framework. The agents may represent individual banks or other institutions along with their balance sheets and simple instructions such as when to sell assets or go bankrupt. The behaviour of the whole banking system may then be observed, be it in periods of stress or prosperity. Moreover, these models can also be integrated into the network infrastructure, providing a useful tool for financial systems research.

4.1.2 Examples of Applications for Modelling Banking Systems

The research on financial stability and the systemic risk inherent in the interconnectedness of financial institutions became a hot topic after the recent financial crisis. An overview of the network character of the crisis can be found in Sheng (2010), risk assessment framework for systemic linkages is provided in IMF (2009) and the recent advances in modelling systemic risk using network analysis are provided in ECB (2010).

However, studies on banking systems resilience that use network theory and agent-based modelling had been appearing even earlier before and already they form a solid body of knowledge. A detailed literature survey of research focused on the intertwined financial structures is provided in Allen, et al. (2009). The research using the aforementioned approaches can be basically divided into two categories, the empirical studies and theoretical models.

[29] (Tesfatsion, 2006a; p. 835)

4.1.2.1 Empirical research

There have been several studies focused on modelling of the real-world interbank exposures and the banking systems' disposition to crises caused by contagion effects. An extensive survey and comparison of individual approaches along with closer examination of their assumptions pointing to possible sources of bias can be found in Upper (2011).

These models usually describe local banking systems. For example, an empirical analysis of the network structure of the Austrian interbank market is provided in Boss, et al. (2004); Upper, et al. (2004) found out that the interbank lending in Germany takes form of a two-tier structure; Wells (2004) examines the UK banking system and concludes that usually one banks' default should not be sufficient to trigger next rounds of failures but still the losses suffered by the neighbour banks may be rather substantial. Among other studies, see also e.g. Van Lelyveld, et al. (2006) for the model of the Dutch interbank market and Muller (2006) for Switzerland.

However, a frequent problem of the empirical approach is that the data on the individual interbank exposures is unavailable to the researches and even the regulators, who must often rely only on the aggregate balance sheet figures. For this reason, the majority of the empirical studies use the maximum entropy assumption, which supposes that the banks spread their lending as evenly as possible given a certain sum of their interbank assets Upper (2011). Clearly, this assumption is rather unrealistic and it often underestimates the potential for contagion Mistrulli (2011).

4.1.2.2 Theoretical models

The first purely theoretical model of network externalities in a banking system was Allen, et al. (2000), who studied contagion through interbank exposures and found that the system vulnerability depends on its structure, where the more complete structures with more interbank links are more resilient to initial shocks. However, this study is undertaken only for unrealistically small systems of four banks. Another early research is provided by Freixas, et al. (2000), who show that the contagion occurs also in systems where some banks occupy "key positions", i.e. are systemically important. The simple framework of contagion through network exposures is extended in Cifuentes, et al. (2005) and Shin (2008), who add a mechanism for price decrease of illiquid assets as a second channel of contagion.

Finally, there are models using simulations on random networks, which examine how the different parameters affect the resilience of the banking system. Gai, et al. (2010) find out that the financial networks exhibit a *"robust-yet-fragile"* tendency, which means that the interbank exposures serve as good shock absorber but when a crisis occurs, they cause its larger extent. Our model is inspired by the approach used by Nier, et al. (2007), who make an agent-based model of an interbank system and find non-linear dependencies of its resilience on certain parameters when performing comparative statics exercises.

4.2 The Model

In the previous two chapters, we focused on the main concepts of banking regulation, its development and its implications for systemic risk. To approach the subject more rigorously, in this part, we will construct a model of a banking system and examine its behaviour under several stress scenarios, given various settings of structural properties and regulatory environment.

First, we provide a high-level overview and detailed description of the model construction. Second, we provide simulation results along with the basic implications and finally, we explore areas for improvement and extension.

4.2.1 Basic Description

The basic infrastructure of our model builds on Nier, et al. (2007), because due to its agent-based nature, it can be modified to account for more complex behavioural rules, such as the regulatory measures. This would not be possible in the case of models that consider the banks to be just passive objects with certain characteristics, such as in Gai, et al. (2010).

We create a system that comprises certain number of banks interconnected with exposures and claims they hold against each other. In line with the network approach, our interbank system is characterized by a graph where the banks are represented by nodes and their exposures by oriented edges. Such interbank system may represent an interbank market, a network of OTC derivatives or payment systems.

In order to be able to study the relationship of the system behaviour and its characteristics, and because the exact data on interbank exposures are mostly unavailable, we do not use any specific real-world banking network. Instead, we perform our simulations on a generic random network as described by Erdös, et al. (1959), which implies that we assume identical and independent probability of interbank exposures across all ordered pairs of banks. However, if in the future the data were available, the model is applicable to any interbank network - only instead of the parameters that are used to build the random graph, we would input directly the dataset that represents the specific network.

Subsequently, the interbank network is examined under a simulated stress scenario, when one or several banks receive a negative shock to the asset side of their balance sheet. The shock is then transmitted to the rest of the banks through the two main mechanisms described in the second chapter: *"Domino"* effects, which describe the transfer of losses through the edges of the network, and *"asset price spiral"* effects, which represent the asset price decline in the periods of stress under low liquidity of the system.

As the model represents a short-term period of collapse of the financial system, we assume that the banks are not capable of borrowing any extra funds and that no edge can be added to the interbank network. In our study, we also abstract from the possibility of state aid in the form of bank bail-outs.

In contrast to Nier, et al. (2007), our model captures not only the impact of the structural properties on the resilience of the system but also adds rules that represent several types of banking regulation contained in Basel III, namely a simplified liquidity measure, a situation where the regulator deprives a bank of its license because of a low capital ratio and a situation where a bank is constrained by a softer measure which does not prevent it from operation but which triggers fire sales of a part of its assets. To our knowledge, we are the first to study the effects of regulation in an agent-based interbank network model.

Table 8: Input parameters of the model

Parameter	*Interpretation*	*Base value*
N	Number of banks in the system	25
p	Probability of connecting two banks with a directed exposure	0.2
E	Total sum of external assets in the system	100 000
θ	Interbank asset ratio (interbank/total assets)	0.2
γ	Capital ratio (net worth/internal + external assets)	0.05
α	Degree of the market's illiquidity	0
$CAD2$	Capital ratio limit that triggers fire sales	0
$CAD1$	Capital ratio limit that triggers bank's removal by the regulator	0
$fsalesTarget$	Capital ratio at which the bank aims by selling assets	CAD2
φ	Liquid assets ratio	0
$shock_{random}$	Shock on a random bank (in percentage of external assets)	1
$shock_{others}$	Shock on all other banks (in percentage of external assets)	0.1
$iterations$	Number of iterations under one set of parameters	500

Note: The blue cells highlight the parameters used by (Nier, et al., 2007)*, the grey cells are parameters original to this model. For the iteration count, we use a higher base value.*

Source: author

Our analysis is based on comparative statics experiments where the simulations are performed under varying combinations of input parameters. These parameters are summarized in the table above along with their base values used by (Nier, et al., 2007) which we use for our simulations unless stated otherwise.

4.2.2 Model Construction

On the level of an individual simulation, the model is built as follows: first, the interbank network is initialized along with the individual banks' balance sheets. Second, we shock the system by wiping out a portion of certain banks' assets and several rounds of defaults and loss transmission unfold. The model runs in several laps (rounds of defaults) until the shock dissipates in the banking system and is not propagated further. Detailed description of rules for the banks' behaviour is provided on the following lines.

4.2.2.1 Interbank Network Creation

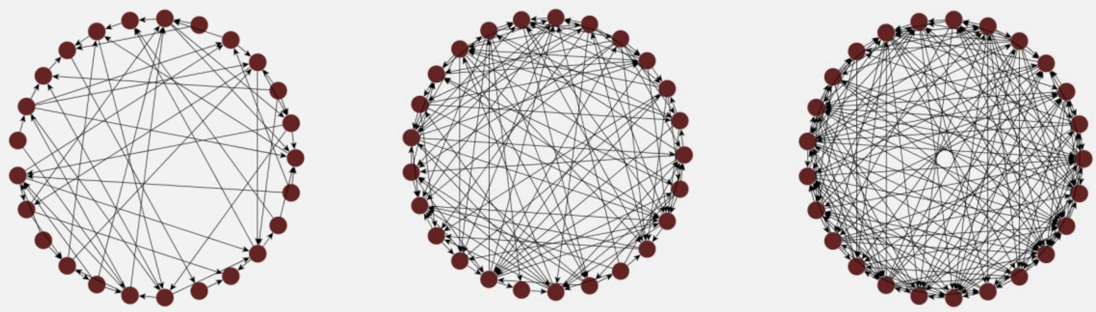
The interbank network is based on two main parameters, which are set in the beginning of a simulation run and which define the form of the random graph:

1. Node count N, which determines the number of banks in the network,

2. probability p_{ij}, with which there exists an oriented edge between node i and node j in the graph, i.e. the probability that the bank i is exposed to the bank j. We expect this number to be fixed among all (oriented) edges between nodes (i,j) and for the sake of simplicity, we denote it as p. There can be two links between two edges each in different direction. In this case, the exposures in our model are not netted but accounted for in full value.

Subsequently, the network is created in two steps: First, there are N banks added to the system, and second, for each oriented pair of banks, an edge is created with probability p. Depicted below are several illustrations of the system's structure under different values of p:

Figure 20: Random networks with different connectivity (N=25)



$p = 0.1$ $p = 0.2$ $p = 0.3$

Source: author

4.2.2.2 Initialization of the Balance Sheets

So far, we have created the system at the aggregate level but the banks are still just empty nodes. Next, we have to initialize the individual banks' balance sheets for the given network realization. Clearly, this must be done in such manner that the variables conform to the aggregate level identities as well as the bank level identities. The particular steps are described by the algorithm below.

First, we need to calculate the global variables of the system. On the aggregate level, the total value of assets is a sum of interbank assets (constituted by all the loans represented by the edges of the interbank network) and external assets (constituted by individual banks' exposures outside the network, e.g. securities and loans to other entities such as households, sovereigns or non-financial institutions).

1. The sum of external assets in the system (denoted by E) and the ratio of interbank assets to total assets (denoted by θ) are given as input parameters. The total value of assets in the system (denoted by A) is calculated as

$$A = \frac{E}{(1-\theta)}.$$

2. The total sum of interbank assets is then determined as a portion of total assets.

$$I = \theta A$$

3. If we denote the sum of outgoing edges from all the banks in the system as Z, the value of one individual edge is calculated as

$$w = \frac{I}{Z}. \tag{1}$$

Subsequently, individual banks' balance sheets are initialized according to the following sequence of rules:

4. An individual bank's interbank assets (i_i) and liabilities (b_i) are calculated according to the interbank network structure:

$$i_i = w \cdot number\ of\ incoming\ edges_i,$$
$$b_i = w \cdot number\ of\ outgoing\ edges_i.$$

5. The value of an individual bank's external assets is a little more difficult to determine. We use the same two-step algorithm as (Nier, et al., 2007):

    a. First, each bank's difference between the internal liabilities and internal assets is balanced by a certain amount of external assets $\tilde{e}_i$.[30]

    $$\tilde{e}_i = b_i - i_i.$$

    If this difference is negative, we assign zero external assets to the current bank in this step,

    b. The rest of the total sum of external assets is then distributed uniformly among the banks. Finally, it holds that

[30] According to Nier, et al. (2007), it can become difficult to meet this constraint if the internal asset ratio is too high. Since the edge distribution in the network is stochastic, some banks may be assigned much more outgoing than incoming edges and thus the sum of external assets in the system may not cover the gap between the interbank liabilities and interbank assets. To avoid such situation, we assume the interbank assets ratio not to exceed 0.7.

$$e_i = \tilde{e}_i + \left[\frac{E - \sum_{i=1}^{N} \tilde{e}_i}{N}\right].$$

6. Each bank's net worth is calculated as a portion of total assets according to the following capital ratio:

$$n\_w_i = \gamma a_i.$$

7. External liabilities are calculated so that the balance sheet identity holds:

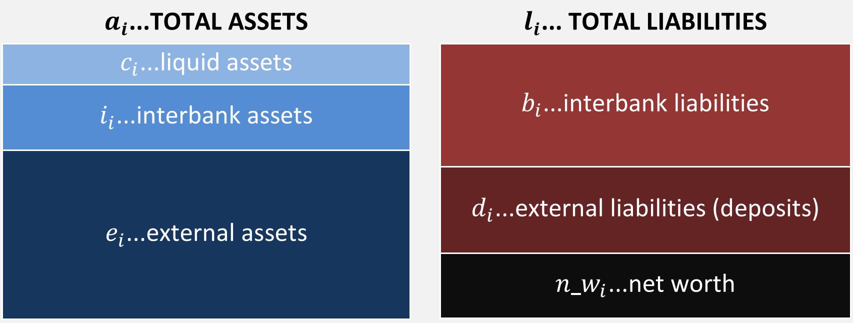
$$d_i = a_i - n\_w_i - b_i.$$

8. In contrast to the work by (Nier, et al., 2007), in the current model, the banks may be required to hold certain amount of liquid assets which can be quickly transformed into cash and which will not depreciate with the decreasing liquidity of the system. The value of these assets for each bank is calculated by a simple rule according to the liquid assets ratio, where a part of the external assets is transformed into liquid assets:

$$c_i = \varphi e_i^{old} \wedge e_i^{new} = (1 - \varphi) e_i^{old}. \quad (2)$$

Now, as the balance sheets are populated, the whole system is initialized and ready for the simulation.

Figure 21: Balance sheet of an individual bank in the model



Source: author

4.2.2.3 *Shock*

After the initialization, the system is in inertia until we induce an adverse shock, which initiates the first lap of the simulation. There are two types of shocks we can examine:

- A situation where a certain portion (most often 100%) of external assets and liquid assets is wiped out from the balance sheet of a random bank - we call this a *"local shock"*.
- A situation where the external assets and liquid assets drop in value. This means that the percentage loss is applied to all banks – we call this a *"global shock"*.

Moreover, it is possible to combine these two types of shocks and e.g. have a situation when one bank is hit heavily with all the external and liquid assets being wiped out and the rest of the system suffers a slight asset price decrease.

4.2.2.4 Shock Impact on a Bank's Balance Sheet

The initial shock may result in knock-on *"Domino"* effects, where in each lap of the simulation, the set of banks that suffered losses transmit the shock further. Let us now consider one representative bank that accepts a shock. Whatever the shock type, it is reflected in the balance sheet and possibly propagated into the rest of the system. The rules for the bank's shock acceptance are described below.

As a result of the shock, the bank loses certain part of its assets. Since the sum of assets must equal the sum of liabilities, the bank has to write off an equal value of liabilities. Let us suppose that the bank suffered a shock of size Δ and hence it holds that

$$l_i - a_i = \Delta_i.$$

The external behaviour of the bank then depends on the size of the shock:

a) In the first place, the shock hits the bank's net worth. If $n\_w_i > \Delta_i$, which means that the bank is able to cover the losses from its own funds, then the whole shock is absorbed by the bank's capital and it is not propagated further into the system.

b) If $n\_w_i < \Delta$, the residual shock further spreads to the interbank liabilities b_i, which means that it is uniformly transferred onto the creditor banks up to the value of the interbank liabilities. Hence, if there are m creditor banks, in the next round each creditor bank receives a shock of

$$min\left(\frac{\Delta_i - n\_w_i}{m}, \frac{b_i}{m}\right).$$

Clearly, since the propagating bank is not able to honour its debt, it defaults and it is removed from the system. The creditor banks evaluate the received shock in the next lap of the simulation. The simulation ends with a lap when no bank propagates the shock further. Additionally, it holds that:

i. If $b_i > \Delta_i - n\_w_i$, which means that the sum of the representative bank's net worth and its interbank assets is able to cover the losses, there is no residual shock to be transferred to the depositors.

ii. If $b_i < \Delta_i - n\_w_i$, the shock remainder is written off of the external liabilities which means that the residual loss is covered by the depositors.

4.2.2.5 Liquidity Risk Modelling and Asset Price Decreasing Mechanism

Not only are the losses transmitted directly through the network. The model also takes into account the liquidity effects that may arise in a stress situation. Along with Gai, et al. (2010), we assume that when a bank defaults and is to be removed from the system, all its assets have to be liquidated. While the liquid and interbank assets can be sold for their full value, the capacity of the market to absorb the illiquid external assets may be limited and thus it may not be possible to sell the assets for their original price. The additional loss caused by the asset sales is then added to the initial shock and transmitted accordingly.

Hence, following Cifuentes, et al. (2005), we introduce an inverse demand function for the illiquid external assets, which takes the form of

$$P(x) = exp(-\alpha x), \quad (3)$$

where x is the value of the total assets the banks need to sell in the current lap as a portion of total external assets originally initialized in the system, α represents the market's illiquidity (i.e. the speed at which the asset price declines) and $P(x)$ is the new discounted price of external assets calculated in each lap. Furthermore according to marking-to-market accounting procedure, at the end of each lap, the external assets of each bank are revalued according to $P(x)$.

Note that for the demand function, it holds that $P(0) = 1$ and $P(x) \in (0,1)$ for $x > 0$, which means that if no assets are sold in the current lap, the price stays at the assets' full value while if there are some fire sales in the current lap, the total asset price is discounted by a coefficient smaller than one.

4.2.2.6 Effects of Capital Regulation

Capital regulation is modelled by two rules. The first one measures whether a bank meets the strict capital adequacy ratio and in case of non-compliance it deprives the bank of its license. The second one represents a softer measure such as Capital Conservation Buffer of Basel III, which does not have to be met at all times but unless it is, the banks cannot pay out bonuses and dividends. If a bank fails to meet this requirement, it has to sell certain portion of its assets in order to return to the required ratio.

1. If $\frac{nw_i}{a_i - c_i} < CAD1$, where $CAD1$ is the strict capital adequacy requirement, the bank is removed from the system similarly as if it defaulted :

   a) In order to repay its debt, the bank sells all its assets. The amount of cash it obtains for the external assets depends on the liquidity of the system and hence it can be lower than their initial value. The decrease in price is modelled via the Asset Price Decreasing Mechanism.

b) Subsequently, the bank settles its debts from the funds it obtains by the asset sale. Since the depositors have the priority, firstly, this pool of funds is used for the repayment of external liabilities. Second, the creditor banks are compensated by the repayment of interbank liabilities. If the bank is not able to repay its interbank liabilities, it uniformly transfers the loss onto the creditor banks. Finally, in the case that there are any funds left after settling all the bank's debt, they disappear from the system.

c) To be able to finally remove the bank from the system, we also have to ensure that it does not have any claims against other banks. As mentioned above, we assume that the bank in liquidation sells all its assets. Since the claims on the debtor banks are sold to some external entity, these banks move the equivalent amount from their interbank liabilities to their external liabilities.

2. If $CAD1 < \frac{nw_i}{a_i - c_i} < CAD2$, where $CAD2$ is the soft capital adequacy requirement, the bank fire-sells some of its external assets in order to reduce leverage and return to full compliance. The amount offered by the bank is calculated as

$$\frac{fsalesTarget(e_i + i_i) - n\_w_i}{fsalesTarget},$$

where the $fsalesTarget$ stands for the capital ratio at which the bank wants to get after the sale.[31]

If $\alpha > 0$, the bank does not receive the full value of the offered assets because of the Asset Price Decreasing Mechanism. Hence the loss it suffers is further evaluated as another shock and again, two possibilities can occur: Either the loss is covered by the bank's net worth, in which case the bank is able to withstand the shock, or it leads to insolvency, in which case the bank has to liquidate its assets, propagate the shock into the system and disappear. Because the asset price has been already calculated in the current round, this bank's offer is added to the total offer from which the price is determined in the next round.

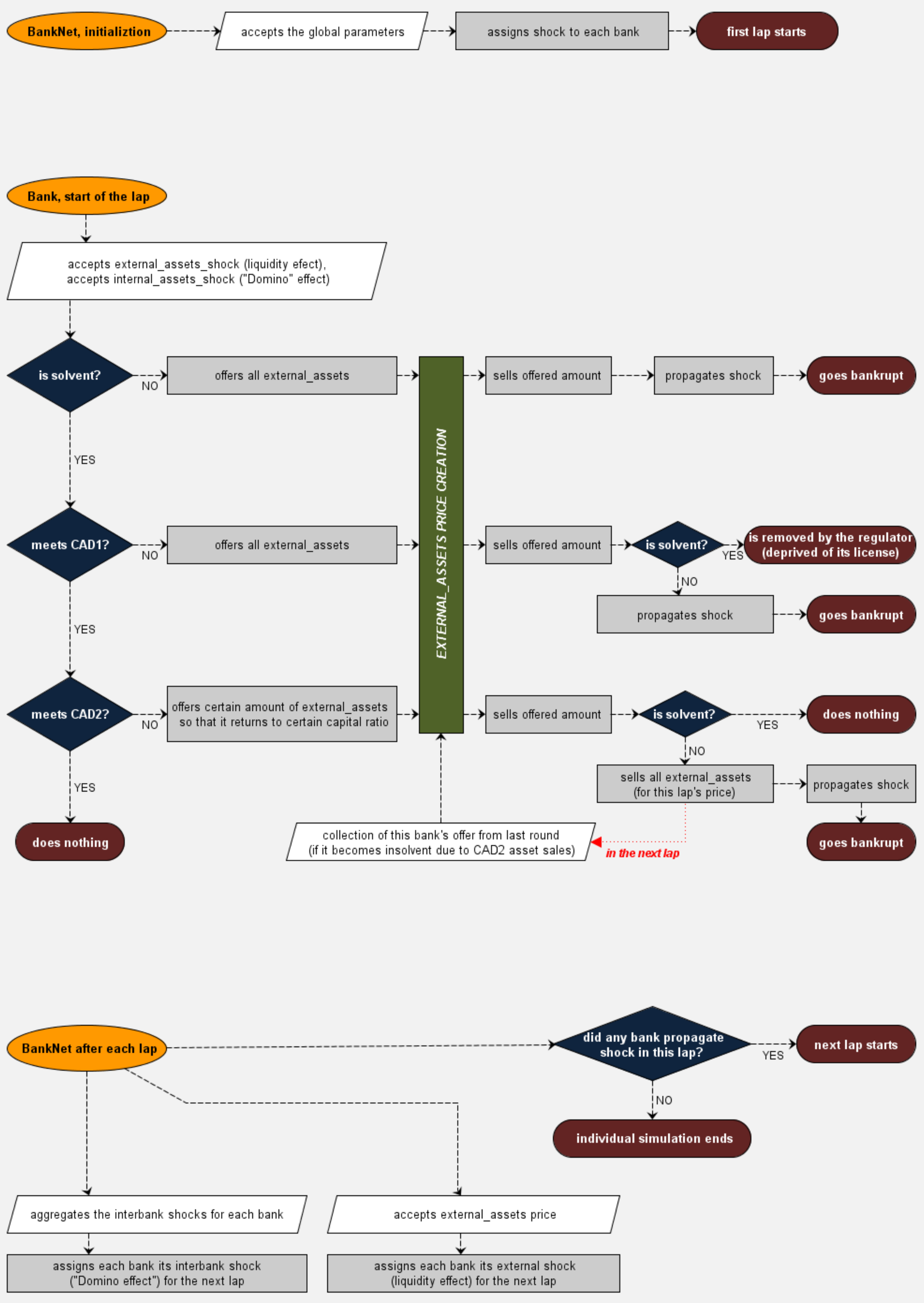
Since in our model, we need to express the $CAD1$ and $CAD2$ ratios in respect to the capital ratio, we use the following parameters:

$$removal\_ratio = \frac{CAD1}{\gamma} \quad (4)$$

$$firesale\_ratio = \frac{CAD2}{\gamma} \quad (5)$$

[31] Usually, we set this ratio equal to $CAD2$. However, if $\alpha > 1$, the bank does not receive the full value of the offered assets and hence in the next round, it will not meet the $CAD2$ criteria either. That is why there is a possibility to set the $fsalesTarget$ a little bit higher than $CAD2$.

Figure 22: Decision process in one individual simulation

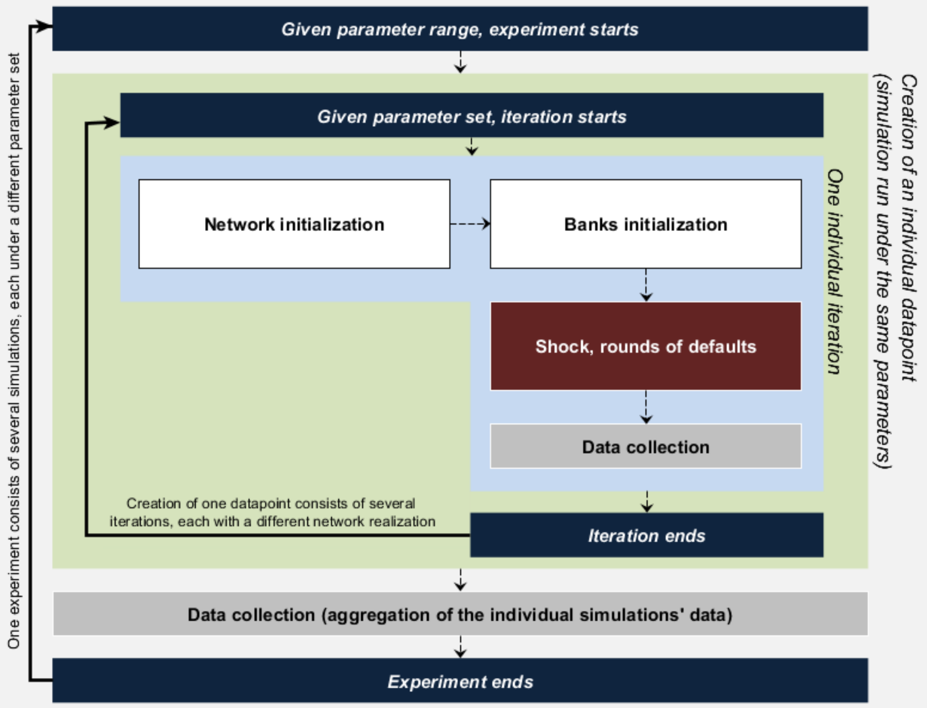


Source: author

4.2.3 Model Control[32]

For each comparative statics experiment, the model is run under several parameter settings which vary in predefined ranges, and the intervals from which we draw the parameter combinations then form the axes of the charts. To obtain the observed values, for each parameter combination we run the model in several iterations, each with a different realization of the random network, and we average the result into a single data point.

Figure 23: Scheme of different levels of the model



Source: author

This approach is in line with Nier, et al. (2007). The difference is that since our model runs fast enough to achieve the results of higher iteration count in reasonable time, we decided to run each parameter setting 500 times instead of the original 100 iterations and if necessary, we even run some simulations 1500 times. Due to low iteration count, we suspect that the charts provided in Nier, et al. (2007) are smoothed artificially, which is not necessary to be done in our model. Moreover, by re-running certain experiments from Nier, et al., (2007), we are able to check for the robustness of their results under higher iteration count.

Given the character of our simulations which do not use real-world data but rather describe the general system behaviour given different parameter settings, we are not too much

[32] The model is implemented in JAVA using NetBeans 6.9.1. The simulations were run directly in the development environment where the control of the application (i.e. parameter input) was performed directly in the code of the Main class. Hence, there is no stand-alone application. Complete code will be provided on request.

interested in particular numerical results, but rather with the patterns that are observable in the charts. Hence, the simulations results are visualized by surface plots, which allow us to observe the effects of two varying parameters at once. We chose this three-dimensional expression because it enables us to examine possible synergies of the parameters and because it shows as much information as possible on the limited space. Still, due to the scope of this thesis, many relationships and parameter dependencies remain without examination. Some of these may be found in the appendices, some are left for future research.

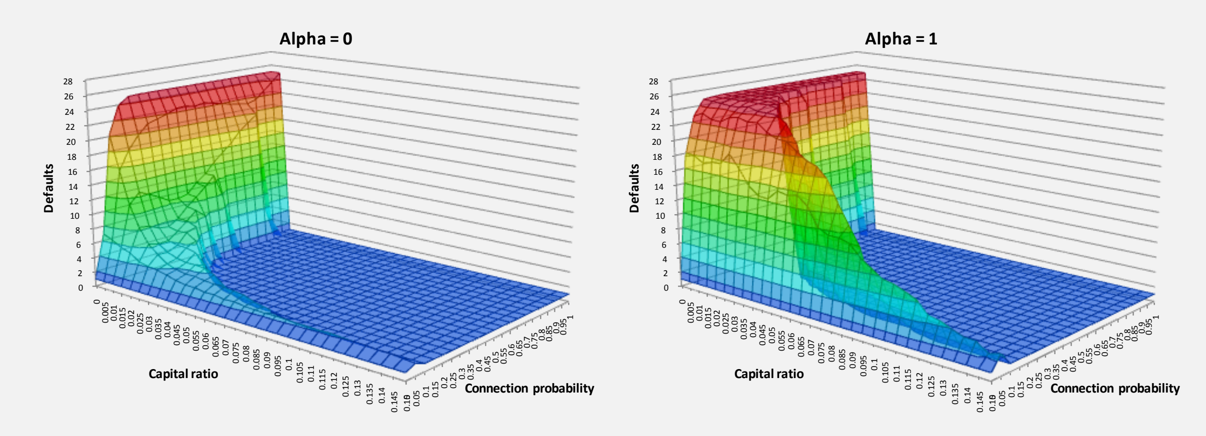
4.2.4 Simulation Results

In this part, we introduce the results of our experiments. First, we provide the analysis of the system behaviour under the basic parameter settings, where we check it against the model by Nier, et al. (2007), introduce the basic mechanisms and provide certain extensions regarding the initial shock. Subsequently, we provide simulations of our model as we move towards simulations under an extended regulatory environment. There, we examine the effects of liquidity regulation and more advanced capital rules on the resilience of the system.

4.2.4.1 Basic Behaviour under Several Types of Shocks

First, we run the model in the basic setting. All the parameters are left at values stated in table 8 apart from n_w_i and p, which are on the axes of the charts, and α, which equals zero for the first chart and unity for the second one. Similarly to Nier, et al. (2007) or Gai, et al. (2010), we hit a random bank in the system by wiping out all of its external assets.

Figure 24: Number of defaults (local shock, basic parameter setting)



Source: author's simulations

Since the used parameter setting is practically the same as in Nier, et al. (2007), the results are also very similar. The only difference is that we let the capital ratio vary on an interval of $[0, 0.15]$, which allows us to see further on the axis of this parameter, and that we should obtain more accurate results because of the higher iteration count for each simulation.

On the left chart of fig. 24, we see that the model behaviour is non-linear in both parameters. First, we look at the comparative statics under varying capital ratio. When these ratios are sufficiently high, at reasonably high connectivity levels, the only bank which defaults is the one we imposed the original shock at. When the capital ratio is between 0.1% and 0.4% (depending on the connectivity), the loss buffers of the first line of the initial banks' creditors are large enough to absorb the losses, which is the reason why over a certain interval of the capital ratio the number of defaults stays constant. However, if the capital ratio falls below this range, the first-line creditor banks default as well, spreading the losses in further laps of failures.[33] Generally, it holds that the smaller the capital buffer, the larger connectivity is needed to prevent a systemic crisis. Clearly, though, when the capital ratio is close to zero, the risk cannot be absorbed even with very high connectivity levels.

Second, we examine the model under varying connectivity. As the probability of connecting two nodes varies while the total amount of interbank assets remains the same, since equation (1) holds, higher probabilities of connection lead to lower interbank exposures and hence lower riskiness that the initial shock triggers further rounds of defaults. On the other hand, higher connectivity means that more banks are exposed to the initial shock-propagator, and hence especially for capital ratios close to zero, higher connectivity results in more defaults.

These two opposing effects, shock dispersion and shock exposure, have different strength under different sets of n_w_i and p. At its low values, the connectivity has a negative impact on the system resilience, since the exposures are large enough to knock-out the defaulting bank's creditors. With higher number of exposures, their individual values decrease and hence the initial sharp decline in the system's resilience levels out. In the low-capital systems the number of failures even drops for a while, forming an m-shaped cross-section of the first chart. Finally, when the connectivity reaches certain level, the interbank exposures are so dispersed that the shock propagated by the first bank is all absorbed by the capital buffers of the first-line of the shock-accepting creditor banks.

The situation changes when we switch on the liquidity channel. The right chart of fig. 24 depicts the same parameter set except for α, which now equals one.[34] In line with Nier, et al. (2007), we find that for $\alpha = 1$, the number of defaults is never lower than in the first case. Instead, the m-shaped relationship between the number of exposures and the number of defaults disappears and is replaced by an area of total systemic breakdown where all the 25 banks fail. Moreover, the fragility of the system becomes more pronounced under high-capital, low-connectivity parameter settings where the probability of default increases severalfold.

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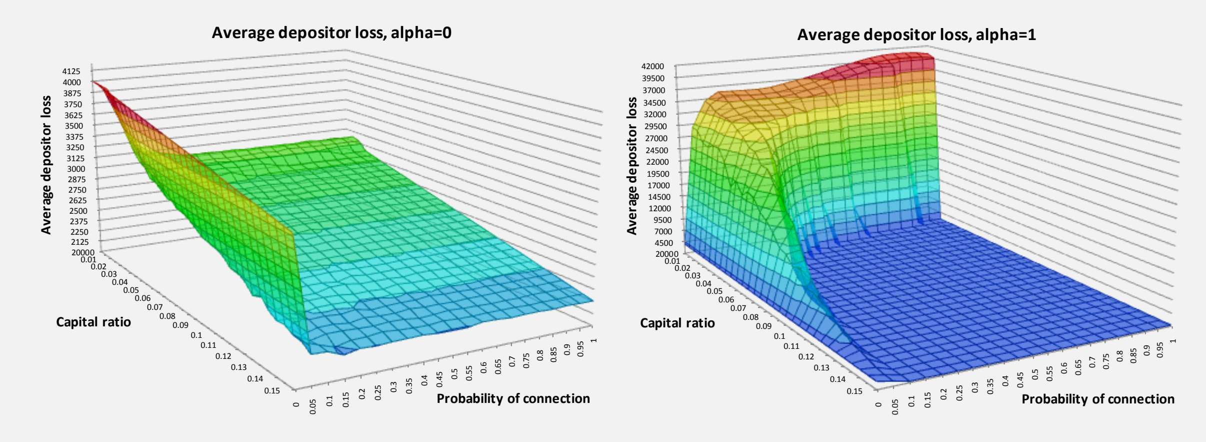
[33] This aspect of the system behaviour can be seen in fig. A-1 in the appendix.

[34] Such value of α means that 10% of external assets sold by the defaulting banks impose a 10% price shock at the external assets on the balance sheets of other banks.

Figure 25: Depositor loss for two different levels of alpha



Source: author's simulations

Even sharper contrast between these two situations can be observed when one examines the write-offs of external liabilities, i.e. the losses suffered by the depositors. As we can see in the left chart of fig. 25, in the first case, except for the situations with very low connectivity where the losses of the first bank to default are covered virtually only by its depositors, the interbank system has high potential of absorbing the initial shock. For higher probabilities of connection, the loss is partly covered by the banks in the first and next lines of default while the higher capital ratios obviously cause better shock dispersion. Moreover, the relationship of the depositor losses and capital ratio is almost linear. In contrast, when the liquidity channel of contagion is turned on as we can see it on the right chart of fig. 25, the depositor losses are far higher and have a shape similar to the number of defaults in fig. 24. Note that the scale of the chart on the right of fig. 25 is ten times as large as the one of the left chart.

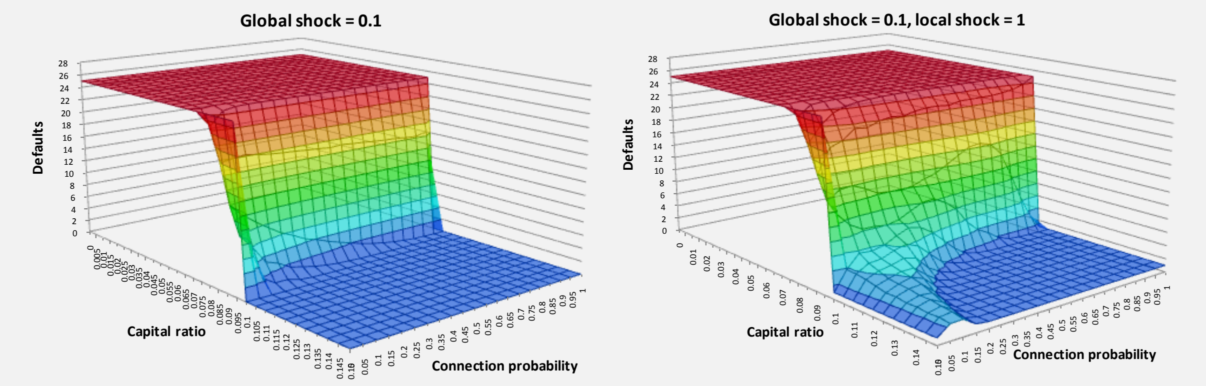
However, when we turn back to fig. 24, we can see that the basic pattern is similar whether the liquidity channel is open or not. In both charts, there are "safe zones" with sufficient capital level and reasonably high connectivity, where the only bank to default is the one that is originally shocked. This area of the chart presents a desirable parameter setting for the real-world banking system and both these parameters are subject to regulation: the capital measures have been comprehensively described in previous chapters and the regulation of connectivity is performed by the large exposure limits which ensure that a bank's interbank assets are diversified to reduce the credit concentration risk.[35] From fig. 24, we can also confirm the work by Mistrulli (2011), who concluded that the ex ante maximum entropy assumption (which in our model equals the assumption that $p = 1$) underestimates the risk of systemic crisis.

Our model also enables us to examine the system behaviour under other types of shocks. Firstly, a situation may occur when all banks suffer minor losses on their external assets,

[35] E.g. in the EU, the credit concentration risk is regulated by a limit that restricts any exposure to any single bank or group of banks to 25% of capital (EU, 2006; Articles 111-117).

which may happen when certain percentage of loans has to be written-off or when an asset which all of the banks possess drops in price. Alternatively, systemic crisis may be an outcome of an aggregate shock which has particularly adverse consequences for one institution: this can be modelled by minor losses on external assets across the whole system, combined with a major breakdown of one bank (Gai, et al., 2010).

Figure 26: Number of defaults (global shock, combination of global and local shock)



Source: author's simulations

In the first case, all of the banks lose 10% of their external assets. As we can see on the left of fig. 26, when the capital ratio and hence also the capital buffers of the individual banks are sufficiently large, all the banks are able to withstand the shock. With declining capital ratio, there is a short interval on which increasing connectivity results in shock dispersion and increased system resilience. This happens because the shock is of similar size to the banks' capital buffers. Some of the banks default and propagate the shock further but with sufficient number of exposures, the shock is absorbed by the first line of creditor banks. Nevertheless, since the banks' balance sheets are not very heterogeneous, there is a threshold capital level behind which all banks in the system default since they do not have enough capital to cover the losses.

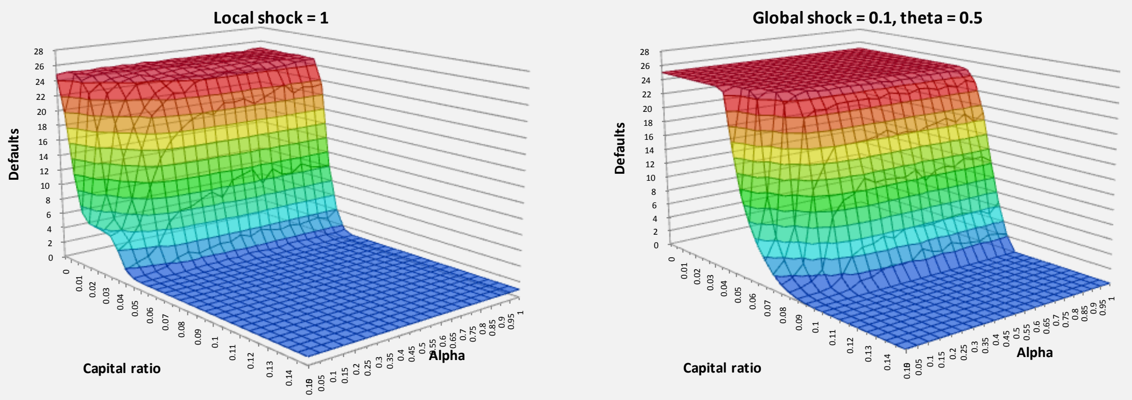
In the second case, one bank loses all of its external assets whereas the rest of the system is shocked by 10% loss. On the right chart of fig. 26, it is clear that both the effects are visible under this setting. For higher capital ratios, the system behaves similarly as with just the local shock, only the "safe zone" is shifted further into higher capital levels, which is caused by the "global" shock which reduces the size of the banks' capital buffers. For lower levels of capital, the system breaks down as the capital buffers are not able to absorb the shock imposed on all banks. Note that this situation is somewhat similar to the one depicted in the right chart of fig. 24, because the liquidity channel has similar characteristics to the "global" shock.

It is necessary to note that the sudden occurrence of systemic break-down for certain capital ratio is given by relative homogeneousness of the banks' balance sheets. Since the only mechanism that makes the banks different from each other is the random network initialization and the interbank assets account for relatively small portion of the total assets, the banks' capital buffers are of similar size. As we can see further, with higher values of θ, the phase-in of the crisis is more gradual. However, again we see that sufficient capital buffers are crucial for the system's resilience.

4.2.4.2 Liquidity Regulation

In this part, we focus on the liquidity measures. Since liquidity is a whole new area of regulation taken into account by Basel III, we observe how and to what extent it improves the system resilience. However, first we examine more closely the effect of system illiquidity, which is represented by the parameter α in equation (3).

Figure 27: Number of defaults (global shock, combination of global and local shock)



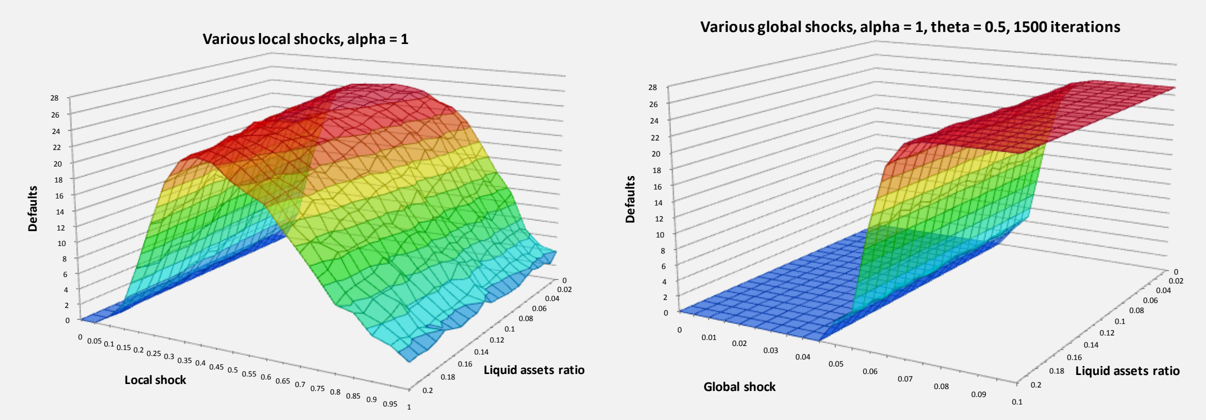
Source: author's simulations

Firstly, we look at the situation when the system suffers a local shock, i.e. one bank loses all of its external assets, which is depicted in the left chart of fig. 27. At zero alpha, the Asset Price Decreasing Mechanism is not in action and the shape of the relationship of the default count and the capital ratio is the same as in the case of the left chart of fig. 24 for $\theta = 0.2$. With increasing illiquidity of the system, this cascade-like shape is being smoothed out as the number of defaulting banks is sharply increasing for capital ratios ranging from about 2% to 4%. For even higher levels of alpha, there is a capital ratio threshold triggering a total systemic break-down and causing all the banks to fail. This happens because the external assets decline sharply in price, which constitutes a secondary shock that affects all the banks. Since under this setting, the balance sheets of all banks are similar, the phase-in of the systemic crisis occurs at a relatively short interval of capital ratios from 4% to 3%.

Second, we model a situation when all the banks are affected by a shock accounting for 10% of external assets. Moreover, to illustrate that the phase-in of systemic crisis is more gradual in heterogeneous systems, we set $\theta = 0.5$ and thus the interbank assets account for 50% of total assets in the system instead of the benchmark value of 20%. Since more assets are now determined by the random network structure and less are assigned uniformly, the variance in the banks' balance sheets values is higher and the function of default count is less steep.

As we can see in the right chart of fig. 27, with increasing alpha, the situation worsens for a certain interval of capital ratios, this time ranging from 5% to 10%. This result has a lot in common to the case of a local shock: in case of a liquidity crisis, the initial relationships of the system resilience and capital ratios are smoothed out and the systemic breakdown occurs even when the capital ratios are higher. Again, it is obvious that sufficient capital buffers are necessary and moreover, it is clear that the regulation must take into account the extra losses stemming from the illiquidity of the system, which can be done in three ways: by increasing the shock absorption capabilities of the banks via increasing the capital ratio, by artificially decreasing the amount of assets offered in the market via bailing out certain banks, or by introducing an additional liquidity measure. The last possibility is examined in the following figures.

Figure 28: Number of defaults under various shock values and various liquidity measures



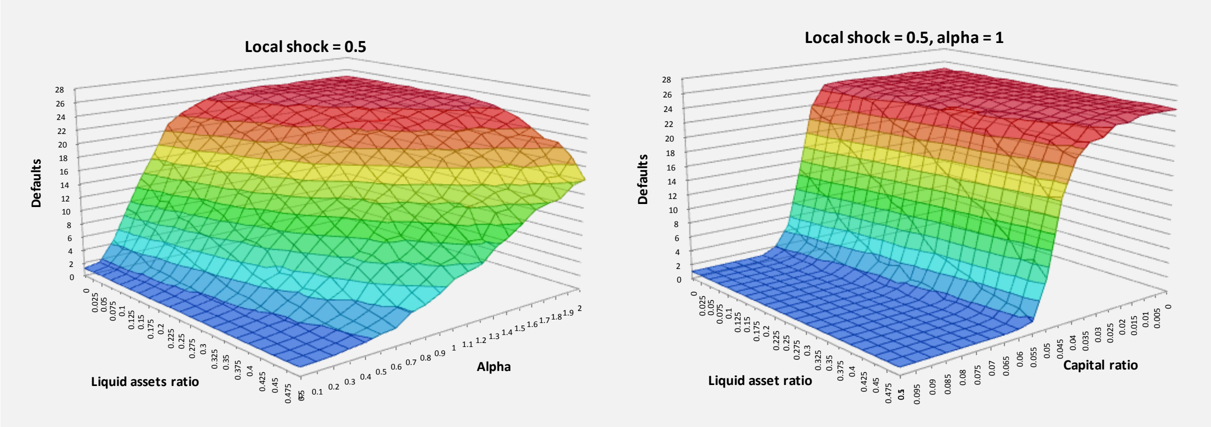
Source: author's simulations

In the left chart of fig. 28, we observe how the system reacts under different local shocks and various liquidity ratios, as modelled by equation (2). The first interesting finding to note is that the default rate is not a monotonously increasing function of the shock value. This is caused by the liquidity effects: Since $\alpha = 1$, the value of all banks' external assets is affected by the asset fire sales of the bank which is hit by the original shock, and the more assets this bank has to sell, the more significant is the subsequent liquidity effect. Clearly, when we wipe out all of this bank's external and liquid assets, although it transmits the loss further through the network, it has no assets left to sell and thus it does not affect the global external assets price. In contrast, when the local shock accounts for only about a half of the bank's external and liquid assets, the loss is still large enough to spread through the interbank network and additionally, the remaining half of the external assets is sold in the illiquid market, and subsequently decreasing the global price and affecting all other banks through marking-to-market. Under even lower shock values, the initial loss becomes less and less able to cause a systemic crisis.

When we look at the liquidity measures on the second axis, we can see that the regulation somewhat lessens the number of defaulted banks but with so little efficiency that it initially does not seem worth the extra funding costs it imposes on the banks. However, when we look at the left chart of fig. A-2 in the appendix, we can see that the liquidity regulation has a very significant effect on the amount of depositors' losses incurred by the banking crisis.

A slightly different situation occurs when we hit the system with the global shock, as presented in the right chart of fig. 28. As shown before, there is a shock value threshold range in which the crisis phases in, and behind which the whole system crashes. As to the liquidity regulation, in this case it does not reduce the default rate at all. However, again, when we look at the right chart of fig A-2, it is obvious that given certain shock values, higher liquid assets ratio results in fewer losses for the depositors.

Figure 29: Liquidity regulation vs. alpha and vs. capital ratio (local shock)



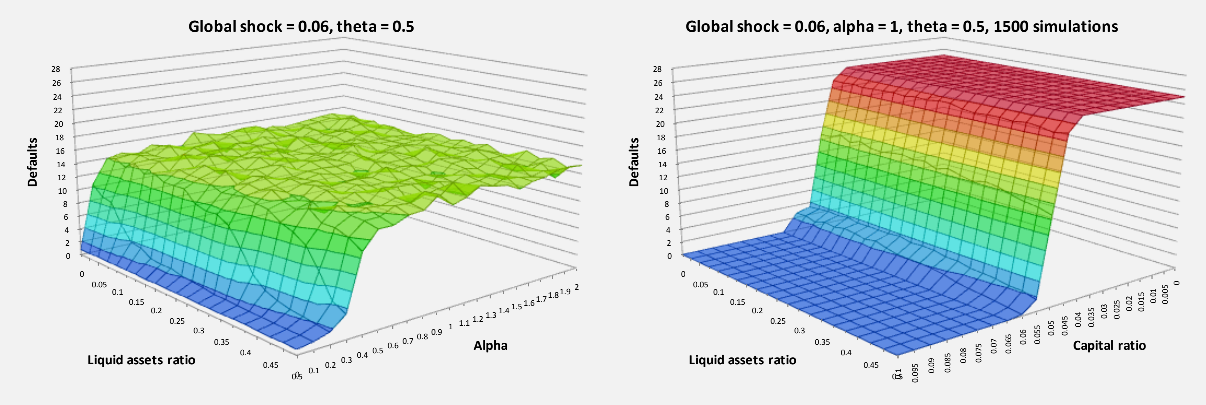
Source: author's simulations

Next, we examine in more detail how the liquidity regulation increases the system's resilience when a local shock is imposed on one individual bank. As we have shown before, the worst situation emerges when half of the bank's assets are wiped out and hence, we will focus on this particular case.

In the left chart of fig. 29, we see how the system's resilience depends on the illiquidity of the system and the rate of liquidity regulation. Obviously, with increasing alpha, the number of failed banks tends to increase. However, we also see that particularly for $\alpha < 1$, the liquidity regulation works well in protecting the system against total collapse. For higher levels of alpha, albeit there are still some positive effects, it takes ever higher liquidity ratios for the benefits of the regulation to kick in. Moreover, when we look at the right chart of fig. A-3, we observe that for the depositor protection, the liquidity regulation is even more effective.

When we set $\alpha = 1$, we can observe the performance of liquidity regulation under different capital ratios, as depicted in the right chart of fig. 29. From the result of the simulation, we see that for high capital ratios (approximately until 7.5%), the regulation is not necessary as the capital buffers are large enough. At lower capital ratios, there is an interval where the large-scale systemic breakdown is phasing in – here the liquidity regulation is very important and may prevent a number of bank failures. When the capital buffers are too small, the regulation does not have any effect on the default rate but, as we can see in the right chart of fig. A-3, it still works very well for moderating the depositor loss.

Figure 30: Liquidity regulation vs. alpha and vs. capital ratio (global shock)



Source: author's simulations

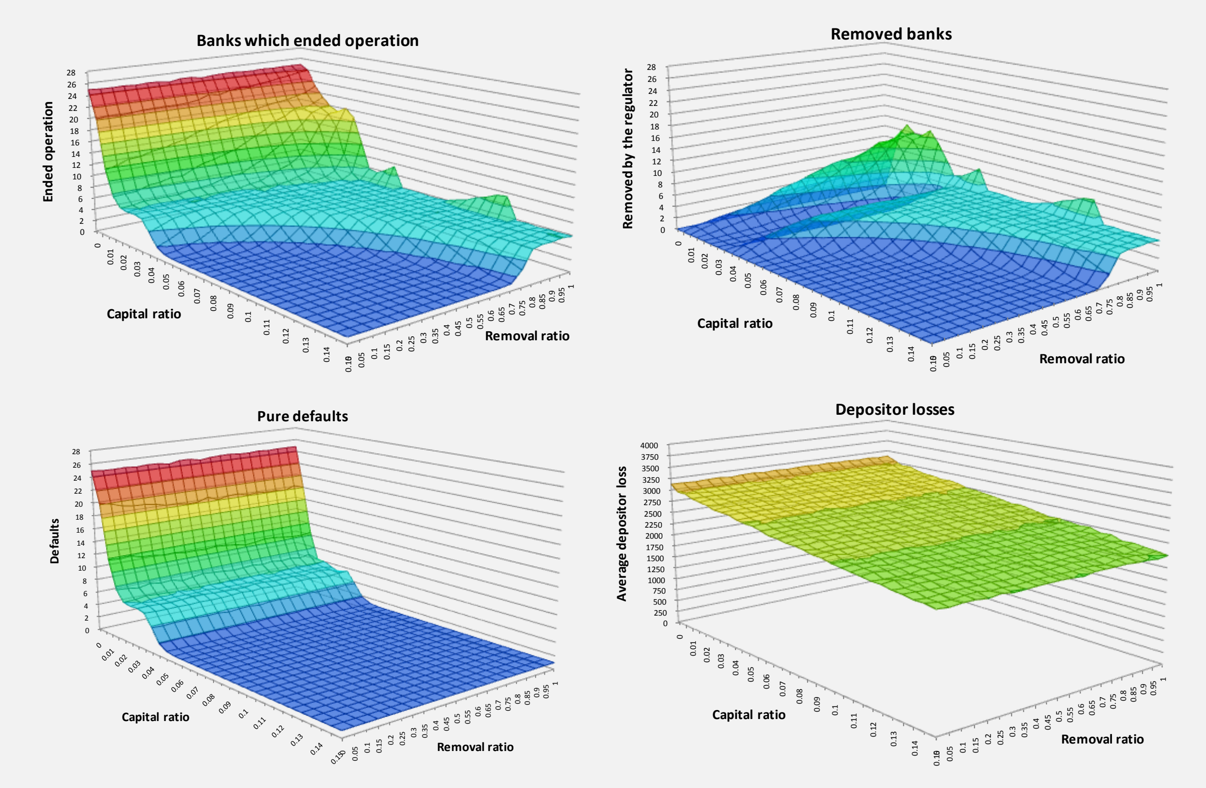
The last situation we focus on when studying the liquidity regulation is the global shock affecting all the banks in the system. We set the shock value to 6% since in the right chart of fig. 28, it constitutes the moment when the system turns into the crisis. From the left chart of fig. 30 we see that under this parameter set, the regulation reduces the default rate only for $\alpha < 0.5$ and when the alpha is too large it has no effects on systemic stability. However, similarly to the local shock case, in the left chart of fig. A-4., we see that the liquidity measures are reducing the depositor losses very efficiently when the crisis breaks out.

When we set $\alpha = 1$ and examine the system behaviour under varying capital ratio, it is clear that for the average banks' resilience, the liquidity regulation has effect only at a very tiny interval of 5%-6% capital ratio. Also, as we can observe in the right chart of fig. A-4, for some capital levels when the depositor loss would be very high without the regulation, the liquidity ratio has a significant effect on its mitigation.

4.2.4.3 CAD1 measure

As to the capital regulation, up until now, we focused only at the capital ratio describing the size of the banks' capital buffers. However, the capital regulation is not as easy as that – it is not possible to simply prescribe a capital ratio and count on all banks' compliance. Instead, there must be repressive mechanisms which ensure that all the banks have enough capital so that they do not pose a threat to the system. We will examine two discretionary tools: in this chapter, we observe what happens if the banks that do not comply with the regulation are deprived of their license, and in the next one, we observe the effects of a "softer" regulatory measure on the resilience of the system.

Figure 31: CAD1 measure (local shock)

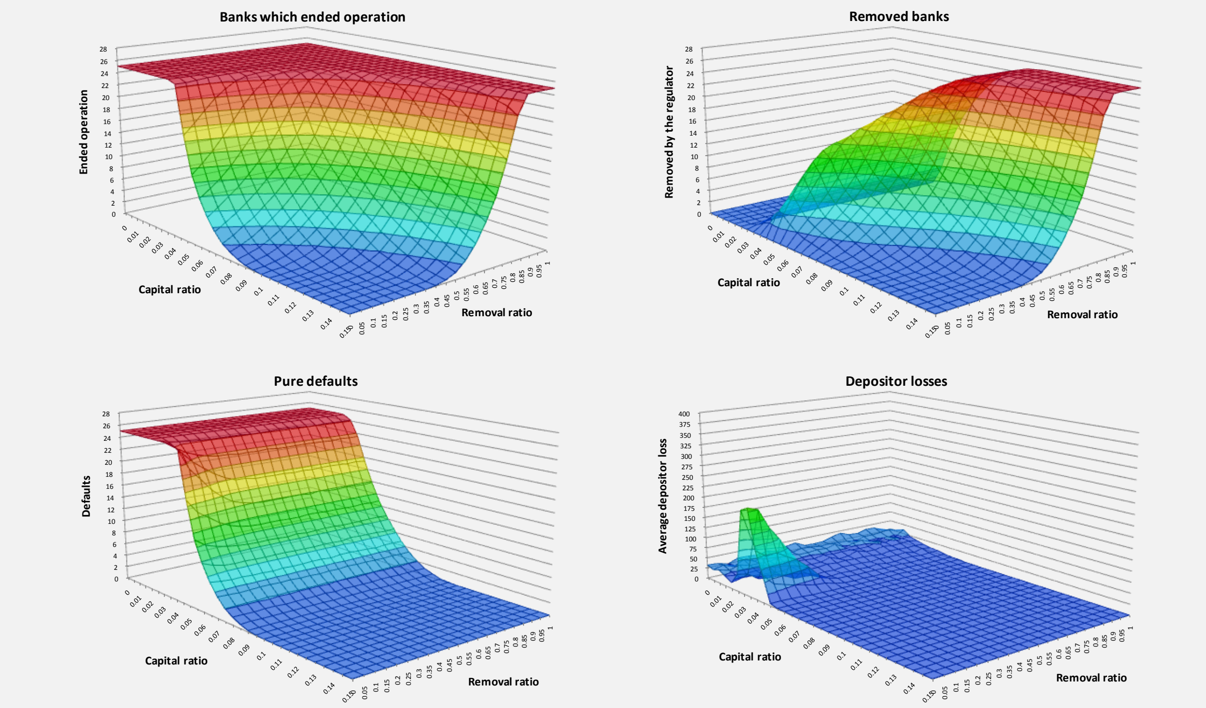


Source: author's simulations

The simulation results in this part are presented as follows: the top left chart depicts the average number of banks that ended operation, either because they defaulted or because they were removed for not meeting the regulatory requirements, the top right chart presents the number of banks that were removed by the regulator and the bottom left one the banks that defaulted and imposed external losses on the rest of the system. It holds that the top right and the bottom left charts result in the top left one when summed up. Finally, the bottom right chart depicts the losses suffered by the depositors. On one axis, there is the capital ratio that determines the amount of capital the banks have on their balance sheets, on the other one there is the removal ratio as defined by equation (4).

First, we examine a local shock hitting one random bank, a situation depicted in fig. 32. As expected, we see that higher removal ratios result in more banks removed from the system, which clearly leads to higher number of banks that ended operation. We see that for high capital levels, the regulation takes out the banks that would not otherwise default, but on the other hand, when the capital buffers are small, the banks default before the regulation manages to remove them from the system. Hence, this measure fails to improve the resilience of the system, since the number of defaulted banks stays constant for all levels of the removal ratio as we can see in the bottom left chart. Moreover, the same holds for the depositor protection as the depositor losses are not affected by this measure either.

Figure 32: CAD1 measure (global shock)



Source: author's simulations

Next, we study the case of a shock affecting all banks. As we can see in fig. 32, again, the higher the removal ratio, the more banks are forced to end their operation. Also, it holds that for small capital buffers (until approximately 2.5%), no banks are removed since almost all of them default right after accepting the shock. However, this situation differs from the one of a local shock in two aspects. First, as we can see in the top right chart of fig. 32, high removal ratios cause that the regulator removes all banks in the system even though their capital buffers would be large enough for them to withstand the shock, which is clearly a rather unrealistic result.[36] Second, there is an interval of capital ratios (approximately [2.5%, 5%]), where the regulation succeeds to lower the number of defaulted banks and the depositor losses.

In figures A-5 and A-6, the two aforementioned cases are depicted for the situation when the channel for the liquidity effects is open. When $\alpha = 1$, we can see in the bottom left charts of both figures that the default rate is growing with increasing removal ratio even though there are very few banks finally removed by the regulator (as depicted in the top left charts). This

[36] In the real world, the removal threshold does not account for 100% of the capital the banks ought to have (for example, according to *Zákon č. 21/1992 Sb. o bankách*, the Czech banks should end their operation when their capital ratios fall below one third of the original Basel requirements). Also, we would expect many of the institutions to be bailed out instead of simply deprived of their licenses.

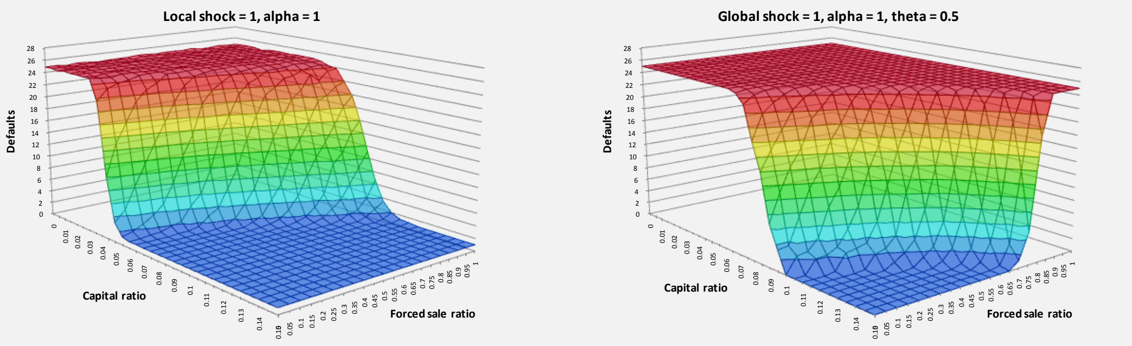
phenomenon occurs because at certain amount of losses the capital ratios fall below $CAD1$ and the removal process begins, but as the banks are being removed and their assets sold onto the illiquid market, the asset price falls sharply. Subsequently, the funds obtained by the banks for the illiquid assets do not suffice to cover their liabilities and finally, even the banks that were initially meant to be removed are forced to default.

Finally, we must repeat that however inefficient the removal of troubled banks from the system might be when a crisis emerges, it is a very important as a coercive measure to ensure that the capital buffers of the banks are large enough. Clearly, without the threat of a ban on operation, the banks would not be willing to limit their leverage. When we think about the $CAD1$ measure as a necessity for ensuring certain capital buffers, i.e. when we fix the removal ratio and consider the inverted relationship $\gamma = removal\_ratio_{fix} \cdot CAD1$, we see that there are obvious effects on the system's resilience, even in the case of non-zero alpha.

4.2.4.4 CAD2 measure

The last aspect of regulation we will examine is a smoother measure in form of a capital limit ($CAD2$) below which the banks are not forced to end their operation, but restricted from certain activities, such as paying out dividends or bonuses to the management. We assume that in this situation, the banks will try to return at the compliance level as quickly as possible by selling a portion of their assets in order to deleverage their balance sheets.

Figure 33: CAD2 measure (local and global shocks)



Source: author's simulations

Similarly to the previous case, it is possible to understand this capital measure as a way to ensure that the real capital ratios with which the banks operate are sufficiently high. Since then the forced sale ratio determines the relationship between $CAD2$ and capital ratio as defined by equation (5), the higher the $CAD2$, the higher are the capital buffers and the more resilient is the system. However, as we can see in fig. 29, for both types of shocks, the higher forced sale ratio we need to ensure that there is certain capital level in the system, the more defaults occur.

4.2.5 Summary of Simulation Results and Policy Implications

Table 9: Results summary

Experiment	Shock	Result
Basic behaviour	Local	▪ Large capital buffers are the essential means to ensure systemic stability. ▪ Given a fixed value of interbank assets, the more is the system intertwined, the more resilient it is against total breakdown, particularly when the market liquidity is low. ▪ On the other hand, higher number of interbank connections makes the system more fragile when the capital levels are low. ▪ When the market is illiquid, the losses to the depositors are significantly higher. ▪ For both liquid and illiquid markets, there are "safe zones" where sufficiently high capital buffers and enough connectivity ensure that the shock is absorbed in the system.
	Global	▪ On a small range of capital ratios when the crisis is phasing in, to a certain extent, the interbank connections have shock dispersion effects and reduce the number of defaults. ▪ The more heterogeneous are the banks' balance sheets, the larger interval of capital ratios it takes for the system to break down.
Liquidity measures	Local, global	▪ On a certain interval of capital ratios when a crisis is phasing in, increased illiquidity of the system can drastically worsen the situation, causing more banks to default. ▪ Given a local shock, the liquidity regulation decreases the number of failed banks only at a particular range of capital ratios. However, it can lessen the depositor loss for all capital levels for which the crisis occurs. ▪ Given a global shock, the liquidity regulation is efficient only at a specific set of parameters, particularly small alpha and capital ratio under which the system is on the verge of a breakdown. However, again, it works very well for preventing the losses from spreading onto the original depositors.
CAD1 measure (bank removal)	Local	▪ For high capital levels, the regulation takes out the banks that would not otherwise default ▪ When the capital buffers are small, the banks default before the regulation manages to remove them from the system. ▪ This measure fails to reduce the number of failed banks as well as the amount of depositor losses ▪ When α=1, the default rate is growing with increasing removal ratio even though there are very few banks finally removed by the regulator. ▪ When we think about the CAD1 measure as a necessity for ensuring certain capital buffers, we see that it has obvious positive effects on the system's resilience, even in the case of non-zero alpha.
	Global	▪ High removal ratios cause that the all banks are removed even though their capital buffers would be large enough for them to withstand the shock. ▪ There is an interval of capital ratios where the regulation succeeds to lower the number of defaulted banks and the depositor losses. ▪ When α=1, the default rate is growing with increasing removal ratio even though there are very few banks finally removed by the regulator. ▪ When we understand the CAD1 measure as a necessity for ensuring certain capital buffers, we see that it has obvious positive effects on the system's resilience, even in the case of non-zero alpha.
CAD2 measure (soft requirement)	Local, global	▪ Similarly to the previous case, it is possible to understand CAD2 measure as a way to ensure that the real capital ratios with which the banks operate are sufficiently high. Then the higher the CAD2, the higher are the capital buffers and the more resilient is the system. ▪ For both types of shocks, the higher the forced sale ratio we need to ensure that there is certain capital level in the system, the more defaults occur.

Source: author

Table 9 presents a summary of the simulation results. First, in our model, it is obvious that the levels of individual banks' capital buffers are crucial for systemic stability. Moreover, the relationship between the capital ratio and the number of defaults in most of the situations appears to be of a "step-like" shape with sudden occurrence of a systemic break-down rather than of a gradual nature. Hence, the regulatory protection needs to be scaled for much larger shocks which are maybe not very likely to occur but when they do, once the stress situation breaks through the capital barriers and triggers a systemic crisis, the impact is devastating.

Second, the illiquidity in times of a major distress may have adverse effects for the resilience of the system and it definitely increases the losses suffered by the depositors. Liquidity regulation which forces the banks to hold a certain portion of high-quality liquid assets then may increase the system stability when the shock is about to spill over the capital barriers, and it always reduces the depositor loss when high number of banks in the system fail. Hence, there is a rationale for liquidity regulation.

Third, we could have seen that once a crisis breaks out, the ad-hoc discretionary measures alone, forcing the troubled banks to end operation or sell a part of their assets, have almost no or very little effect on improving the situation and when the illiquidity is high, any measure which increases the number of assets sold in the market is rather counter-productive. However, since CAD1 and CAD2 contribute to maintaining the overall capital ratios, they are worth the extra costs they generate. The best option would seem be to use these as preventive measures that enforce the banks to have enough capital but do not use them in major distress. On the contrary, during the crisis, measures that make the banks not propagate the shocks through the network and that reduce the amount of assets sold in the market are more appropriate – such as are state bail-outs. However, as mentioned earlier, the possibility of a state aid results in increased moral hazard.

Finally, as we have mentioned, there are issues with data availability. Since even the regulators do not usually precisely know how the real-world interbank exposures look like and because the maximum entropy approach used for estimation of these data underestimates the systemic risk, it is necessary that the banks provide more detailed data on their exposures so that the banking system models may be more efficient in pointing at potential weaknesses.

4.2.6 Possible Further Extensions

Clearly, due to the scope of this thesis, not all of the aspects of the model could have been described and it would be interesting to explore other parameter combinations as well.[37] Also, we are working on the implementation of a systemic surcharge for the too-interconnected-to-fail banks into our model. However, for this to be achieved, it is necessary

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[37]In fig. A-7, we provide several additional relationships, which use the basic settings to test our model against the results by (Nier, et al., 2007). However, the interpretation of these charts is left to the reader.

yet to solve an issue with comparability of the situation with and the situation without the SIFIs regulation.

Also, our model assumes a random interbank network, which is an assumption that can be replaced by more sophisticated network structures that are closer to reality, e.g. the small-world networks or scale-free tiered structures. The occurrence of the systemic breakdown would be also probably less sudden and more gradual if the modelled banks were more heterogeneous – in this case it is possible that given a certain shock size, the liquidity regulation and the CAD measures would prove efficient on a wider range of overall capital ratio. Ideally, the effects of regulation may be studied on the real-world interbank network data. Finally, because of its agent-based nature, it is possible to extend the model with other features, such as endogenous network creation or more types of agents, such as central banks, hedge funds or individual depositors.

5 Conclusion

Because of the two types of market failures, asymmetric information and existence of externalities, it is necessary to regulate banks' operation. The main aim of banking regulation is protecting the depositor and assuring systemic stability, i.e. ensuring that the distress of one or more banks will not bring the whole system to collapse. Since the banking business has a cross-border character, the regulation has to be performed on an international basis.

The Basel committee was established to ensure international coordination of banking regulation. In 1988, it published the first version of regulatory standards known as Basel I which prescribed a simple capital ratio that the internationally active banks should have been required to maintain. However, this prescription was criticized for its over-simplicity and in 2004 it was followed by Basel II, a second regulatory document increasing the complexity of the regulatory measures and giving the large banks the possibility to calculate their individual capital requirements via the IRB approach. Nevertheless, the recent financial crisis pointed at the deficiencies of Basel II. It showed that banking regulation had fallen victim to regulatory capture by large international banks and that it failed to protect the financial system since it did not ensure sufficient capital buffers. Moreover, it even contributed to the economic downturn because of its pro-cyclical nature.

With the economic crisis, there came a revision of the current regulatory framework, which finally escalated into the publication of a new set of standards known as Basel III. This latest set of standards should increase the system's resilience by redefining what constitutes the regulatory capital, and by raising the current capital ratios or adding new ones. It also adds measures for increasing the banks' liquidity so that they are better able to withstand transient shocks. However, there are also doubts about its efficiency – as with the Basel II, the lobby of the international financial institutions has been again trying to shape the form of the new rules, or at least secure long transition periods for their implementation.

In order to be able to devise efficient regulatory standards, it is important to understand how the individual measures affect the behaviour of the banking system. That is why in the last chapter, we focused on simulation of different regulatory environments. We have constructed an agent-based network model of a banking system, which we have used for stress-testing of several different regulatory measures. First of all, in our simulations, we have confirmed that sufficient capital buffers of individual banks are crucial for protecting the stability of the whole system. Second, while for the system protection, the liquidity regulation seems efficient only on a small range of capital ratios, it proved capable of reducing the depositor losses once the crisis breaks out. Third, we see that the regulatory measures work best as a prevention which ensures that the banks possess sufficient capital buffers. However, once the system is collapsing, removal of the banks that do not meet specific capital requirements is not very effective and if the overall market liquidity is low, it can even worsen the situation. Fourth, again the "soft" regulatory measures such as the Capital Conservation buffer of Basel III work well as a tool for pushing the long-term overall capital levels up. However, when we assume that the banks behave so that they comply with this measure at any rate and so they fire-sell a certain portion of their assets when they find themselves below the required capital ratio, when the banking system faces a distress period and the market is illiquid, this measures can contribute to the financial crisis.

Finally, it is necessary to bear in mind that banking system modelling suffers from a serious lack of data and the banking regulation suffers from strong interest group pressure. Were the interbank relationships and the individual banks' portfolios more transparent, it would be much easier to point at the potential weaknesses and devise targeted regulatory measures for systemic stability protection. Moreover, were the regulators more independent and less influenced by the lobby of the banking industry, these measures would be much easier to implement and exercise.

References

Admati, A., et al. 2010. Healthy banking system is the goal, not profitable banks. *Financial Times.* 2010, November 9.

Akerlof, G. A. 1970. The Market for "Lemons": Quality Uncertainty and the Market Mechanism. *The Quarterly Journal of Economics.* 1970, Vol. 84, 3, pp. 488-500.

Allen, F. and Babus, A. 2009. Networks in Finance. In *The Network Challenge.* Wharton School Publishing, 2009, ch. 21, pp. 367-382.

Allen, F. and Gale, D. 2000. Financial Contagion. *Journal of Political Economy.* 2000, Vol. 108, 1, pp. 1-33.

Barth, J. R., Caprio, G. jr. and Levine, R. 2005. *Rethinking Bank Regulation: Till Angels Govern.* Cambridge University Press, 2005. ISBN 9780521855761.

BCBS. 2011a. BIS Statistics. [Online] 2011a. [Cited: 20 February 2011.] http://www.bis.org/statistics/index.

—. 2011b. Fact sheet - Basel Committee on Banking Supervision. [Online] 2011b. [Cited: 3 March 2011.] http://www.bis.org/about/factbcbs.htm.

—. 2010a. *Basel III: A global regulatory framework for more resilient banks and banking systems.* Bank for International Settlements, 2010a. ISBN 92-9197-859-0.

—. 2010b. *Basel III: International framework for liquidity risk measurement, standards and monitoring.* Bank for International Settlements, 2010b. ISBN 92-9197-860-4.

—. 2010c. *Results of the comperhensive quantitative impact study.* Bank for International Settlements, 2010c. ISBN 92-9197-861-2.

—. 2009. *History of the Basel Commitee and its Membership.* Bank for International Settlements, 2009.

—. 2006a. *Core Principles for Effective Banking Supervision.* Bank for International Settlements, 2006a. ISBN 92-9197-725-X.

—. 2006b. *Results of the fifth quantitative impact study (QIS 5).* Bank for International Settlements, 2006b. ISBN 92-9197-716-0.

—. 2004a. Bank Failures in Mature Economies. *Basel Committee on Banking Supervision Working Paper.* 4, 2004a, 14.

—. 2004b. *International Convergence of Capital Measurement and Capital Standards: A Revised Framework.* Bank for International Settlements, 2004b. ISBN 92-9197-669-5.

—. 2001. *The New Basel Capital Accord: an explanatory note.* Bank for International Settlements, 2001.

—. 1999. *A New Capital Adequacy Framework.* Bank for International Settlements, 1999.

—. 1988. *International Convergence of Capital Measurement and Capital Standards.* Bank for International Settlements, 1988.

Beck, J. 2010. Trade finance blown off course. *The Banker.* 2010.

Benston, G. J. 1998. *Regulating Financial Markets: A Critique and Some Proposals.* Institute of Economic Affairs, 1998. ISBN 0255364156.

Blankfein, L. 2008. Do Not Destroy the Essential Catalyst of Risk. *Financial Times.* February 8, 2008.

BOE. 2009. *Financial Stability Report: December 2009.* Bank of England, 2009. Vol. 26.

Boss, M., et al. 2004. The network topology of the interbank market. *Quantitative Finance.* 2004, Vol. 4, 6, pp. 677-684.

Brunnermeier, M. K. and Pedersen, L. H. 2009a. Market Liquidity and Funding Liquidity. *The Review of Financial Studies.* 2009a, Vol. 6, 22, pp. 2201-2238.

Brunnermeier, M., et al. 2009b. *The Fundamental Principles of Financial Regulation: Geneva Reports on the World Economy.* Centre for Economic Policy Research, 2009b. ISBN 0955700973.

Cifuentes, R., Ferruci, G. and Shin, H. S. 2005. Liquidity risk and contagion. *Journal of the European Economic Association.* 2005, Vol. 3, pp. 556-566.

Clifford Chance. 2010. *Basel III – the shape of banks to come.* Clifford Chance LLP, 2010.

Dale, R. 1994. Issues in International Banking Regulation Global Policies for Global Markets. *Financial Review (Japan).* 1994, 32, pp. 118-150.

Davis, K. 2007. Banking Concentration, Financial Stability and Public Policy. In *The structure and resilience of the financial system.* Reserve Bank of Australia, 2007.

Detragiache, E. and Demirgüc-Kunt, A. 2002. Does deposit insurance increase banking system stability? An empirical investigation. *Journal of Monetary Economics.* 2002, Vol. 49, 7, pp. 1373-1406.

Dewatripont, M. and Tirole, J. 1994. *The Prudential Regulation of Banks.* Massachusets Institute of Technology, 1994. ISBN 0262041464.

Dewatripont, M., Tirole, J. and Rochet, J-Ch. 2010. *Balancing the Banks: Global Lessons from the Financial Crisis.* Princeton University Press, 2010. ISBN 9780691145235.

Diamond, D. W. 1984. Financial Intermediation and Delegated Monitoring. *Review of Economic Studies.* 1984, Vol. 51, 3, pp. 393-414.

ECB. 2010. *Recent Advances in Modelling Systemic Risk Using Network Analysis.* European Central Bank, 2010.

Elliott, D. J. 2010. *Basel III, the Banks, and the Economy.* The Brookings Institution, [Online] 2010. [Cited: 8 April 2011.] http://www.brookings.edu/~/media/Files/rc/papers/2010/0726_basel_elliott/0726_basel_elliott.pdf.

Erdös, P. and Rényi, A. 1959. On random graphs. *Publicationes Mathematicae.* 1959, Vol. 6, pp. 290-297.

EU. 2006. *EU Directive 2006/48/EC.* 2006.

Fabozzi, F. J. and Kothari, V. 2008. *Introduction to Securitization.* Wiley, 2008. ISBN 0470371900.

Farmer, J. D. and Foley, D. 2009. The economy needs agent-based modelling. *Nature.* 5 August 2009, 460, pp. 685-686.

FED. 2011. FRB: Statistics and Historical Data. [Online] 2011. [Cited: 21 February 2011.] http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm.

Freixas, X. and Rochet, J-Ch. 2008. *Microeconomics of Banking.* 2nd ed. MIT Press, 2008. ISBN 0262062704.

Freixas, X., Parigi, B. and Rochet, J. C. 2000. Systemic risk, Interbank relations and liquidity provision by the Central Bank. *Journal of Money, Credit, and Banking.* 2000, Vol. 32, 3, pp. 611-638.

G20. 2010a. The G20 Seoul Summit Leaders' Declaration. [Online] 11-12 November 2010a. [Cited: 4 April 2011.] http://media.seoulsummit.kr/contents/dlobo/E1._Seoul_Summit_Leaders_Declaration.pdf.

—. 2010b. The G-20 Toronto Summit Declaration. [Online] June 2010b. [Cited: 4 April 2011.] http://www.g20.org/Documents/g20_declaration_en.pdf.

—. 2009. Leaders Statement: The Pittsburgh Summit. [Online] September 2009. [Cited: 8 March 2011.] http://www.g20.org/Documents/pittsburgh_summit_leaders_statement_250909.pdf.

Gai, P. and Kapadia, S. 2010. Contagion in financial networks. *Proceedings of the Royal Society A.* 2010, Vol. 466, No. 2120, pp. 2401-2423.

Group of Ten. 2001. *Report on Consolidation in the financial Sector.* Bank for International Settlements, 2001. ISBN 92-9131-611-3.

Gurley, J. G. and Shaw, E. S. 1960. *Money in a Theory of Finance.* The Brookings Institution, 1960. ISBN 0815733224.

Hannoun, H. 2010. *The Basel III Capital Framework: A decisive breakthrough.* Bank for International Settlements.

Hermsen, O. 2010. Does Basel II destabilize financial markets?: An agent-based financial market perspective. *The European Physical Journal B.* 2010, Vol. 73, 1, pp. 29-40.

ICC. 2010. *Report on findings of ICC-ADB Register on Trade & Finance: Statistical analysis of risk profile of trade finance products.* International Chamber of Commerce, 2010.

IMF. 2011. Data and Statistics: World Economic Outlook Database. [Online] 2011. [Cited: 12 April 2011.] http://www.imf.org/external/pubs/ft/weo/2011/01/weodata/weoselgr.aspx.

—. 2009. *Global Financial Stability Report: Responding to the Financial Crisis and Measuring Systemic Risks (April 2009).* International Monetary Fund, 2009. ISBN 1589068092.

John, K., John, T. A. and Senbet, L. W. 1991. Risk-shifting incentives of depository institutions: A new perspective on federal deposit insurance reform. *Journal of Banking & Finance.* 1991, Vol. 15, 4-5, pp. 895-915.

KPMG. 2010a. Basel 3: Pressure is building... [Online] 2010a. [Cited: 7 April 2011.] http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Basel-3-dec-2010-v3.pdf.

—. 2010b. Evolving Banking Regulation: A marathon or a sprint? [Online] 2010b. [Cited: 6 April 2011.] http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/Evolving-Banking-Regulation-2010.pdf.

Lall, R. 2010. Reforming Global Banking Rules: Back to the Future? *DIIS Working Papers.* 2010, 16.

—. 2009. Why Basel II Failed and Why Basel III is Doomed. *GEG Working papers.* 2009, 52.

Lewis, T. G. 2009. *Network Science: Theory and Applications.* Wiley, 2009. ISBN 9780470331880.

Lux, T. and Marchesi, M. 2000. Volatility Clustering in Financial Markets: A Micro-Simulation of Interacting Agents. *International Journal of Theoretical and Applied Finance.* 2000, Vol. 3, 4, pp. 675-702.

McKinsey&Company. 2010. *Basel III and European banking: Its impact, how banks might respond, and the challenges of implementation.* McKinsey&Company, 2010.

Mejstřík, M., Pečená, M. and Teplý, P. 2009. *Basic principles of banking.* Karolinum, 2009. ISBN 9788024615004.

Meyers, L. A. 2007. Contact network epidemiology: bond percolation applied to infectious disease prediction and control. *Bulletin of the American Mathematical Society.* 2007, Vol. 44, pp. 63-86.

Mishkin, F. S. 2004. *The Economics of Money, Banking and Financial Markets.* 7th ed. Addison-Wesley, 2004. ISBN 0321285468.

Mistrulli, P. E. 2011. Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns. *Journal of Banking & Finance.* 2011, Vol. 35, 5, pp. 1114-1127.

Modigliani, F. and Miller, M. H. 1958. The Cost of Capital, Corporation Finance and the Theory of Investment. *The American Economic Review.* 1958, Vol. 48, No. 3, pp. 261-297.

Muller, J. 2006. Interbank Credit Lines as a Channel of Contagion. *Journal of Financial Services Research.* 2006, Vol. 29, 1, pp. 37-60.

Nier, E., et al. 2007. Network models and financial stability. *Journal of Economic Dynamics and Control.* 2007, Vol. 31, 6, pp. 2033-2060.

Pakravan, K. 2010. Banking 3.0 - financial regulatory systems made simple. *The Banker.* 2010, 1.

Roll, R. 1986. The Hubris Hypothesis of Corporate Takeovers. *The Journal of Business.* 1986, Vol. 59, 2, pp. 197-216.

Sell, F. 2001. *Contagion in Financial Markets.* Edward Elgar, 2001. ISBN 9781840645644 .

Sheng, A. 2010. Financial Crisis and Global Governance: A Network Analysis. In *Globalization and Growth: Implications for a Post-Crisis World.* Commission on Growth and Development, 2010, pp. 69-93.

Shin, H. S. 2008. Risk and Liquidity in a System Context. *Journal of Financial Intermediation.* 2008, Vol. 17, 3, pp. 315-329.

Schelling, T. C. 1969. Models of Segregation. *The American Economic Review.* 1969, Vol. 59, 2, pp. 488-493.

Schooner, H. M. and Taylor, M. W. 2009. *Global Bank Regulation: Principles and Policies.* Elsevier, 2009. ISBN 9780126410037 .

Sinkey, J. F. 2002. *Commercial Bank Management in the Financial Services Industry.* 6th ed. Maxwell Macmillan, 2002. ISBN 0130909106 .

Talley, S. H. 1983. Bank capital trends and financing. *Staff Studies.* Board of Governors of the Federal Reserve System (U.S.), 1983. No. 122.

Tarullo, D. K. 2008. *Banking on Basel: The Future of International Financial Regulation.* Peterson Institute for International Economics, 2008. ISBN 9780881324235 .

Teplý, P. and Pečená, M. 2010a. *Credit Risk and Financial Crises.* Karolinum Press, 2010a. ISBN 9788024618722.

Teplý, P., Černohorská, L. and Černohorský, J. 2010b. Key Economic Policy Lessons From The 2008 Financial Crisis. *Anadolu University Journal of Social Sciences.* 2010b, Vol. 10, 2, pp. 123-134.

Teplý, P. 2010c. The Key Challenges of The New Bank Regulations. Paris : World Academy of Science, Engineering and Technology, 2010c. 66, pp. 383-386.

Tesfatsion, L. 2006a. Agent-Based Computational Economics: A Constructive Approach to Economic Theory. In *Handbook of Computational Economics.* Elsevier B. V., 2006a, Vol. 2, 16, pp. 831-881.

Tesfatsion, L. and Judd, K. N. 2006b. *Handbook of Computational Economics.* Elsevier B.V., 2006b. Vol. 2. ISBN 0444512535.

The Economist. 2010. Agents of Change. July 2010.

US 1899. *Auten v. United States National Bank of New York.* 1899.

Upper, C. and Worms, A. 2004. Estimating Bilateral Exposures in the German Interbank Market: Is There a Danger of Contagion? *European Economic Review.* 2004, Vol. 48, 4, pp. 827-849.

Upper, Ch. 2011. Simulation methods to assess the danger of contagion in interbank markets. *Journal of Financial Stability.* forthcoming, 2011.

Van Lelyveld, I. and Liedorp, F. 2006. Interbank Contagion in the Dutch Banking Sector: A Sensitivity Analysis. *International Journal of Central Banking.* 2006, 2, pp. 99-133.

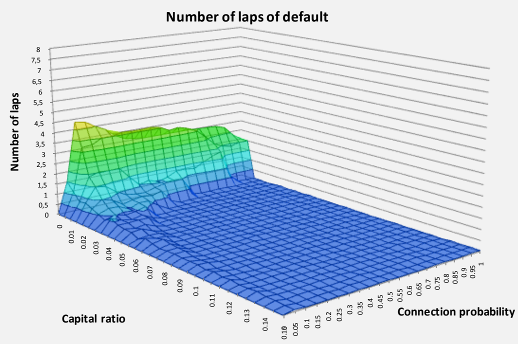
Wells, S. 2004. Financial interlinkages in the United Kingdom's interbank market and the risk of contagion. *Bank of England Working Papers.* 2004, 260.

Wilhite, A. 2006. Economic Activity on Fixed Networks. In *Handbook of Computational Economics.* Elsevier B.V., 2006, Vol. 2, 20, pp. 1013-1045.

Zákon č. 21/1992 Sb. o bankách (ČR).

Appendix

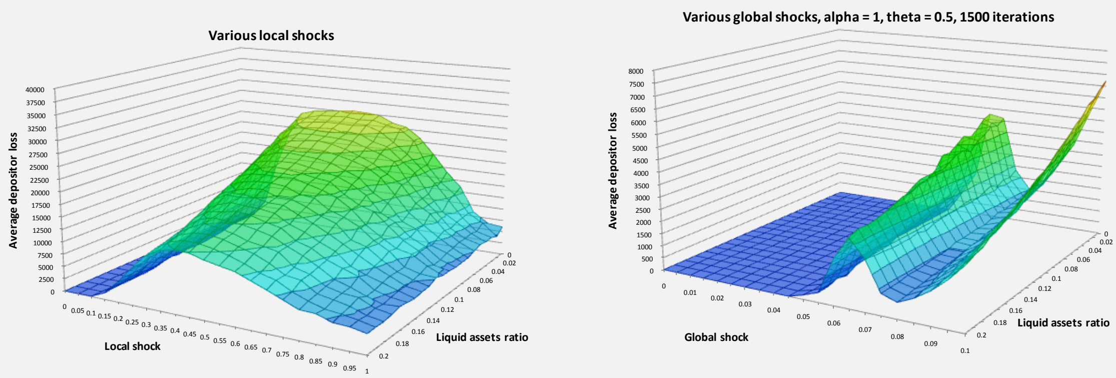
Figure A-1: Laps of default, alpha = 0, basic setting



Note: The chart depicts the average number of laps it took to end the simulation.

Source: author's simulations

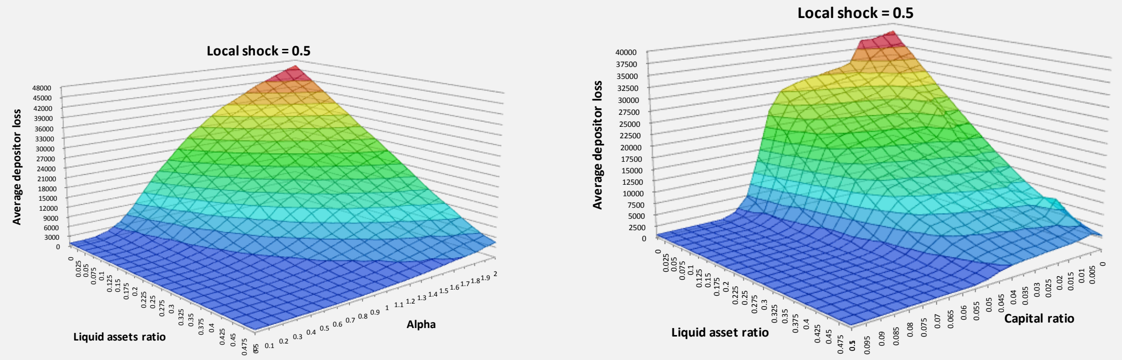
Figure A-2: Liquidity regulation - depositor loss vs. Liquid assets ratio and shock size



Note: In the right chart, the depositor loss is not an increasing function of the shock value because it also depends on the dynamics of the simulation, i.e. how many laps it takes for the system to crash.

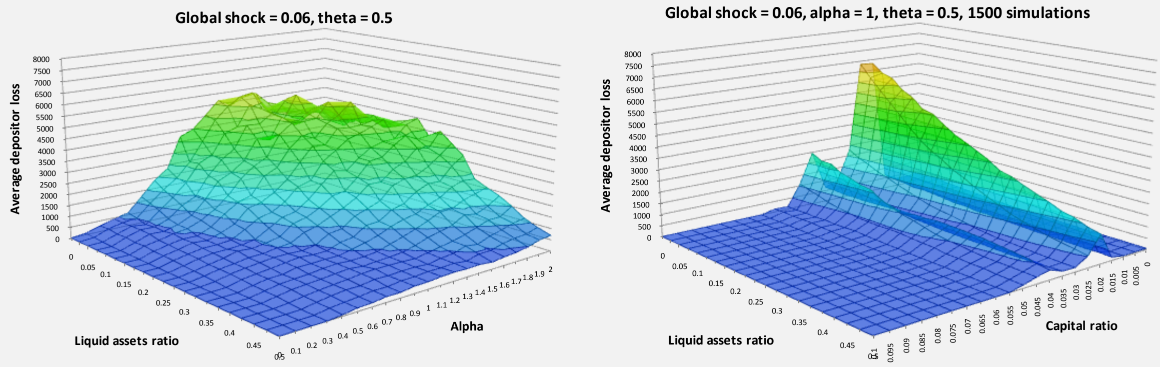
Source: author's simulations

Figure A-3: Liquidity regulation - depositor loss in case of a local shock



Source: author's simulations

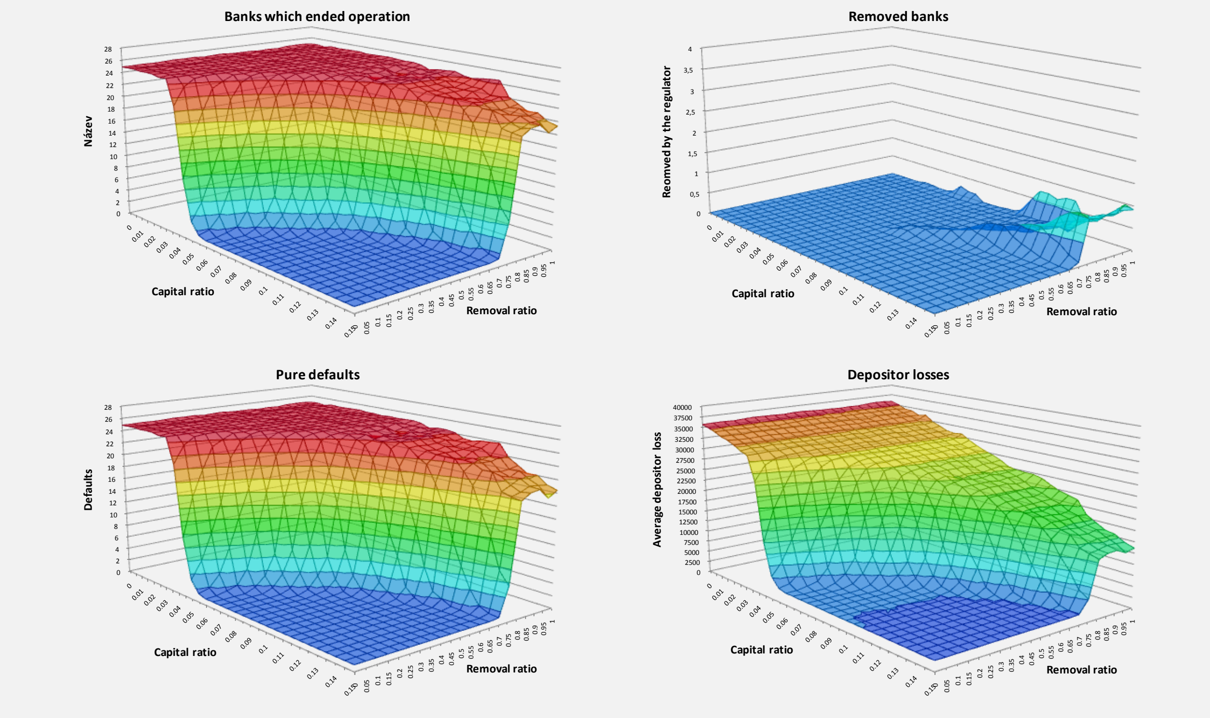
Figure A-4: Liquidity regulation - depositor loss in case of a global shock



Note: In the right chart, the depositor loss is not an increasing function of the shock value because it also depends on the dynamics of the simulation, i.e. how many laps it takes for the system to crash.

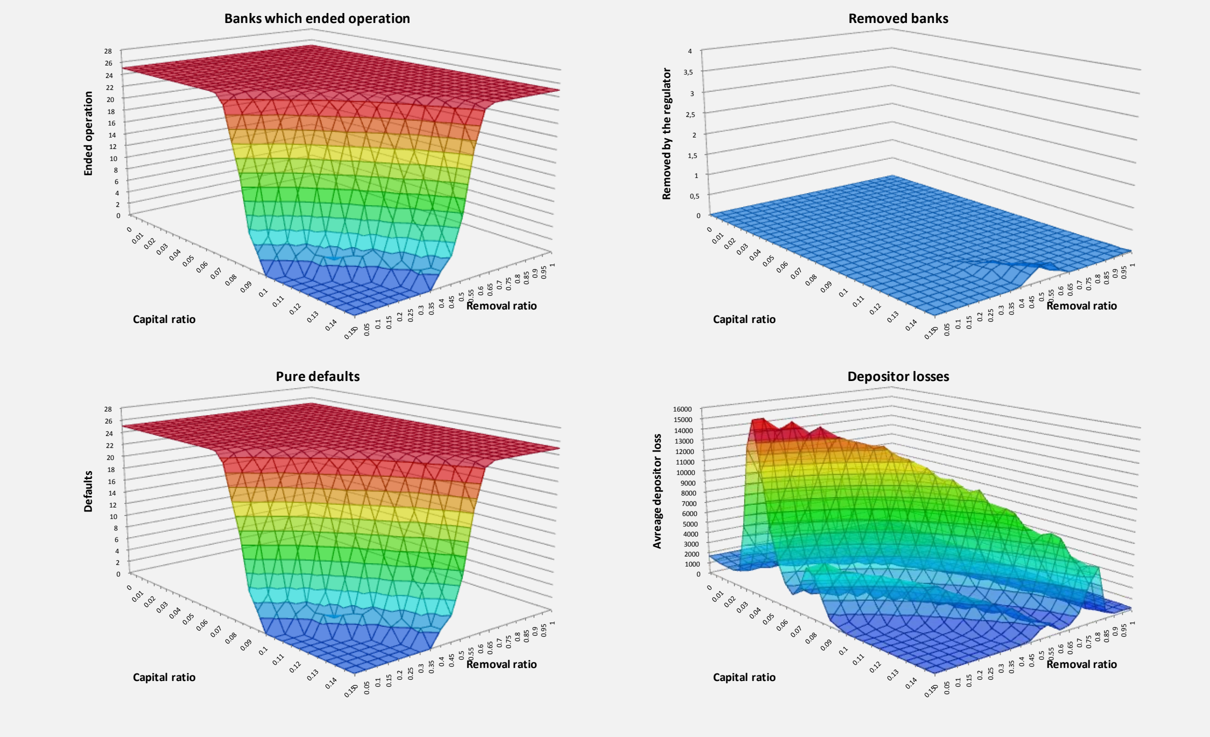
Source: author's simulations

Figure A-5: CAD1 measure, local shock = 1, alpha = 1



Source: author's simulations

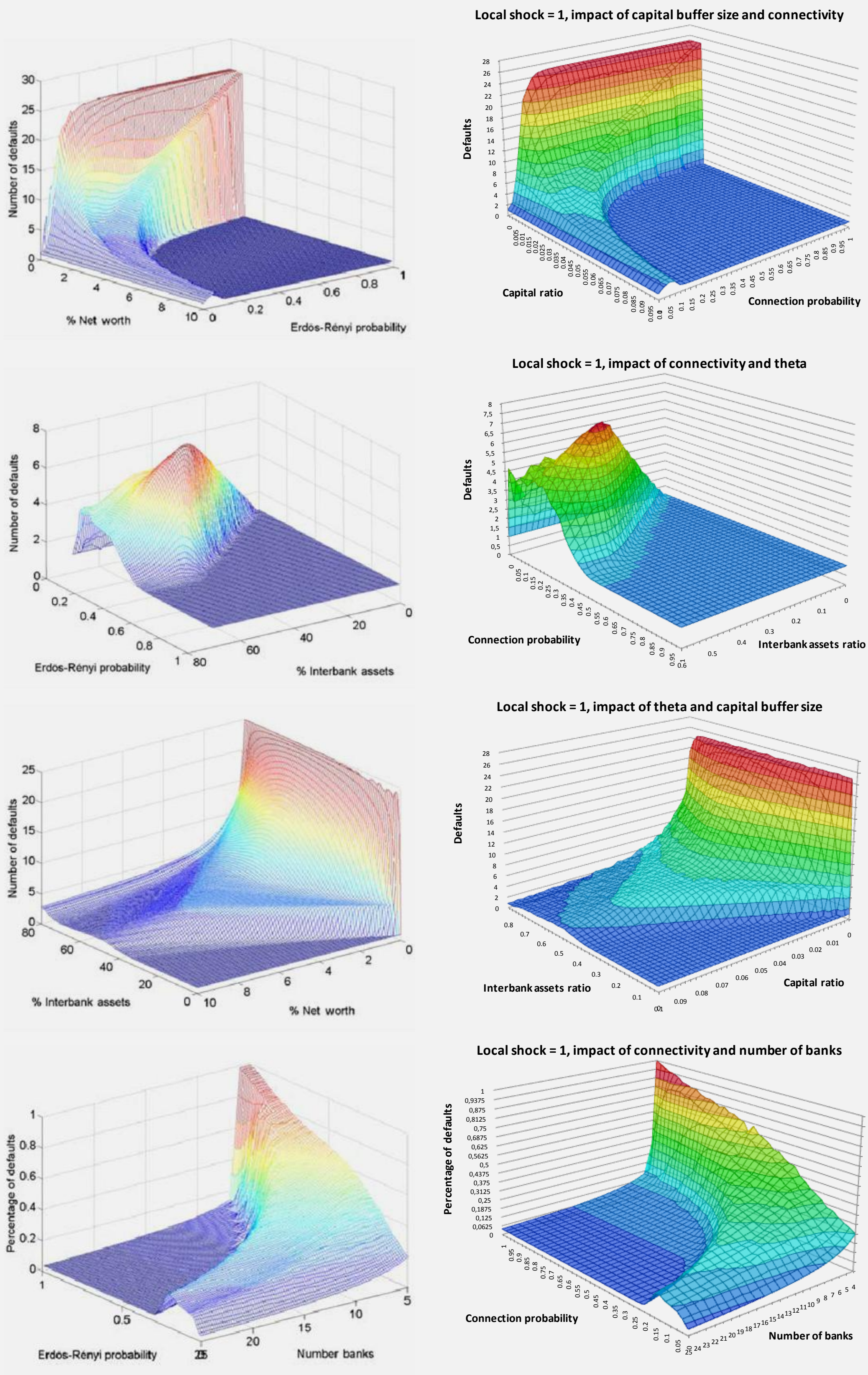
Figure A-6: CAD1 measure, global shock = 0.1, alpha = 1



Note: In the right chart, the depositor loss is not a decreasing function of the capital ratio because it also depends on the dynamics of the simulation, i.e. how many laps it takes for the system to crash.

Source: author's simulations

Figure A-7: Reproduction of the results of (Nier, et al., 2007) for several parameter combinations



Note: On the left side, there are results generated by (Nier, et al., 2007)*, on the right side are our simulations.*

Source: (Nier, et al., 2007)*, author's simulations*