University of the Aegean
Department of Business Administration, Business School

An Agent-based Modelling Platform for Financial Crisis Simulation

Dissertation submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Efstathios Polyzos **December 2018** **Doctoral Thesis**

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Chios, December 2018

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Executive Summary

The prediction and the consequences of banking crises continue to be a fab in academic and political discussions. Researchers attempt to describe the causes and the effect of these crises on the other branches of the economic environment. Despite the frequent and the gravity of financial crises, authorities have proved to be unable to prevent them or to contain their negative consequences.

In this dissertation, we present an agent-based modelling platform that attempts to explain the links between the financial system and the rest of the economic ecosystem. We begin by discussing major financial crises which date as far back as the 18th century. We then present our modelling platform and the literature that supports it and show how it can be applied to simulate the economic system.

Then, we execute simulations, employing our agent-based model to examine the effects of banking regulation and of banking crises on various aspects of the economy. We examine the consequences on financial stability and on the real economy and find that the suggestions of Basel III are inadequate to prevent banking crises and, additionally, have negative effects on the banking sector and on the total output. Our findings suggest that some of the criticism against the proposed measures is justified, since neither economic crises nor contagion are diminished under Basel III. At the same time, our findings support that the stability goal is met, at least in part.

We also assess the adequacy of various solutions to bank distress with respect to subjective well-being and we find the detrimental effects of instability on happiness. We also show that societal preferences should be taken into account, the different choices of response carry a different opportunity cost in terms of

welfare. To this effect, we propose an ideal policy mix, which depends on the preferences and on the macroeconomic goals of authorities.

We also test for the effects corporate governance factors on the ability of financial institutions ability to weather the storm during times when the banking system experiences distress. In this part of our research, we test existing risk estimation models and show that governance factors should be taken into account when evaluating the state of banking institutions. Our empirical results put further emphasis on the inclusion of these factors in the regulation regarding banking supervision, particularly in context of the Eurozone banking union.

We modify our modelling platform to simulate two current events: the banking crisis in Greece and the oncoming Brexit. In Greece, we examine whether capital controls were enforced at the appropriate time and attempt a prediction on the end of these restrictions. We demonstrate their destructive effects on both the financial system and the real economy and show that the response of Greek authorities was delayed. Regarding Brexit, we test for the short-term and long-term effects on both sides of the Channel, taking into account the relative strength of the UK economy and the banking sector *vis-à-vis* the EU. Our results in this part of the research confirm predictions regarding the output cost of Brexit, but show that there is big burden to be borne by the EU as well, with the banking system suffering significant losses, particularly over the longer term. We also propose that that policymakers should take into consideration the dynamic effects that may be caused by UK bank assets moving to the EU after Brexit, since our model shows that, as the UK banking system loses its assets, the end state of the UK economy is deteriorated while the end state of EU economy is improved.

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Part A - Theoretical Background

Chapter 1. Introduction

We are experiencing a post-financial crisis state of the economic systems worldwide, which are still trying to deal with the repercussions. This crisis has clearly demonstrated the flaws of the global banking system, as both its manifestation and its consequences were not limited to only a single economy. Additionally, the crisis has increased mistrust in the banking system, both among its participants (financial institutions and investors) but also from the part of governments and regulatory authorities. Even now, 10 years later, this trust has yet to be restored.

The regulatory response to the financial crisis was the introduction of a stricter framework for capital requirements and the establishment of new procedures to dynamically monitor financial institutions. These were included in a series of measures termed Basel III, a new set of rules which are gradually being phased, in a process that started in 2013 and has yet to be completed. Under these rules, financial institutions must operate and fulfil a very particular role in the economic system. The immediate criticism of the new measures suggested that they did little to deal with the problems of their predecessor, Basel II, and in particular those that were regarded as root causes of the crisis (Quignon, 2011, Allen et al., 2012).

In the current thesis, we present an agent-based framework which was designed to simulate financial and economic systems. This model has been used to

examine a series of situations that relate to banking crises and banking regulation. We propose that this agent-based model can be used for behavioural modelling of the participants in the economic and financial system. We will show how this type of model is better suited for the purposes of this form of study. The model employs features from the relevant literature and permits us to perform simulations on a variety of situations and gather statistics on key economic figures.

Despite the fact that there have been many trending topics in current economic and financial literature relating to the financial crises, our work focused mostly on the financial stability approach and how financial crises are transmitted within the economics systems, both among the financial agents as well as towards the real economy. The way each crisis finds its way through the financial institutions has been an important topic in the literature. Current research deals with different aspects of these issues, proposing models that describe a subset of the economic agents and their transactions. Additionally, there are numerous studies that quantify the results of crises in money terms and that propose different solutions to the problem. Our work focuses mainly on financial stability and examines the effects of banking crises on the market structures.

Our empirical study includes using the different versions of the model on a series of simulations. We begin by modelling the effects of the increased regulation of Basel III on the banking system, as compared to other alternatives. We show that financial stability is improved under Basel III, but that the financial system is restrained by the strict set of rules. Then, we discuss the effects of Basel III on the real economy, indicating possible alternatives, where we show than increased regulation produces a negative effect on economic performance. We also examine possible solutions to bank distress, with respect to financial stability,

economic performance and subjective well-being, and show that the newly implemented bail-in solution is not a panacea that will solve all the problems of the financial system, by limiting moral hazard, without creating new issues. Finally, we have shown that corporate governance mechanisms play an important part in bank viability and that they should be taken into account during regulatory design, in conjunction with financial data.

Keeping up with current events, we have designed two more implementations of the model. Motivated by the adoption of capital controls in Greece, which have yet to be fully abolished, we examined the effects of the twin crises (economic and political) in the banking system and attempted a prediction of the end date of the restrictions. Additionally, we simulated a Brexit-type situation in our artificial economic system and presented the short- and long-term effects of the separation, pointing the research towards the negative effects of this on the EU banking sector.

Our work contributes to six aspects of the existing literature. First, it adds to a series of studies that examine the effects of the implementation of Basel III on the banking business (Miu et al., 2010; Blundell-Wignall & Atkinson, 2011; Allen et al., 2012; Chortareas et al., 2012; Petitjean, 2013), but from a more hands-on point of view. Second, it corroborates existing literature (Chortareas et al. 2012, Quignon, 2011) on the spillover effects of banking crises to the real economy and on the suitability of Basel III with respect to the mitigation of these effects. Third, to the best of our knowledge, this is the first study that uses agent-based modelling to examine the links between subjective well-being and financial stability. Fourth, it is the first effort to utilise an agent-based modelling platform as the medium with which to carry out simulations in the fields of management and corporate governance. Fifth, it models the effects of a Tobin tax on the

economy, both from the aspect of financial stability and from the aspect of societal welfare. Sixth, it proposes the best policy mix to handle banking crises according to society's preferences. Lastly, it supports the use of agent-based modelling as a means to describe economic and financial systems, a technique that has seen limited support in the past but is undeniably suitable for such a task.

This work is split into two parts. In the first part, we start by presenting a thorough review of the most important financial crises in economic history. We are focused on crises which are related to the banking sector and not to stock market crises (e.g. the dot-com bubble of the early 2000s in US stock market). Through this discussion, we aim to single out similarities between the banking crises and show that the progression of the events is similar in most cases. We then present the relevant literature that will help us develop and support the agent-based model. The literature presented is broken into subsections, following our handling of different aspects of financial systems. Following that, we present our agent-based model. We describe the model design and include the formal model definition.

In the second part, we describe our empirical findings in terms of the banking sector, the real economy, the subjective well-being of households and corporate governance. We also present the particulars of our more focused studies, on the Greek banking sector and on the possible effects of Brexit. We present the relevant literature, we explain the particular implementation of the model in these cases and analyse our findings. We conclude this work by presenting the policy implications and our conclusions.

Chapter 2. Major Financial Crises

As a first step in this research, it is important to go through the list of major financial crises that date as back as the 18th Century. In any economy, financial institutions play a unique role, acting as intermediaries between lenders and borrowers, thus facilitating the trade of financial assets in an economy. If these financial institutions fail in large numbers, then we can term this occurrence a financial crisis. This type of crises normally leads to a significant slow-down of the flow of funds between lenders and borrowers, which can severely hinder the ability of firms to conduct their business and thus cause recessionary pressures.

Our goal in this section is to discuss the historic events and link them to current literature and to our modelling efforts. We show that even though each crisis has had its own unique characteristics, both from a historical and a financial standpoint, there are similarities to be found and lessons to be learnt from all of them. However, our discussion also shows the short memory of policymakers and of market participants, since all the lessons learnt are easily forgotten, leading up to the next financial crisis, in too short a period.

2.1. Amsterdam Banking Crisis (1763)

The Amsterdam Banking Crisis of 1763 is quoted as the first known financial crisis in history. The crisis has its origins on the Treaty of Hubertusburg, which was signed in Germany in February 1763 and which marked the end of the Seven Years' War. This war, which began in 1756, involved all the major European powers of that time but did not include the Netherlands. The signing of the Treaty was a chance for a fresh start in Europe, since it put an end to the war with few changes in the borders.

During the seven years of the War, banking firms in Amsterdam had generated enormous profits by trading with European banks, in particular by lending vast amounts of money, which the borrowing banks in turn lent to their governments in dire need of financing due to their war efforts. As collateral, Dutch banks accepted large quantities of goods which were transported from Europe to Amsterdam.

The events leading up to the crisis exhibit many similarities to the Financial Crisis of 2007. In the late eighteenth century, Amsterdam was an important cog in the global financial system (Roussakis, 1997). Financial activity was generally controlled by a small group of merchant banking firms, which were in essence privately-owned firms, dealing in both commodities and financial products. Their financial intermediation function was not that of current deposit institutions, since accepting deposits was viewed as a risky venture (Schnabel and Shin, 2004). Instead, they implemented a complex securitisation scheme which has come to be known as the "acceptance loan", which was based on an IOU-type instrument, the bill of exchange.

The initial goal of the bill of exchange was to serve as a short-term contract which dictated that one party was supposed to pay a fixed sum of money at a future date, usually over the short term. However, financial innovation took over and it gradually became an important tool in long-term borrowing. As these bills were actually used to finance long term loans, the short-term obligations were rolled over repeatedly, pushing the maturity back. This did not prevent the maturity mismatch, which should have worked as deterrent to the use of these products. However, the bills of exchange were often traded in the secondary market and each seller actually served as a guarantor to the loan obligation. This (in theory) insured the party holding the bill against the default of the issuer and

in effect prevented the circulation of low-quality bills. This system had some good safety nets but was very prone to a generalised financial crisis which would lead to the simultaneous default of multiple market participants.

This perplexing guarantee scheme, along with the low acceptance fees[1] rendered the bills of exchange a very commonly used tool in the financial markets of the time. However, the guarantee system essentially meant that all participants were bound together by the bill which they had traded. Also, it meant that financing firms could be on both sides of the trade, as they could have a liability on a bill of exchange for which they were the initial lender. Also, the constant and unhindered trading of financial products led some Amsterdam merchant bankers to heavy leverage, thus making them vulnerable to market fluctuations and to a possible slowdown in credit availability.

In 1763, the end of the Seven Years' War saw many merchant bankers with extremely high leverage and significant balance sheet interconnectedness. It also brought forth an immediate drop in the abnormally high prices, that had skyrocketed due to the ongoing war. This means that the goods used as collateral for the enormous loans made during that period immediately lost their value. This lead many banking and trade firms in Amsterdam to bankruptcy and with huge amounts of soared debts. Despite the fact that, initially, most Dutch bankers acted in a conservative manner and did not allow for a rapid growth in their wartime business, others expanded quickly, accumulating huge profits. They seemed to believe that they had undertook sufficient risk insurance (through the multiple guarantees on the bills of exchange) and hedging (through the different maturities of assets and liabilities).

[1] These were the fees paid to market participants for assuming the obligation to pay the bill of exchange.

The bad example in the use of this new financial innovation for expansion was a merchant bank belonging to the de Neufville brothers. Their business grew rapidly, by endorsing a large number of bills of exchange and served as an example for other merchant bankers to follow the same strategy. The de Neufville bank entered into a deal to buy grain from the Russian army, speculating that grain prices would continue to rise. However, the end of the war meant that the brothers lost their wager and the resulting price decline began to also push other prices downwards. This immediately led to a slowdown of credit availability, as it became difficult to roll over existing obligations from endorsed bills of exchange. This further pushed commodity prices down, as commodity merchants made hasty sales in search of liquidity. The interconnectedness of the market meant that any bankruptcy would lead to a Domino effect.

The downfall of the de Neufville bank occurred in July 1763, when they failed to make their payment obligations, and led to a failure of all their creditors around Amsterdam. The bank had leveraged its way into growing to a huge size and the shock was impossible to recover from. The resulting bank run[2] put the merchant bankers under heavy pressure as it meant that it was now impossible to roll over payment obligations from the bills of exchange.

This led to as many as 38 Amsterdam firms going into bankruptcy during the next two months. However, their size was nowhere as near as that of the de Neufville brothers' bank and thus many were able to go back into business shortly after settling their loan obligations. The lessons learned from the Amsterdam Banking Crisis pointed to the combination of the securitisation

[2] The bank run did not take place directly on the merchant banks. There was a group of intermediaries call the "cashiers" who served as a bridge between the larger banks and commodity merchants. They suffered the first wave of the bank run.

system and of the large shock to the commodity prices used as collateral as the culprit for the crisis, not unlike the 2007 crisis. Similarly, the response of the Bank of Amsterdam, which was to supply unlimited amounts of liquidity by putting new money on the market, was replicated in 2007.

2.2. Stock Market Crash (1929)

As World War I ended, the United States enjoyed a decade of post-war economic expansion, which was characterised by such wealth that it has come to be known as the Roaring Twenties. The industrial sector thrived and attracted workers primarily from rural areas, who migrated towards the cities in search of financial prosperity. Indeed, the post-war boom seemed like a unique opportunity for a significant amelioration of the quality of life for all Americans.

Figure 1. A Collection of Newspaper Headlines from 26 March 1929

The positive performance of the industrial sector was matched with a continuous rise in the stock market, which many speculated would not end. However, as we approached the end of the 1920s, the US economy showed clear signs of a slowdown, with all early indicators showing a disturbing decline. Also, the

optimism in the financial sector meant that there was an increase in easy credit for consumers, which in effect led them to accumulate high debts. Matched with the decline in steel production and the drop in new construction projects, this was a recipe for disaster.

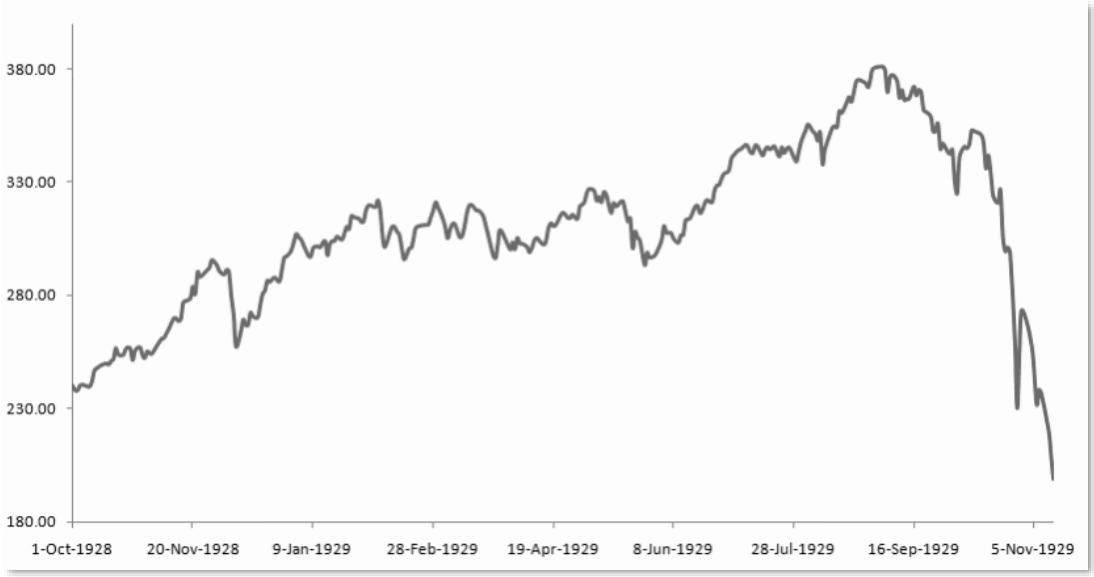


Figure 2. Dow Jones Average (Oct. 1928 - Nov. 1929)[3]

On 25 March 1929, there was a small crash in the stock market, following a negative outlook announcement from the Federal Reserve regarding speculation in the stock market. However, a further increase in available credit halted the drop and things resumed to normal, with a continuing rise in the stock market which led to September 1929, when the Dow Jones average had gained more than 20% since June (Figure 2). The market rise had continued for nearly ten years and had seen the Dow Jones Industrial Average on a peak value of 381.17 on 3 September 1929, nearly ten times as much relative to the start of the rally, around 10 years earlier.

[3] All the historical data series and the corresponding graphs have been adapted from sources in Thompson-Reuters Eikon.

In the days leading up to the crash, the well-known Yale economist Irving Fisher appeared reassuring when he wrote in a New York Times article his famous quote: “Stock prices have reached what looks like a permanently high plateau.” The optimism that had prevailed up to that point was shaken by another famous quote, this time an investor and financial expert, Roger Babson, who said “A crash is coming, and it may be terrific”[4], during his speech at the Annual Business Conference in Massachusetts on 5 September 1929. These two public statements are thought to have activated the negative trends that constituted the Great Crash, as they initiated a mini crash, which some analysts at the time described as a healthy self-correction.

However, following another mini crash in the London Stock Exchange, there was significant instability in the market. There was not a continuous downward trend but rather an incessant switch between high volume sales and price increases. However, on Thursday, 24 October 1929 started there was an 11% drop in the market at the opening bell. On that particular day, trading was heavy and this resulted in delays in reporting trades in stock brokers around the country, which further exacerbated the investor panic. A group of major investors tried to take some action to restore balance in the market, by buying blue chip stocks in values higher than market value, but this failed. As news of the crisis spread over the weekend, the trading day of 28 October 1929 ended with a further 13% drop in the market.

The pivotal day in the crash is reported to be 29 October 1929, which has come to be known as "Black Tuesday” when the selling panic peaked, leading the Dow Jones to a further 12% decrease with high volume sales[5]. Despite effort from

[4] This phrase is known as the Babson Warning.
[5] The trading volume of 29 October 1929 set a record that was left untouched for almost 40 years.

prominent financiers of the era, including the Rockefeller family, to exhibit confidence, the market lost $30 billion two days. The market continued to tumble down rapidly until mid-November, while the record low of the 20th Century was on 8th July 1932, when the index closed at 41.22, with a 89% total loss for all market shares. It must be noted that the drop was so deep that the market managed to reach its pre-crisis levels as late as 1954.

The causes of the Stock Market crisis of 1929 are still a matter of controversy, but most economists agree that it was a combination of the speculative bubble that preceded the crisis with the eminent slump of the US economy, signs of which were clear in all early indicators. Economic activity in general (including stock trading) had peaked, especially in the second half of the 1920s and this included mainly the sectors of steel production and construction. This brought on a generalised sense of economic euphoria and (more importantly) excess funds for investors and households, which could be invested in the continuously rising stock market. The fad was so strong that many were taking out loans in order to invest more and this practice further fuelled the share price increase. However, all these indicators had already slowed down at the beginning of 1929 and some had already began to drop.

In the commodity markets, there was an oversupply of wheat in 1929 from the production of previous years, which caused a sharp drop in wheat prices and threatened the incomes of the farming populations. However, climate incidents in other parts of the world, notably Canada, Argentina and Australia, meant that this excess supply could be exported, thus stabilising prices. This situation transpired in the summer of 1929, but, as the summer ended, European farmers in France and Italy also experienced a good harvest, signalling the end of the positive outlook for US farmers.

Following the lessons learnt from the 1929 crash, stock markets around the world introduced new institutions that allowed regulatory authorities to suspend trading in case rapid declines were observed, since this measure was believed to have been able to halt panic sales, especially those of 28 and 29 October 1929, which remain to this day the largest two-day decline in the Dow Jones Industrial Average. The US economy was hurt by a deep recession of more than 10 years with a record loss in GDP[6] of around 40% and unemployment surpassing 25%.

One of the most important pieces of regulation, the Glass-Steagall Act, was implemented in 1933. The Glass-Steagall Act required a clear separation of investment and commercial banking activities, since excessive risk-taking by banks using depositors' money was considered one of the causes of the crash. This emblematic legislation survived nearly three-quarters of a century before being repealed in 1999, in what has been argued as the start of a deregulatory trend that facilitated the Financial Crisis of 2007 (see section 2.6).

2.3. UK Secondary Banking Crisis (1973–1975)

The UK Banking Crisis of 1973-1975 was termed a "Secondary" banking crisis to reflect the source of the problem, which was smaller ("secondary") banks, and not to lessen its significance. The smaller banks had contributed to a huge credit expansion, which was led primarily by rising housing prices in the previous years. In order to maintain their share in the loans market, these banks had been leveraged significantly by borrowing large amounts of money, based on the optimistic view that increasing housing prices would maintain their upward trend.

[6] GDP: Gross Domestic Product.

However, as all bubbles, this housing bubble burst around the November 1973 oil crisis. This combination of the previous reckless credit expansion with the plunge in housing prices left the secondary institutions holding many loan assets with an LTV[7] value far greater than 100%. The Bank of England intervened, directly bailing out nearly 30 banks and assisting 30 more, spending funds in excess of £100 million (Reid, 2000). The crisis was further exacerbated by the effect of a global mini stock market crash, which occurred in part due to the oil crisis and hit the UK right in the middle the housing price crash.

A few measures were implemented in an effort turn the situation around for the housing market and for the credit market, but the inflationary pressures meant that there was need for contractionary measures, which would put the banking sector in further distress. It must be noted here that the causes of this crisis are also a matter of controversy, on which Reid (2003) suggests that it was a combination of loose regulation, problems in the housing market (including the price bubble and a rent-price freeze in 1971) and political uncertainty and unrest, which culminated in public sector and industrial strikes.

2.4. The Japanese Asset Price Bubble (1986–2003)

As the 1980s began, Japan was a booming economy, showing signs of greater potential for future development. Fuelled by technological innovation, a high work ethic and export-led growth, Japan enjoyed a status as one of the leading countries on the world level with unparalleled prosperity. This achievement is even more noteworthy if we are to consider the significant damage by US bombings during World War II on most large cities (including Tokyo) as well as

[7] LTV (Loan-To-Value) is a banking term referring to the ratio of the loan asset value over the value of the property used to secure it.

the horrendous atomic bombings of Hiroshima and Nagasaki. The country exited the World War II with little industrial capability, shattered infrastructure and chronic food shortages. Additionally, the country was under occupation by the Allied Powers, which were led in 1946 by General Douglas McArthur.

However, this occupation proved to be constructive for Japan as the Allied command focused on rebuilding infrastructure and strengthening the country. As a result, despite their historical differences, especially during World War II, the cooperation of Japan with the United States has since been a very positive one, even after the Allied occupation came to an end, in 1952. The country had agreed, bitterly according to some (Hara, 2003), to accept US soldiers permanently stationed in its soil. This, however, meant that the Japanese did not need to focus on security at all and could now focus on developing their economy. To a certain extent, the Japanese growth miracle is a testament to the economic benefits of the absence of the possibility of military conflict.

As a direct result, there was a gradual but steady rise in the standard of living. The positive economic performance brought forth political stability which created a virtuous cycle with further growth. Thus, the growth rates started to accelerate significantly during the 1960s. Expansion continued unhindered until the mid-1970s, when the oil crisis manifested. Japan, with little oil production to cover its increasing needs, turned the crisis into an opportunity to improve its economic performance by specialising in sectors where it could best compete with its rivals. This decision led the Japanese to focus mainly in high technology industries. As we entered the 1980s, the Japanese economy was an international point of reference for its economic performance. Its growth rate was significantly higher than its trading rivals.

In September 1985, the Plaza Accord was signed in New York, between Japan, the United States, France, West Germany and the United Kingdom. This agreement allowed the US to intervene in currency markets in order to depreciate the dollar against the yen (and the Deutsche Mark) and thus increase competitiveness of the US industries against their two biggest trading rivals. The US economy was already in a recession in the early 1980s and major industry players lobbied the government for protection against foreign exports.

This is considered the starting point of the Japanese crisis (Frankel, 2015) since Japan's growth model was predominantly export-led. Despite the *de facto* acceptance of Japan as an important global economic power, the agreement created fears of a domestic recession. As a precaution, authorities pursued expansionary fiscal and monetary policies to battle the effects of the expected sharp appreciation of the yen.

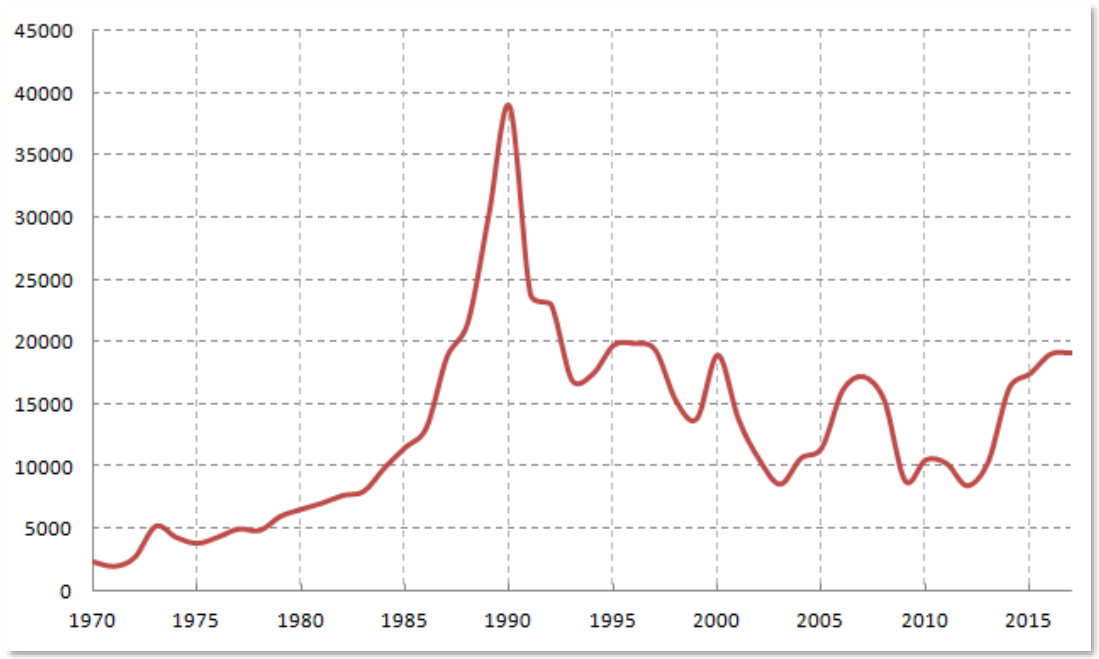


Figure 3. The Nikkei 225 Stock Index (1970-2015)

At the same time, a strong yen created a confidence and optimism in the future of the Japanese economy. This belief – supported by abundant liquidity and self-fulfilling expectations of ever rising prices of stocks and land – led to asset price bubbles. Stock and land prices peaked in December 1989 and March 1991, respectively. The Bank of Japan lowered interest rates to encourage domestic consumption and investment. Despite the lower interest rates, the Japanese banks had abundant funds[8] to lend and created a spree of personal and corporate loans, which was further stimulated by the cheap cost of the yen.

The significant credit increase, coupled with a widespread feeling of prosperity and power, led Japanese individuals and companies alike to start purchasing assets, mainly domestic real estate. This started increasing asset prices and further spurred on the lending party of Japanese banks. Despite the clear signs of overvaluation, banks continued to accept real estate as collateral in order to continue lending money. The increased financing and the appreciated yen, combined with the accumulated dissatisfaction of the previous years of austerity, meant that individuals and corporations were also able to spend money excessively abroad as well, either by purchasing high-value assets[9] or for personal, luxury goods. In 1989 the Nikkei 225 Stock Index peaked nearly 40,000 points, a huge increase relative to the 10,000 of 1985 (Figure 3), while land prices peaked in 1991.

As the asset bubble burst, there were three direct effects on the domestic economy. First, the resulting economic slowdown first led to growing levels of Non-Performing Loans (NPLs), especially after the second half of the 1990s. The

[8] The Japanese are notoriously known for their high savings rates and, before the appreciation of the yen, had already amassed enormous amounts in personal savings.
[9] The most notable purchase of the era is the purchase of the Rockefeller Centre in New York for $846m by the Mitsubishi Estate Company in 1989.

increase of the NPLs meant that there would be regulatory issues with domestic banks, since they would normally need to increase their capital reserves[10]. This would tend to decrease available new credit to the economy, which would cause further deflationary pressures. Additionally, the extended use of overvalued land as collateral for high-risk loans created a significant NPL problem in the banking sector, which was further exacerbated by the economic recession. What is more, many loans were on property-related sectors such as construction and real estate, which were directly hit by the bubble burst (Cowling and Tomlinson, 2000). Finally, the last issue relates to the stock market. Japanese retail banks were allowed to hold common stock assets on their balance sheet. As the stock market deflated, the banks' balance sheets shrank significantly, thus hindering their ability to handle the increasing NPL assets. In this manner, the credit crunch was unavoidable, despite efforts from authorities to avoid such an event.

As banks started to fail[11], monetary authorities tried to support the banking sector by increasing liquidity, but political problems discouraged the use of public funds to help banks in distress. Non-financial instruments were also used, namely increased deposit protection and strengthened regulatory requirements, but they did not help in addressing the issues of the larger banks, especially considering the fact that the economy had already slowed down significantly by the mid-1990s.

As the economy started to slowly recover, the outbreak of the Asian Financial Crisis (see section 2.5) in 1997 called for tighter fiscal policies which sent Japan back into a slump. This triggered a banking crisis, which started in late 1997 and affected the larger financial institutions. In an effort to prevent a bank run, the

[10] Actually, the increase in mandatory capital reserves resulted not only from increasing NPLs but also from increasing regulatory requirements.
[11] In 1991, the Toho Sogo Bank was the first to fail in this series.

Japanese government made available a whopping 60 trillion yen as part of the deposit guarantee system, which at the time amounted to nearly 12% of GDP. The banking crisis became evident according to all possible definitions (see section 3.2) after the (temporary) nationalisation of two major banks, the Long-Term Credit Bank of Japan and the Nippon Credit Bank. As the NPLs continued to be a major problem for problematic banks, the recognition of the full scale of the problem brought forth a series of increased provisions and direct write-offs which cost retail banks around 100 trillion yen.

The burst of the Asset Bubble and the resulting economic and banking crisis cost the economy much more than the directly provided public funds. The economic slowdown of such a rapidly growing economy cost Japan approximately 18% of its GDP (Laeven and Valencia, 2008).

2.5. The Asian Financial Crisis (1997)

The Asian miracle of the so-called "tiger economies" of South-East (SE) Asia, namely Singapore, Malaysia, Thailand, Indonesia, Hong Kong, and South Korea began little after the mid-1980s. In a setup similar to the Japanese economy, the tiger economies were powered by their dominant export sectors and enjoyed a GDP growth rate steadily over 5%, which was impressive by any standard. These countries benefitted from a unique combination of relatively cheap, but well-educated labour force, which, coupled with trade liberalisation at the international level, helped them achieve unprecedented, export-led levels of growth.

The Asian Economic Model was touted (Kuznets, 1988) on its superiority relative to the United States or Western European nations. It seemed that the countries

of the SE Asian region had assembled a capitalist economy much more effectively than their Western competitors. This economic growth was based on state-directed capitalism and the hype surrounding it suggested that it combined the dynamics of the free market economy with the benefits of central planning (Lim, 1998). It was deemed that industrial policy was the result of close cooperation between local governments and domestic businesses, which helped in formulation long-term strategic goals which were ineffable in Western economies. In addition, the lax regulation of financial trading was argued to allow for more flexibility for Asian corporation, with its admirers failing to acknowledge its risks. Finally, the government policies designed to encourage exports and protect domestic producers from cheaper imports were celebrated as a vehicle of growth, despite the doctrines of free-trade economics.

The success of the Asian Economic Model came to a sudden end in 1997 in a domino meltdown that began in Thailand. On 5 February 1997, a Thai construction company, Somprasong Land, announced its failure to make a scheduled interest payment, thus going into default. We will examine the reasons why the property market was the first victim, but we should note that the property market was clearly at the epicentre of fears regarding the financial condition of its participants. After the default of Somprasong Land however, it became evident that many property developers would soon experience significant financial difficulties, dragging with them many of the country's financial institutions, which were exposed to them. In addition, many of these institutions were heavily leveraged by using dollar bonds to finance the market in the local currency, the Thai baht. This practice left the banks widely exposed to the default risk of their debtors, since it meant that, in essence, they would be unable to absorb any increase in NPLs. As the biggest financial institution in the

country, Finance One, failed, despite despaired efforts from authorities to save it, it was now clear that other institutions would soon follow.

In spite of the impending banking crisis, the financial crisis was mainly ignited by a currency crisis. It must be noted at this point that most governments in SE Asia had made a strategic choice to peg their currency to the US dollar. This was a sound strategy in the previous decade of positive economic growth and of the strong financial sector. However, the collapse of Finance One brought on fears of a generalised crisis and provoked a currency attack on the baht. The attack was justified financially, since many private Thai debtors had taken out dollar-denominated loans and thus it was reasonable to assume that the demand for dollars would increase, relative to the baht. The traders took short future positions on the baht putting strong pressures of devaluation on the currency, which the government tried to battle by purchasing baht in the foreign exchange market and by raising the interest rates. The interest rate increase, however, put further pressure on the local debt crisis.

In response to these pressures, the Thai government was forced to abandon the dollar peg and allow the currency to float freely in the exchange markets. This led the baht to a free fall (Figure 4) that resulted in a devaluation of more than 50% in less than one year's time. This effectively doubled the amount of baht required to service the dollar denominated debt commitments undertaken by Thai financial institutions and businesses, causing a n new series of bankruptcies and pushing the Thai stock to record lows. The Thai government called in the International Monetary Fund (IMF), in a desperate move to avoid country default and to restore international faith in its ability to meet its financial obligations. The IMF policies of fiscal austerity deepened the recession and did little to help the domestic corporate debt crisis.

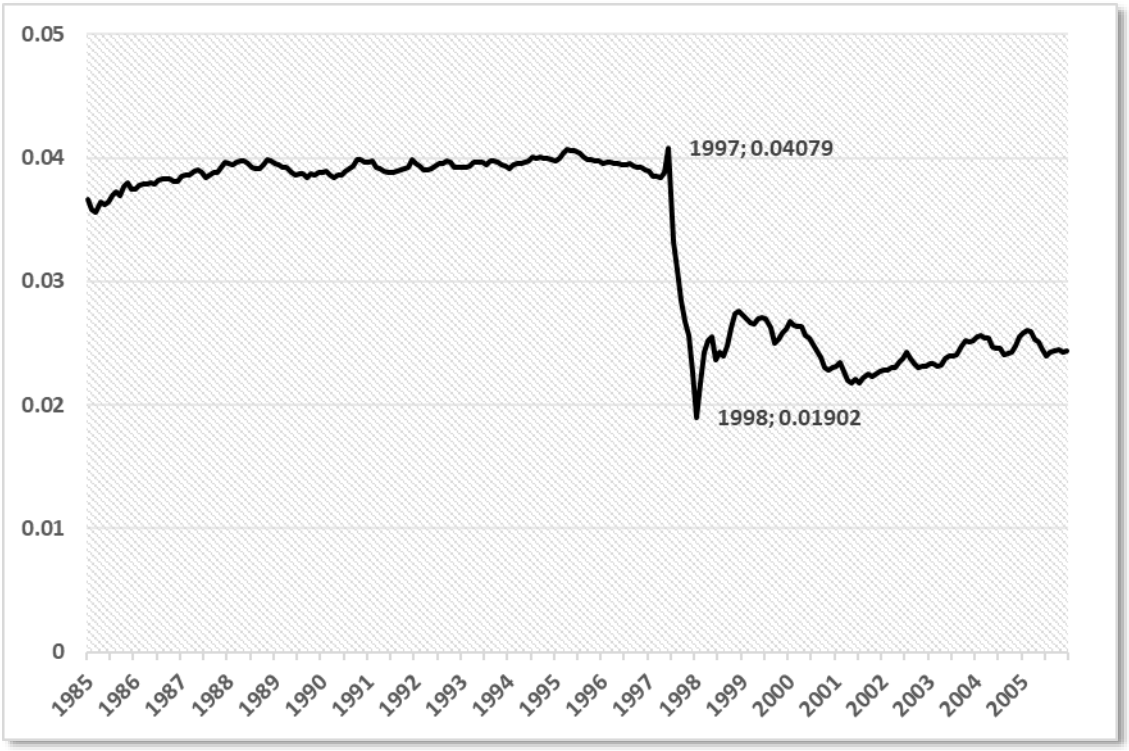


Figure 4. Exchange Rate of the Thai baht to the US Dollar (1985-2005)

The next currency to get hit by speculative attacks was the Malaysian ringgit, with the Indonesian rupiah and the Singapore dollar following right after. Malaysia let its currency float freely in the summer of 1997, leading to a devaluation 50%, with similar losses for the Singapore dollar. The devaluation of the rupiah resulted in a loss of value of 75%. By 1998, the stock markets in most tiger economies had lost over 70% of their value.

Despite the differences between the economies, the causes of the crisis were similar, as most of them based their growth model on the same economics principles. Exports were the main engine of economic growth, with most economies achieving growth rates on their export sector by around 15%. Also, they were able to shift their production from basic commodities (e.g. textiles) to more complex ones (e.g. cars or electronics). The economic growth ignited an investment boom (both domestic and international, the latter being most

prominent in Malaysia) mainly on construction, in order to develop the necessary infrastructure, including commercial and residential properties. Despite the increase in supply, property values increased, based on the widespread economic optimism of the positive performance. As was the case in the other crises we examined, the building boom was financed by domestic banks, using the overvalued properties as collateral. The credit-based construction surge included industrial properties, particularly for exporters, who had soaring profits and were looking to expand their business, often encouraged by politicians setting forth national investment strategies. It also included government projects, as local authorities tried to attract foreign white-collar businesses into their countries.

In sum, by the mid-1990s SE Asia was in the middle of an unprecedented investment boom, much of it financed with borrowed money. As the volume of investments grew rapidly, the quality of these investments deteriorated, especially considering that many were based on the over-optimistic projections that demand would continue to grow at the same excessive pace. This naturally resulted in significant excess capacity, particularly in the property sector, which is one of the causes which incited the burst of the asset bubble.

A further aggravating factor was the fact that much of this debt was not in local currencies, but in US dollars, as we mentioned earlier. Since local currencies were pegged to the dollar and dollar interest rates were lower, this was a reasonable choice, so long as domestic authorities in the region could maintain the dollar peg. Should currencies start to depreciate against the dollar, the debt of domestic firms would increase, putting pressure on their efforts to serve their obligations. If this pressure was coupled with decreasing demand, it was a certain recipe for default.

When the currency speculation began, the local authorities had no choice but to try to defend their currency, hoping that the attacks would stop. Considering the vibrant export sector of the Asian tigers, this would normally be feasible, even in the case of the coordinated attacks which their countries experienced. However, in reality their Balance of Payments (BoP) was in deficit, primarily due to the strong investment boom of the late 1990s, which required an abundance of foreign goods. In the calm and optimistic setting of the previous years, it was easy for local governments to maintain the dollar peg. Once they were under speculative attacks, it was impossible to fight off the aggressors and the peg was abandoned quite quickly.

Many economists had been arguing for a long time before the crisis that the Asian economic miracle had little to do with the Asian Economic Model of financial flexibility and cooperation between governments and businesses. They warned about the potential risks of government-directed investments and loosely regulated financial systems. In the aftermath of the crisis, the need for close financial regulation was reaffirmed, but its application was slack, as attested by the Financial Crisis of 2007. In fact, there is a pattern which is gradually being formulated, regarding the causes of the major financial crises, which we will discuss in more detail in section 2.7.

A final point of interest in the Asian Financial Crisis is the near collapse and consequent bailout of Long-Term Capital Management (LTCM), a private hedge fund which had been experiencing very high returns before the crisis. The company was started by professionals of the financial industry and employed as members of the board of directors two Nobel-winning economists, namely

Myron Scholes and Robert Merton[12]. Following the crisis in SE Asia, the fund saw its returns drop significantly, as risk aversion among investors increased. In addition, some strategy errors led to significant losses and resulted in a collapse of the company's equity, as its investors started liquidating their positions (Jorion, 2000). In fear that a collapse of an important player in the market could initiate a generalised panic, the Federal Bank of New York organised a bailout deal with the fund's major creditors. Despite its relatively small magnitude and its isolated nature, this bailout should alert authorities as to the risks of globalised trading strategies. In addition, the company's financial innovations[13] helped its management avoid regulatory control and increase its leverage to a huge extent; in a sense, this is what saved them, since they had already become too-big-to-fail.

2.6. Financial Crisis of 2007

The Financial Crisis of 2007[14] is the most recent major crisis in the international financial system. Despite its deep impact and the major repercussions that it has had, it appears that the lesson learned from this event have not really been assimilated into regulatory policy. We will begin this section by describing the series of events in this crisis, discussing the setup of the US banking system during this era. We will continue by giving the causes of the crisis and what

[12] The two economists shared the 1997 Nobel Prize in Economic Sciences for their work in options pricing, which appeared to separate the risk of the option from the risk of the underlying security.
[13] The details of the firm's practices to increase its leverage are outside the scope of this discussion. More information can be found in Dunbar (2000).
[14] There is some discussion as to the starting point of the crisis. Similarly, to Reinhart and Rogoff (2008), we consider that the crisis originated in the subprime mortgage market, the collapse of which began in mid-2007. However, other researchers refer to the crisis as the Financial Crisis of 2007-2008 (Erkens et al. 2012), the Financial Crisis of 2008 (Ivashina and Scharfstein, 2010) or even the Financial Crisis of 2007-2009 (Acharya et al., 2009).

could have been done to prevent it and conclude by discussing the pivotal role of the Credit Rating agencies in this crisis.

2.6.1 Series of Events

The Financial Crisis of 2007 is thought to have begun in the first quarter of 2006 when sales of new homes in the US stopped a continuously increasing path which had started as early as 1963. The latest peak in the market was caused by the administration of George W. Bush, who, in an effort to secure re-election in the 2004 Presidential elections, promised to improve home ownership rates in the country. As a response, many mortgage brokers, especially some under federal control, started force-feeding mortgage loans to potential home buyers, often without any credit background.

This created a particular subset in the mortgage market, which was termed the subprime mortgage market. Loans in this market were designed under a balloon interest payment[15], under the (optimistic) assumption that home prices would continue to appreciate. In an all too familiar pattern in the crises that we have already examined, the collapse in the housing market would mean that we would experience an upsurge of future defaults in this particular market area, the subprime loans. If this market was big enough, this would easily lead to a full-scale financial crisis, especially if major financial institutions were exposed to them. But then, why would major financial institutions be exposed to such a risky market, without the proper protection from regulatory authorities? We will examine the answer to this question in section 2.6.2.

[15] The balloon interest payment scheme is designed to aid borrowers who expect their financial conditions to improve significantly during the course of the loan. Loans of this type postpone part of the amortisation towards maturity, thus making payments easier during the first years.

As we approached the summer of 2007, two mortgage lenders who had focused on the subprime market, had already failed. In late June 2007, two hedge funds which were managed by Bear Stearns collapsed. What was interesting about these two funds is that they had invested heavily in securities which were backed by assets in the subprime mortgage market.

Before we move forward, we need some digression, in order to explain the asset backed securities. The mortgage lenders, many of whom were relatively small in size, needed to increase their liquidity in order to continue financing the housing boom of 2004-2006. In this effort, they created bonds based on the debt obligations of their debtors, which were backed by property assets. These collateralised bonds were then sold to investors for a relatively low cost, despite their increased risk, due to positive ratings from the credit agencies, the reason for which may not have been totally legal (Becker and Milbourn, 2011).

Now, as the subprime mortgage lenders started to default, the prices of these products began to fall. Consequently, the investors on the aforementioned funds demanded more collateral. After a failed effort to sell some of their assets, it became clear that the hedge funds had invested heavily in illiquid assets which would now start declining in value. Failure was looming and despite efforts from Bear Sterns to help the funds, these ultimately failed. This changed the nature of the crisis from a crisis in the subprime mortgage market to a generalised systemic crisis.

The market started to catch on to the fact that collateralised loans were not as safe as they had been advertised, but that they were supported by assets of questionable credit quality, which were starting to forego their lost their liquidity as their prices had clearly entered in a downward path. These instruments were the product of financial innovation, they were new and exciting when they were

introduced, but they were hard to value and price. As the crisis expanded, these products became highly illiquid. Additionally, they were connected to complex derivative instruments and often they were not traded in an organised exchange market (which would significantly improve their liquidity). Finally, the error of the buyers of these products is that they purchased them, even thought they had very little information about their defining characteristics and the assets that they contained. Finally, the novelty in these products resulted in little, if any, regulatory oversight, which, similarly to the SE Asian economies, was thought to promote flexibility, but in effect increased the risk, especially in case of a generalised breakdown.

This caused the entire financial market to shut down, with a temporary freeze in all short-term markets. In the coming months, many subprime lenders started going bankrupt, forcing the financial institutions that were exposed to their products to write off any possible claims. In addition, the lack of transparency and the absence of an organised market meant that the exposure of financial institutions was unclear and thus counterparty risk was very difficult to assess. This meant that the interbank market froze as well, since banks essentially stopped lending to each other and began to increase liquidity as a precaution to the further spread of the crisis.

The defining event in the evolution of the crisis was the collapse of Lehman Brothers, the fourth largest investment bank in the United States. The size of the bank created a full-blown crisis that could have caused the collapse of the entire financial system, had it not been for the immediate response of US regulatory authorities. However, the realisation that a bank the size of Lehman Brothers could fail, then maybe other investment banks could follow. Investors started to run on investment banks, since they believed they could not get

sufficient information regarding their exposure to subprime mortgage products. The intensity of the run, which included all types of financial institutions, resulted in a government bailout to A.I.G. in September 2008 and an announcement of generalised federal bailout plan to support the country's biggest financial institutions.

It is not difficult to link financial crisis, which began in the summer of 2007, to the ensuing recession, which began in December of 2007. However, the financial crisis was caused in part by plummeting house prices, which also led many households to lose a big part of their wealth, suggesting that the recession had already began from 2006, even before the financial crisis. However, the events of 2007-2008 in the financial sector led to significant turbulence in the markets and thus to a deep credit crunch. This aggravated asset price deflation and naturally led to lower household spending on goods and services resulting to a contracting economy. After a certain point, the twin crises fed each other and created a massive problem for authorities to deal with.

2.6.2 Causes

As in all crises that we have examined, the roots and the causes of the Financial Crisis of 2007 can be found in a combination of events which led to a culmination. However, there is a certain agreement among academics (Acharya et al., 2009) that the main two ingredients of the explosive mix were the credit boom and the housing bubble, which in a sense fed into each other, similarly as in most other crises that we examined.

As we mentioned earlier, the US government, under George W. Bush, attempted to boost home ownership for Americans to ensure re-election in 2004. This essentially meant that the mortgage credit market would need to finance this

housing boom and, thus, had to secure greater liquidity. As this liquidity could not be directly supplied by the Federal Reserve, it was certain that financial innovation would find new ways to solve this problem. This means that, at least in part, the crisis was an oversight error of the Federal Reserve. An addition, their decision to keep interest rates low for a long time meant that banks could enjoy cheap funding and thus sell cheap loans to potential customers. This helped feed the housing bubble, since the decreased financing cost offset the rising housing prices.

However, in the author's opinion, the main problem was the poor regulatory control of the financial innovations that helped shape the collateralised debt obligations and allowed them to be traded at unreasonably low prices, similar to low risk products. The most representative move towards deregulation was the repeal of the Glass-Steagall Act in 1999, which was had affiliations between commercial and investment banks. Implemented in 1933, after the Stock Market Crash of 1929, this legislation proposed a clear separation of depository activities from risky investments.

The mortgage market during this period went on a loan binge, which brought in many news loans with poor underwriting practices such as lack of down-payments or income or even employment verification. As mentioned earlier, balloon interest or interest only mortgages were taken out. These tools were very common among subprime or near prime mortgage markets. Credit in general was widely available across all markets and the slack underwriting practices inevitably led to low quality loans, similar to the low-quality investments of the SE Asian economies. What is more, the rest of the world observed and adapted the new financial products that fuelled the US credit boom, taking the problem to the international level.

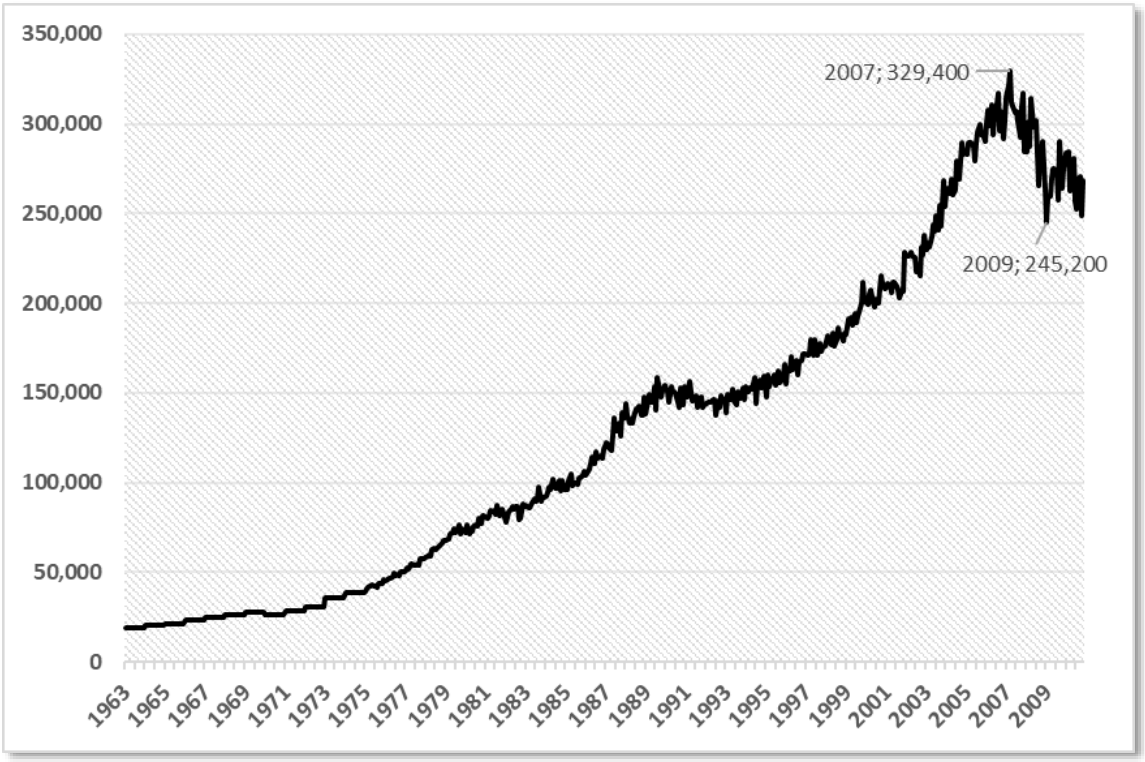


Figure 5. Average Sales Price of New Homes in the US (1963-2010)

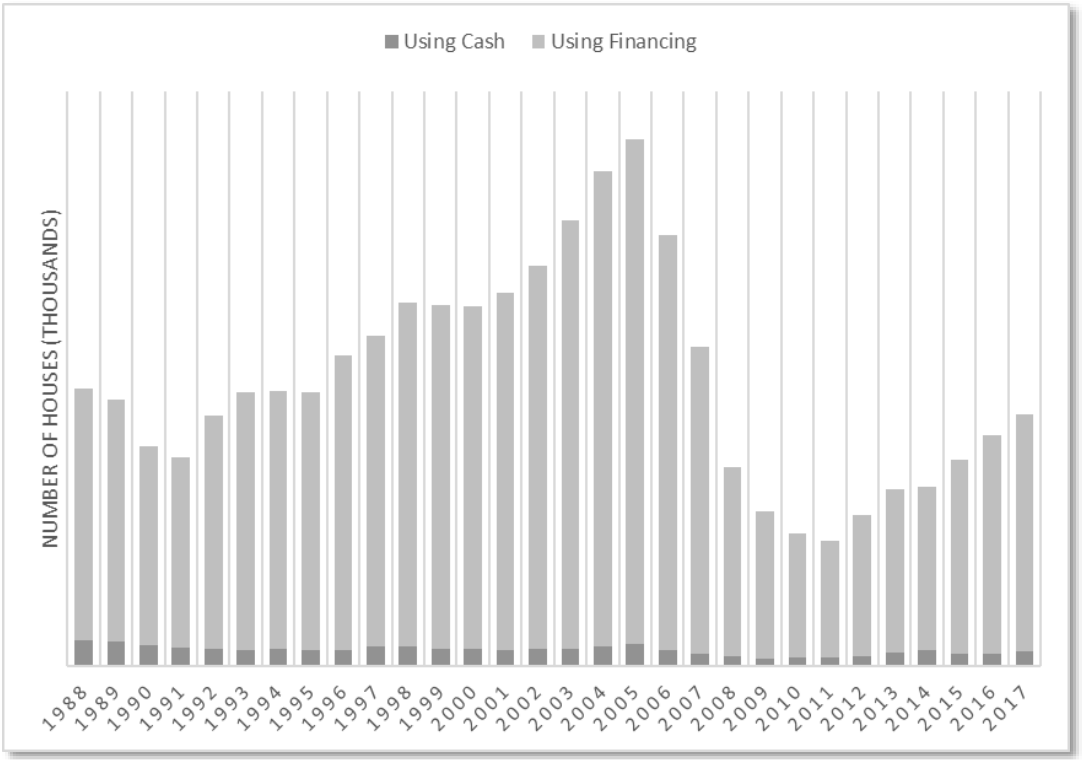


Figure 6. Number of Houses Sold in the US by Fund Source (1988-2017)

When the housing market collapsed, this led to a wave of defaults in the mortgage sector. What was particular about this surge in defaults was not the defaults themselves, but the expectation that many more would follow (Reinhart, and Rogoff, 2008). In terms of magnitude, the drop in housing prices from the peak in the first quarter of 2007 to it low in the beginning of 2009 was over 25% (Figure 5). The loss of wealth is huge and, as we mentioned earlier, this could explain the severity of the financial crisis, as well as the ensuing recession. However, similar shocks to asset prices in the US (e.g. the high-tech bubble in 2000) which led to recessions did not lead in such a large-scale financial crisis (Reinhart, and Rogoff, 2008).

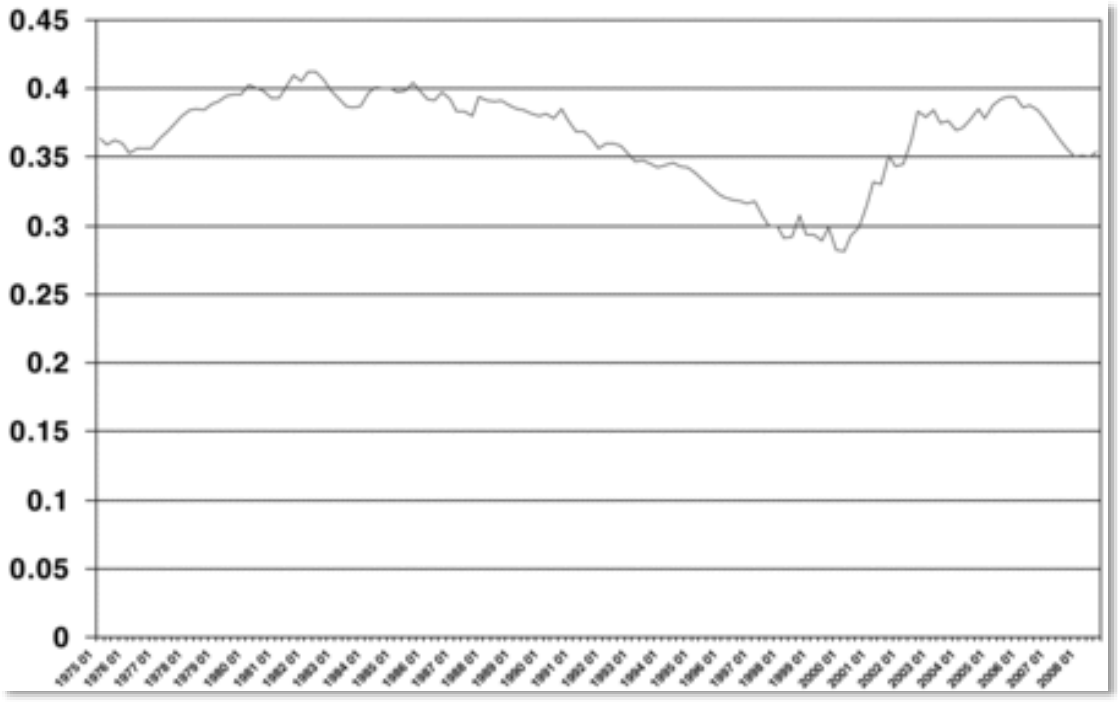


Figure 7. Housing Wealth/Total Household Assets (1975-2008)

***Note**: This figure shows the ratio of home value (on owner-occupied and tenant-occupied homes) over total household assets.*

The unique characteristics of the housing bubble burst in 2006 are summed in four main points (Acharya et al., 2009). First, the collapse in values related to assets which were principally leveraged, meaning that they had been purchased using bank credit. Given that most new sales were financed (Figure 6), this meant that the loss of asset values led households to negative equity levels. Since homes are normally the main wealth asset for most households, having negative equity on this asset means that they were essentially broke, leading them to default on their loans. Figure 7 provides an estimate of the relative contribution of home value to total household wealth, showing clearly the importance of home value to total value of household assets.

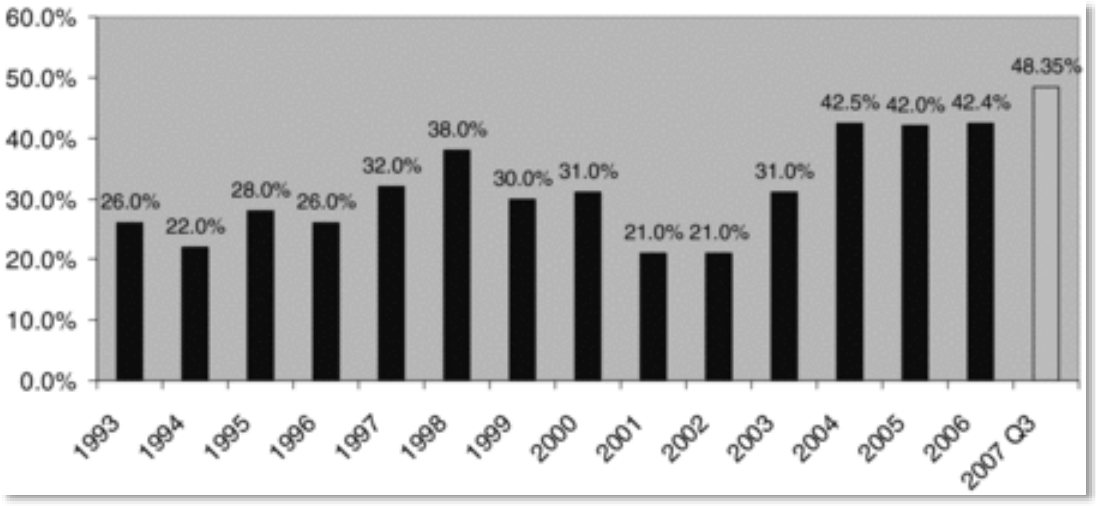


Figure 8. Quality of New Debt Issuance (1993-2007)

Figure 8 shows the value of securities rated B- or below as a percentage of total value of new securities for 1993 to Q3 2007.

Source: Standard & Poor's Global Fixed Income Research

The second point to be made is that, despite the huge increase in the quantity of new loans (and, in some ways, because of it), the quality of loans across most markets had weakened significantly. There was a significant rise in the issues of lower rated securities from 2004 to 2007. Figure 8 shows that there is an

important spike in the percentage of lower-rated securities (rated B- or lower) jump after 2004. This means that apart from their regular risk, these securities carried a significant connection to the real economy, with a recession threatening them all with default. Additionally, the incentive of borrowers in the subprime market to repay was low, since there was an increase in limited-documentation[16] and piggyback[17] mortgages, as well as a hike in the LTV ratio of new loans. Figure 9 shows this information graphically. This was permitted, despite the bundling of the loans securities, due the complex nature of the securitisation process, which we will examine in section 2.6.3).

The third point relates to the distribution of risk in the financial sector. Securitisation of loans into mortgage-backed securities meant that the risk was spread among many investors and, more importantly, that each security should be able to withstand isolated losses to some of the underlying products. However, the generalised failure of the mortgage market as well as the extensive spread of the mortgage-backed securities in the banking sector left financial institutions holding huge amounts of leveraged loans when the market collapsed. According to Acharya et al. (2009), banks and other financial institutions in the United States maintained real estate related assets at a level of around about 47 percent of their total assets, with the figure in smaller banks reaching 67%. This means that credit risk from mortgages, which were of particularly low quality, was not transferred to investors in the capital market, but instead remained in banks and mortgage brokers, even though one can argue that banks and investors maintained close ties.

[16] Limited documentation loans permit borrowers to apply for a mortgage with little or even no information regarding their employment status, their income or their assets.
[17] A piggyback mortgage is any additional mortgage loan beyond the borrower's first mortgage. Piggyback mortgages are secured with the same collateral as the initial loan.

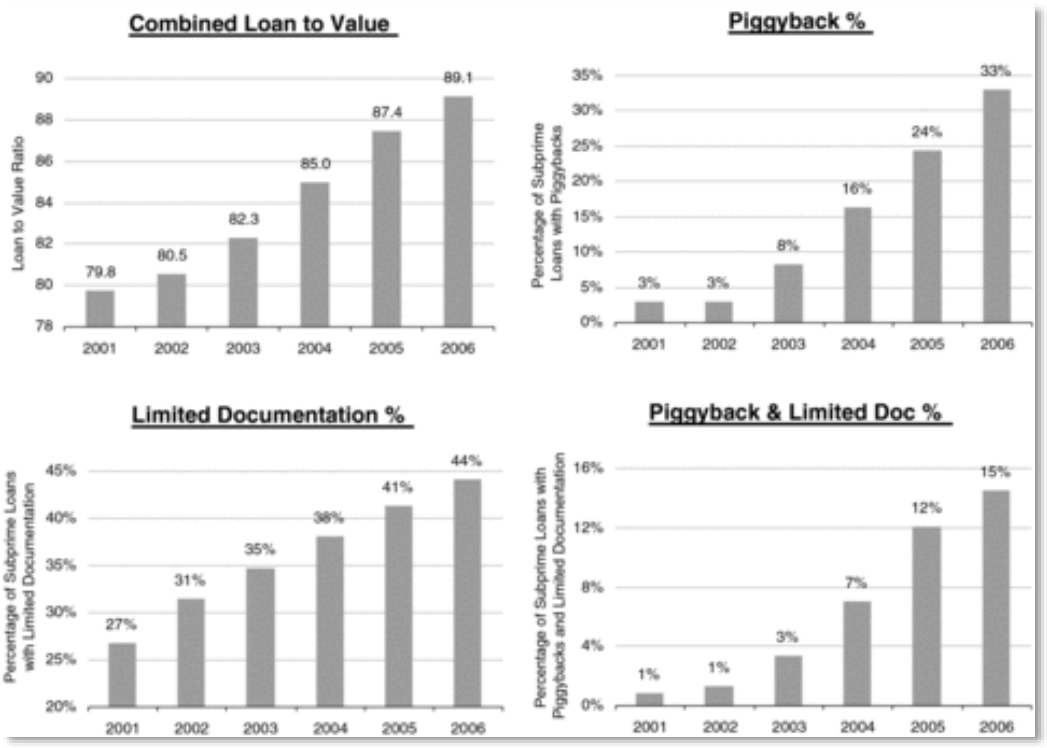


Figure 9. Credit Quality in the Subprime Mortgage Market (2001-2006)

***Note**: This graph shows the measures of quality in the subprime mortgage market. The graph in Q1 shows the loan-to-value ratio (LTV), Q2 shows the piggyback loans, Q3 shows the loans with limited documentation and Q4 shows the loans that were combined piggyback and with limited documentation. These are estimated over the period 2001-2006.*

The final point that we need to make is that the potential losses from these products were significantly increased due to the extensive leveraging of financial institutions (Barrell and Davis, 2008). This, in essence, was an oversight problem, since the Fed should have been made aware of the practice and put an end to it early. However, banks managed to get around capital requirements so easily that it may raise the question if the Fed knowingly turned a blind eye to the extensive leveraging in order to permit the credit boom and the achievement of the housing goals set by the US government. Alan Greenspan blamed his free-market ideology for the lack of intervention, which he admitted to Democratic

Representative Henry Waxman in a Congressional hearing in October 2008, in a statement termed as his "Mea Culpa" (Leonhardt, 2008).

For investment banks in particular, the Securities & Exchange Committee (SEC) amended in 2004 the net capital rule of the Securities Exchange Act of 1934 (Rule 15c3-1), which had forced dealers and brokers to maintain a certain amount of net capital to offset possible losses. This amendment allowed brokers or dealers with certain minimum levels of net capital to request an exemption from the standard net capital calculation rule. As a direct result, large investment banks were now permitted to use internal models to calculate their net capital requirements for market and derivatives-related credit risk. Hence, any reported regulatory figures did not adhere to SEC standards but were the result of internal calculations.

Despite their large risk, the managers in investment banks chose to invest in the products for many reasons, the primal reason being their short-term personal gains. Managers' compensation comes to a great extent from cash bonuses which are linked to short-term profits, which are usually one-sided, meaning that they are positive when they beat their targets, but zero when profits are poor. This means that that they are willing to accept much larger risks even if there is a remote possibility of huge gains, thus deviating significantly from the acceptable goal of long-run value maximisation of the firm. Another important reason for accepting risky bets is the nature of the investment banking business to maximise the risk/return profile, without a moral sense of the general good.

2.6.3 The Role of the Credit Rating Agencies

The role of the credit rating agencies was central to the advent of the crisis. Credit rating agencies are institutions designed to provide information to global

investors. Their job is to make an educated analysis of the risk associated with various debt securities, including corporate or government bonds (domestic or foreign), stocks and collateralised securities, such as the collateralised debt obligations and the mortgage-backed securities which were the root cause of the 2007 crisis. Their ratings relate to the possibility that the debt issuer will fail to make the required payments on the particular security. Ratings are commonly characterised by a letter grade, with the highest and safest being AAA, with lower grades moving initially to AA, then A, and down the alphabet from then on. The three main credit rating agencies are referred to as the Big Three, which are Standard & Poor's (S&P), Moody's and the Fitch Group. Their ratings are central to the international financial system and possible changes in their ratings have immediate implications in the global markets. These three companies account for around 95% percent of the credit ratings market and maintain a close relationship with the SEC.

In the aftermath of the Financial Crisis of 2007, the rating agencies were criticised for failing (or deliberately misrepresenting) the credit risk associated with the mortgage-related securities, particularly those including subprime mortgage (Benmelech. and Dlugosz, 2010). It was deemed that this failure was what essentially enabled the financial meltdown of 2007-2008. The criticism was targeted primarily at the rating methods for securitised products created by bundling subprime mortgages. Critics suggested that their models were complex and unreliable models and failed to take into account the increased risk of subprime mortgages (Diamond and Rajan, 2009).

In fact, many of these structured products had steady AAA ratings during the housing boom and were downgraded only after the housing market had collapsed. This is especially aggravating given the early indicators (e.g. house

sales - Figure 6) were already suggesting an impending decline in housing prices and the rating agencies failed to take those signs into account, thus ignoring the potential effects on loan defaults. Additionally, the unreasonably high ratings did not take into account the systemic risks associated with these low-quality structured products, especially in case they were kept as a major percentage of the assets in the banking sector.

Another source of criticism relates to conflicts of interest. The ratings on the structured products may be ordered by the bond issuers, but more often they were ordered by investors. This has an inherent conflict of interest, since the managers of the investment banks have a high incentive to push for higher ratings, thus greatly improving the risk/return profile of their fund.

However, despite pressure from customers, it is clear that the responsibility of the agencies, particularly given their systemic role, should remain in the accurate representation of the default probability of the underlying products of structured bonds and asset-backed securities. Their systemic role means that credit ratings from the Big Three also strongly influence investor perceptions of creditworthiness and in essence shape the global market.

But how is it that the real risk behind these products was hidden from investors? Let us examine the "originate-to-distribute model" of securitisation and the effect that credit ratings have on it. The model is depicted in Figure 10. The originator is the mortgage bank which has issued the loan to the borrower. As the subprime mortgage products are bundled, the originators used major financial institutions as sponsors to market their products. This is where the role of the credit rating agencies was crucial. If the ratings were not so high, major investment banks would not have been able to get involved in this transaction, due to the increased risk of default in the underlying products.

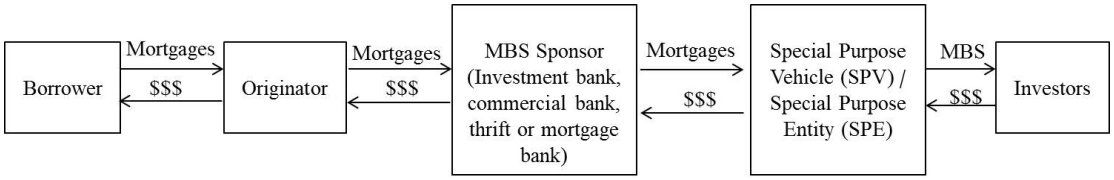


Figure 10. Originate-to-distribute model of Securitisation

Source: Bayar (2014)

Additionally, the nature of the "originate-to-distribute model" of securitisation reduces the incentives for the originator (the mortgage bank) to monitor the creditworthiness of the borrower, because in effect the debt obligation was not to her, but rather to the end investor (Bayar, 2014). What is more, every party in the transaction was making a fee from this process and this includes the credit rating agencies, which gave a AAA rating to sanction this practice and for which rating subprime mortgages was a major part of their business before 2007. Each of these intermediaries in Figure 10 was earning some income, either by charging fees or (more importantly) by transferring the credit risk down the line.

The mortgage-backed securities could not have been marketed and sold without the approval of the Big Three, since investors blindly relied on them. Furthermore, the relationship of the Big Three to the financial system was (and still is) so close, that investors are often obligated to use their ratings. Basel III regulatory requirements depend on their ratings. And the worst part is that, despite the well-established problems of this process and the flaws of the rating agencies, in 2013 Bloomberg reported that the market had resumed its practice of "market-shopping" for better ratings in asset-backed securities (Bloomberg, 2013).

2.7. Conclusions

In this section, we have illustrated the features that typify financial crises. The twin problems are an asset bubble and a credit boom, both of which feed each other; the asset bubble starts a credit boom, which permits further increase of prices, which in turn allow the credit to expand continuously. The asset bubble gradually increases the probability of a significant price shock and the credit boom leads to the leveraging of financial institutions. To make matters worse, the leveraging of financial institutions is backed by the overpriced assets of the asset bubble. Ultimately, when the bubble bursts (often due to an external event or a – non-seldom – combination of circumstances) this triggers a process of massive deleveraging, which has devastating effects on the underlying market and on the financial sector. The financial crisis then spreads easily to the real economy, due to the inevitable credit crunch.

Another decisive factor in the financial crises that we have presented is financial innovation. Despite the fact that innovative products have helped improve the financial sector and have facilitated the flow of funds between lenders and borrowers, they have also allowed for ways to circumvent regulatory requirements, thus hindering oversight. Furthermore, these products have thwarted the flow of information, which is essential in financial markets, since they cannot function properly otherwise. Reporting and disclosure to regulatory authorities and to other market participants is fundamental to any financial system. When investors cannot appropriately price a financial product, this means that they will be able to properly assess the potential losses that they faced with. Also, if investors cannot discern the actual party holding the risk for a product, this can turn into a crisis of trust, leading to excessive risk aversion, squeezing off liquidity in financial markets.

The solution for the problem of information has always been the implementation of impartial, informed private firms, which have the ability to gather and assess information on behalf of investors. However, it has been clear from the Financial Crisis of 2007 that this system can also fail.

It is clear that financial stability is critical to economic growth, since both the financial system and the real economy are closely linked with other, both in times of crises but also in times of economic expansion. The experiences described in the section, in both emerging markets and advanced economies, clearly demonstrate the common features of financial crises. These crises lead to financial instability and have important consequences on the real economy, leading to severe economic shocks. These shocks have the ability to be persistent over time, as the twin crises (economic and financial) fuel each other constantly. If the real effects persist, there can also be significant long-term effects on welfare and subjective well-being.

Financial crises can also be very costly, since they usually bring forth bankruptcies among market participants, from households and corporate firms to large, systemic financial institutions. These crises cannot be resolved solely with the participation of private economic agents (banks, firms and households) and they require government intervention. Given that market participants will often take government intervention for granted, especially if their size grows to systemic levels, this will increase the moral hazard problem. Acharya et al. (2009) suggest that financial crises represent a failure of the setup of the financial system, since it has failed to allocate savings effectively to worthy investment projects. The crises also come with a significant fiscal cost in the form government bailouts to borrowers in distress.

This is not to say that risk (and thus failure, to a limited extent) is undesirable in a capitalist economic system. The absence of risk significantly reduces the potential gains of economic activity and has negative effects on long-term economic growth. It would be interesting to examine, however, the long-term performance of alternative economic systems, such as the Islamic banking model, where risk and reward are shared equally among borrowers and lender.

Risk management, at the systemic level, is the goal of financial regulatory authorities, whose job is to balance the protection of financial stability with risk and financial innovation. It must be noted here that even single institution failures can provoke a generalised crisis, even if the institution is relatively small in size, due to the interconnectedness of financial institutions. Thus, financial pollution (i.e. the tendency of a financial institution to act with the sole purpose of maximising its own profits, ignoring the system as a whole), is in essence the reason why financial regulation is required.

Chapter 3. Literature Review

In this chapter, we present selected literature on banking crises and on the modelling of financial systems. The relevant literature is presented in sections, which relate to various aspects of our modelling work. It must be noted here that the literature review is far from exhaustive, since the topics discussed are among the favourites of researchers. Consequently, we have chosen to include only those papers that have contributed to our work, either directly or indirectly, or that can be used to further improve the modelling platform in the future. Even in this chapter's sections, the literature presented is discussed by topic, which often forced us to forgo any type of chronological ordering and examine the selected articles in separate sets.

3.1. Banking System Models

Our modelling essentially tries to imitate the banking system and the various systems surrounding it. The concept of our model and its agent-based nature can be attributed to the work of Tsomocos (2003a, 2003b). His work proposes a mathematical model, which incorporates agent-based characteristics, and can be used to predict the behaviour of economic agents based on a series of randomised initial endowments. In effect, our platform expands this mathematical model to a multi-period frame (as opposed to a two-period model allowed in Tsomocos' work) and allows for unlimited repetitions that produce statistical data for further analysis. In addition, our modelling platform is more versatile since it can incorporate different events and thus perform simulation on a wider variety of cases. Tsomocos also introduces the role of the Economic Agents and the Regulator, which is similar to the role that we have implemented.

He also discusses the risk of the securities issued by banks. However, in the mathematical model of Tsomocos, the risk is treated as exogenous and random, while we have chosen to link that risk to the credibility of the issuing bank. Goodhart and Tsomocos (2007) also suggest that dealing with default and bankruptcy should be a key issue in financial analyses.

In a more theoretical context, Chang (2011) suggests some macroeconomic variables that were taken into consideration during the development of our model. Chang also provides implications in terms of the regulatory framework imposed, where he also discusses Basel III. Gorton (2009, 2010) also provides us with a thorough analysis of the effects of banking crises and the ensuing panic on the economy. Gorton (2010) also considers the real estate market, which is indisputably an important part of the banking business.

Additionally, Gorton (2010) characterises the crisis of 2007 a "wholesale" crisis, suggesting that the problems of the banking sector cannot be attributed (at least not to a significant extent) to retail customers. Hence, he proposes further study of the interbank market, an argument also put forth by Pezzuto (2008), Boissay et al. (2013) and Drehmann and Tarashev (2013). The dangers arising from the exposure of financial institutions to each other is demonstrated effectively in the artificial economy that we build. Boissay et al. (2013) also consider issues of moral hazard of financial institutions, during interbank financial asset trading. Memmel and Sachs (2013) stress that contagion can also be found in the interbank market, as we mentioned earlier.

In terms of banking business practice, Soana and Verga (2010) make an *ex post* observation that financial institutions in distress seem to differentiate their credit policy while at the same time experiencing low demand for financial products. The study of Dietrich and Wanzenried (2010) on Swiss banks links

the banking crises to profitability issues, while Chava and Purnanandam (2009) suggest low customer profitability as a possible cause of banking crises. The latter study proposes that banks experiencing high credit risk tend to pass that risk on to their customers in the form of increased interest rates and that may be a cause of contagion between seemingly unrelated economies. Cross-border contagion is not handled in our model, but the aforementioned findings may well be included in future work.

Another important point is the approach proposed by Drehmann et al. (2010), who perform a stress test on a hypothetical bank and analyse the results, to deduce conclusions regarding credit risk and the interest rates. Their approach on bank default and the calculation of bank income has been included in our agent-based model. Similar work on stress testing has been carried out by Castrén et al. (2010) and Quagliriello (2009).

With respect to banks' credit policies, Rajan (1994) attempts to describe the reasons that drive changes in these policies of financial institutions. His findings on moral hazard and the agency problem could be used to expand our model further in the future. Maddaloni and Peydro (2011) use data from both the Eurozone and the United States to establish the relationship between the interest rates and lending policies. They locate the relationship strictly on short-term rates. Sengupta (2014) proposes a model dealing with asymmetric information in the capital market. He proposes a thorough model which attempts to describe the equilibrium obtained when a new, uninformed borrower enters the market. Similarly, to Maddaloni and Peydro, Sengupta's model incorporates the cost of capital, which should be included in the extension of our platform.

Carlson et al. (2013) show that bank lending is affected by capital ratios and conclude that this relationship tends to be stronger in times of financial distress.

The cause for this relationship is twofold: higher capital ratios tend to reduce concerns regarding adverse selection when evaluating loan candidates, but also banks that are in a better financial position (in terms of capital requirements) are better equipped to handle negative shocks on the real economy and on the banking system alike.

3.2. Banking Crises

During the development of the modelling platform, it was crucial to understand how banking crises are created and how they can be defined or predicted. In terms of banking-crisis prediction, seminal work by Wong et al. (2007, 2011) proposes a probit model including variables that may be used to identify banks experiencing financial troubles. Their approach on banking crises, as well as that of Demirgüc-Kunt and Detragiache (1998), is used on our model to characterise a time period as a crisis period. For the same purpose, we also employ the signalling methods proposed by Kaminsky and Reinhart (1999). Early indicators of banking crises are also discussed in Lang and Schmidt (2016)

Another approach is the one described by Pezzuto (2008), who pinpoints a banking crisis in the reduction of inter-bank debt, a reasonable assumption given the recent bank defaults. Davis and Karim (2008) and Laeven and Valencia (2008) provide a thorough survey of the various Early Warning Systems (EWS) which are used to predict banking crises. The discussion in both of these papers was taken under advisement during the development of our model.

Banking crisis prediction and contagion have recently been at the centre of attention in the relevant literature. Aktan and Icoz (2009) examine past banking crises and suggest that the increase in financial innovation has hindered effective

risk management. Babecký et al. (2014) develop a set of early warning indicators by examining an extensive series of banking crises since 1970 and onwards. They find a stable link between debt and banking crises and suggest that banking crises will often lead to currency crises[18]. Their findings, which employ an extensive dataset on financial crises, can be used to confirm the validity of our model while their pool of early warning indicators provided indications as to the aspects that our platform had to expand on.

Lee (2008) seeks the causes of financial stability in bank ownership figures and determines that higher inside ownership of banks favours financial stability. We examine this in further detail in section 3.5. Karas et al. (2013) examine data from bank runs in Russia and establish a relationship between the behaviour of depositors and deposit insurance, in the case of a banking crises. Their findings suggest that deposit insurance often distorts the rational behaviour of (risk averse) households, thus minimising the negative effects of a crisis. In contrast, Diamond and Dybvig (1983) suggest that a bank run may actually be the result of rational behaviour of depositors seeking increased liquidity as a precautionary measure against an oncoming financial crisis.

During our research on behavioural modelling in the banking sector, we examined the work of Beltratti and Stulz (2009), who trace the durability of a financial institution under a banking crisis to its internal structure. Non-performing loans are also considered as important by Porath (2006). Currency fluctuations are also considered in Papi and Lim (1997) and in Campa et al. (2005). On the other hand, Peresetsky et al. (2011) examine the influence of the

[18] Currency markets (and thus crises) are not modelled in our platform.

political stability on the country's economy, a factor that has been omitted in our work, but should will definitely be considered in future extensions.

Castellacci and Choi (2015) expand on their previous work and use their existing dynamic model in an environment with multiple interlinked economies, in a setup similar to the Eurozone. Their modelling approach resembles our model. Majerbi and Rachdi (2014) discuss banking crises in relation to the regulatory framework imposed and seem to favour deregulation for advanced economic systems. These findings are in accordance with our findings.

In contrast to the commercial side of banking crises, some authors choose to focus on the interbank market. Memmel and Sachs (2013) examine contagion in the interbank market and analyse the factors that influence the way financial crises spread among financial institutions. Similarly to other researchers, their findings stress the importance of interbank liabilities on contagion, a factor taken into account in our model. Porath (2006) and Falcetti and Tudela (2008) suggest non-performing loans and interbank loans as signals for a banking crisis, a suggestion included in the model behind our platform.

The fiscal implications of a banking crisis are an issue that is often found in the relevant literature. Honohan and Klingebiel (2003) examine data from no less than 40 banking crises around the world and suggest that the fiscal cost of "accommodating" approaches (deposit guarantee systems, open-ended liquidity support and bailouts) is not lower than the fiscal cost of a bank failure[19].

On the other hand, Demirgüç-Kunt et al. (2006) suggest that these safety nets protect the banking system from loss in deposits since they minimise potential

[19] This can be examined in the simulations of the new system, since the type of solution implemented by the Regulator can be set as a parameter in the simulation procedure.

losses for depositors. Additionally, the propagation of a banking crisis to the real economy may have significant adverse effects on the latter, given the possibility that banks deny credit to creditworthy firms (or that the terms they offer render the investment projects unprofitable). However, they show evidence that supports weak demand as the main cause for the reduction in new loans after a crisis. Morrison and White (2011) support the funding of bank rescue schemes from taxation and not from banks or depositors.

Hasman and Lopez (2011) and García-Palacios et al. (2014) examine the effects of using taxpayers' money to save the banking system. They relate these effects to the opportunity cost on welfare and public goods of government-funded rescuing schemes. Both studies favour recapitalisation as the solution of choice, both in terms of the cost incurred and of the loss in welfare. Both papers also suggest taxation on banking transactions (the Tobin tax or a tax on early withdrawals[20]) as a plausible solution with more social fairness. Poledna and Thurner (2016) propose taxing transactions based on their risk and coin the term Systemic Risk Tax. They use an agent-based model to examine the effects of this type of tax and show that it can successfully result in a self-restructuring of the financial market, leading to a reduction in total systemic risk.

Hasman and Lopez (2011) and García-Palacios et al. (2014) also introduce the social welfare factor, which formed the basis for the expansion of our model in this area. Finally, Mayes (2004) discusses the implications of the selection of a bank rescue scheme which should handle moral hazard issues in the procedures of risk management from the part of banks.

[20] The tax on early withdrawals can act as a counter-incentive to withdrawals hindering a potential bank run and may raise enough capital so that the government can finance the entire cost of preventing the crisis.

3.3. Banks and the Real Economy

The issue of the interaction of the real economy with the financial markets has been at the centre of the relevant literature for a long time. An exhaustive review of the literature linking the financial sector to economic output can be found in Arestis et al. (2015). The authors conduct a meta-analysis of the results of various studies in an effort to analyse their differences and find that diversions in the methodological approach tend to result in different findings. However, they note that the final outcome of their work is that all studies demonstrate a positive effect between financial development and economic growth.

Tobin (1969) proposed a monetary framework that showed the way monetary events can influence demand. The model also accepts exogenous variables and was used to provide a general model setup for the goods market in our platform. Greenwald and Stiglitz (1993) propose a simple yet thorough dynamic model that describes firms' behaviour in terms of production and capital demand. Their work deals with adverse selection issues caused by imperfect information in the banking system. Their model setup is followed on these areas, since it incorporates nearly all the implications of production on other aspects of the economy. Additionally, the authors propose a series of further features, like unemployment, output shocks and expectations. Finally, Greenwald and Stiglitz suggest that there is a contagion effect among firms in real economy shocks, which we are not monitoring yet.

Later work by Hoggarth et al. (2002) shows that there is in fact a significant effect of banking crises on the real economy (estimated to an output loss of 15-20%). The authors also describe the way banking shocks affect the real economy and suggest that there is a link between banks' willingness to finance firms and the

economy's total output. Similar conclusions can be found on Dell'Ariccia et al. (2008), who suggest that a sector's response to a banking crisis is proportionate to its dependency on external financing. Additionally, the authors suggest that even though external shocks can affect both the banking system and the real economy, the negative effect on the former amplifies the effect on the latter.

Angkinand (2009) examines the effect of banking regulation on the severity of banking crises on the real economy. Even though some of his findings are country-specific, Angkinand suggests that regulatory measures have positive effects on mitigating output losses in times of crisis. Similar results on the effects of banking crises on the real economy can be found in Goodhart et al. (2006) and in Iqbal and Kume (2014). The relationship between the financial market and the real economy has also been established by de Bandt et al. (2008), who show that an increased corporate default rate tends to lead to interest rate spikes. On the other hand, Costeiu and Neagu (2013) tested the Romanian banking system and found that it can withstand macroeconomic pressures.

3.4. Unemployment and Happiness

Even though there are known difficulties in defining and measuring subjective well-being (Kahneman and Krueger, 2006), it has been shown that this is generally affected by financial distress (Giarda, 2013) and income (Kahneman and Krueger, 2006), regardless of the definition used. Diener et al. (1993) also agree that income is an important factor and that this is true for all social classes. Marini (2005) attempts a link between the setup of the financial system and social welfare.

A thorough review of the economics of happiness, the research field which attempts to find links between economic policies and societal welfare, can be found in Powdthavee (2007), while Crespo and Mesurado (2015) approach the issue from a more sociological perspective. The authors find that, apart from demographic factors (e.g. age, marital status, gender etc.) researchers have linked happiness of individuals to GDP (Di Tella et al., 2003), unemployment (Stracca, 2014 and Arampatzi et al., 2015) and inflation (Janiak and Monteiro, 2011).

Additionally, Di Tella et al. (2003) find that happiness is also negatively affected by banking crises both through the effects of the crises on the aforementioned factors and through the crises per se. They note that during a perceived financial crisis, the reported levels of well-being are lower, even though the actual effects of the crisis may not yet be visible in other figures. Ervasti and Venetoklis (2010) use data from 21 European countries and show that both unemployment and financial strain cause a welfare loss. Ratcliffe and Taylor (2015) also suggest that the stock market (and stock market volatility) is linked to the level of happiness of individuals, since it is often an indicator of economic prospects.

However, other researchers seem to add more ingredients to the mix of happiness economics. Jappelli et al. (2013) conclude that the level of debt may affect a household's perceived happiness. Hovi and Laamanen (2016) show that the link between well-being and the absolute level of output is spurious, since output has a generally upward trend, while well-being does not. They propose the use of deviation of output from its long-term average trend as a variable with a stronger explanatory power. Happiness is also linked to economic development (Stevenson and Wolfers, 2008) and, thus, GDP growth and there seems to be no evidence of a "satiation point", a point of economic development

after which a country would have no further improvement in subjective well-being.

Senik (2014) and Van Praag et al. (2003) imply that net wealth may also be a factor. Giarda (2013) corroborates these findings and also proposes that a banking crisis causes financial distress in an asymmetric manner to households, implementing the distinction according to the Eurostat deprivation index. This asymmetric effect is also demonstrated by Arampatzi et al. (2015), with unemployment being the transmission channel in this case. Finally, there appear to be consumption preferences which affect happiness, which are in fact closely linked to behaviour towards risk. Zhu (2005) proposes a simulation model which clearly distinguishes household agents based on consumption preferences, characterising them as "patient" or "impatient".

Happiness, however, may also be linked with government policies. Di Tella et al. (2003) suggest that even as unemployment rises, the state can mitigate the negative effects in well-being by implementing welfare improving policies. The authors examine unemployment benefits as the go-to choice for correcting welfare losses and show that there is a positive link with reported levels of happiness. Pacek and Radcliff (2008) show that higher government spending in welfare in general is *ceteris paribus* linked to a higher level of perceived happiness by individuals. Often, this parameter is overlooked in the relevant literature discussing financial crises.

The relationship between the financial sector and subjective well-being has been examined in the relevant literature. García-Palacios et al. (2014) show that there is a welfare opportunity cost to bailing out banks using public money. They conclude that the preferences of households in terms of public services and the propensity of banks to invest act on moral hazard are decisive factors in

determining the optimal solution, proposing a tax on early withdrawals as a relatively efficient alternative to bailouts. Policy responses to mitigate the moral hazard are also examined in Cheng et al. (2015).

In general, researchers (Zhu, 2005, Allen and Gale, 1998, Chari and Jagannathan, 1988) tend to consider household agents as utility-maximising agents, who behave rationally under a constant utility function. However, we can argue that, during a severe banking crisis, the agents' utility function will shift significantly. In such a case of (real or perceived) financial fragility, the preferences of some economic agents will change and they may no longer focus on consumption or on maximising their wealth (by investing excess funds). These agents will instead behave with the main purpose of retaining their current level of wealth, which is at risk due to the perceived banking crisis. Hence, the rational behaviour hypothesis of maximising utility through maximising wealth and consumption and maintaining financial stability is no longer valid. This needs to be handled in any modelling effort.

3.5. Banks and Corporate Governance

Additionally to the above research, there exists a new trend in academic research that has turned the focus on modelling bank survivability as opposed to profitability, which was the favoured topic before the financial crisis of 2008. Existing studies mainly examine risk and risk management and have linked these to the financial characteristics of banks. Philippas et al. (2015) implement the SIR[21] epidemiological model in an effort to predict the final state of a bank during

[21] The SIR Model is a compartmental model in Epidemiology which classifies the population into three health states: Susceptible, Infected, Recovered (thus SIR). In mathematical epidemiology, compartmental models help understand the dynamics of the spread of an epidemic.

a banking crisis. Haq and Heaney (2012) find a significant negative relationship between total banking risk and the dividend payout ratio, which they attribute to the effort of banking firms to increase income for their shareholders. Broll et al. (2015) also attempt to model the relationship between risk and return in banking institutions.

Note that some researchers make the case that greater risk-taking can be in the best interest of shareholders in the presence of deposit insurance (Beltratti and Stulz, 2009). Caluzzo and Dong (2015) suggest that risk in the financial sector has shifted away from individual risk towards systemic risk, adding that banking systems are now more susceptible to systemic contagion (as opposed to contagion in the banking system). Simper et al. (2015) also show that risk management practices play an important part in bank performance.

Contrary to existing research on bank performance and viability, this paper expands to the field of management and additionally includes corporate governance features. Macey and O'Hara (2003) provide a thorough review of corporate governance in the banking sector and its implications on the financial institutions and on the economic system as a whole. O'Connor and Byrne (2015) show that "sound" corporate governance is linked with firm maturity. Barr et al. (1993) also demonstrate that management quality is closely linked with bank survivability. Sullivan and Spong (2007) show that insider wealth limits risk-taking behaviour whereas stock ownership by hired managers may actually increase risk.

Additionally, wealth concentration, which is the proportion of one's wealth at risk in a given financial institution, was also showed to have a positive effect on risk management (lower total risk), provided that the individual is in a position to influence relevant managerial decisions (Iannotta et al., 2007). Konishi and

Yasuda (2004) examine the Japanese banking sector and reach similar conclusions, establishing a nonlinear empirical relationship of stable ownership and banking risk. García-Marco and Robles-Fernández (2008) corroborate these findings for the Spanish market.

Kangis and Kareklis (2001) demonstrate that the mix between public and private ownership can have an effect on bank performance. Barry et al. (2011) and Haque and Shahid (2016) also confirm the results showing the important role of ownership structure, especially for privately owned banks, where institutional investors tend to implement riskier strategies when owning higher stakes in banks. Wu and Li (2015) examine Chinese firms and comment positively on the effects of board independence on firm performance, while Kaur Virk (2017) shows that board independence is linked with a smaller number of regulatory violations. Laeven and Levine (2009) and Mullineux (2006) also stress the importance of regulation.

Williams and Nguyen (2005) implement the technical inefficiency effects model of Battese and Coelli (1995) using bank governance variables, similar to ours. We employed this methodology in order to implement a risk-governance index in our model, which describes bank features that tend to show "sound" management strategies. Additionally, Gupta et al. (2013) employ an additive index to quantify 42 bank governance factors. They find that corporate governance "failed" during the financial crisis, since the factors that existing literature considered as positive did little to help large corporations. A similar index is constructed by Koerniadi et al. (2014), who find that good governance practices are associated with lower levels of risk. Agoraki et al. (2010) link board size and composition to bank efficiency, suggesting that a small board sise may signify better risk management. Similar results are demonstrated in Conyon and

Peck (1998), who find that a smaller board size results in better corporate performance.

ElKelish (2017) performs a multi-country analysis of corporate governance risks, linking them to agency costs. Similarly, Aebi et al. (2012) propose a series of measures of corporate governance that are better suited to the banking sector. They use empirical data from banks in Europe and in the US and find that independent risk management is crucial to the bank's performance during a financial crisis. On the other hand, standard governance indicators seem to contribute little, if at all, to the amelioration of these results. However, they note the negative effects of risk governance on performance during "normal" times, using common performance indicators for the banking sector. Reddy and Locke (2014) reach similar conclusions from data regarding firms in New Zealand.

Chapter 4. Methodology

4.1. Agent-Based Modelling

Agent-based modelling is a relatively new modelling approach that is gradually gaining wider acceptance in Finance and Economics, due to its ability to describe more accurately the non-linear relationships between multiple economic variables. Their application has seen limited support, especially in social and economic sciences, primarily due to their complex nature and the absence of available tools that would permit researchers without programming knowledge to design and implement them. The models of this class are developed on the principles of object-oriented programming, which ensure that economic agents exchange data (information and assets) accurately and that other structures (agents) use this data in the appropriate manner.

Object-oriented modelling is an implementation of agent-based economics (Tesfatsion, 2006), where the economy is described as a constant interaction between heterogeneous agents, with differing (and often clashing) rational objectives[22]. There is no single equilibrium; in contrast, multiple dynamic equilibria are reached as the outcome of the aforementioned interactions. The lack of a single equilibrium is one of the key advantages of agent-based models as descriptions of real-world economic systems. Additionally, agent-based

[22] It must be noted that, even though agent-based models are generally forward-looking, expectations on particular variables, such as prices, interest rates, etc., are usually not modelled. On the other hand, other forward-looking models (e.g. Gorodnichenko and Shapiro, 2007) examine how agents' expectations affect the optimal policy choice. In this sense, forward-looking behaviour is not considered a given in all situations.

describe an economy using a bottom-up approach, which begins at the individual agent level.

Agent-based models allow researchers to study situations which cannot be properly described using existing equation-based models, as the real-world situations often go way beyond the approximations and the assumptions of these models (Helbing and Balietti, 2018). By failing to explore agent behaviours, if these can only be determined numerically, scientific analysis may end up being limited to extremely complex models which, however, end up portraying simplified or limited versions of reality. Agent based models permit the researchers to assess the effects of agent interactions on the ecosystem of the artificial system portrayed. The end goal of this class of model is to investigate the collective behaviour of different agents in order to gain explanatory insight into the results on the system as whole.

An agent-based model can be used to simulate the independent actions of autonomous, heterogeneous agents, as well as their interactions with each other. These agents normally obey simple rules, exhibit some form of learning or adaptive behaviour and respond to external events or to actions of other agents. When making decisions, agents rely on the ruleset supplied to them in order to assesses each situation individually or even in the context of the environment in which it has been presented to them. Agents may execute different behaviours according to the particular fraction of the system in which they are placed. For example, they may produce, consume, buy, sell, invest, gamble, etc.

Agents are autonomous, but heterogeneous and perform their activities independently, based on the instructions they receive and the experiences that they gain. As social actors, they need a stage for their behaviours, which is the environment designed by the researcher. Now, this environment may change

dynamically according to the particular actions of the agents that it comprises of. These changes occur passively, either in response to the actions of agents or in response to external events, which are placed in the model setup (Getchell, 2008). The behaviour of these agents leads them to repetitive competitive interactions (Bonabeau, 2002), which are a main feature of agent-based modelling. In this way, these models can explore system dynamics which cannot be simulated by pure mathematical methods.

Use of agent-based modelling in economic simulations is supported by Bilina and Lawford (2012) and by Doornik (2002), because in permits the development of a unified environment where researchers can glue together different economic models. Additionally, Upper (2011) argues on the limitations of mathematical models in terms of simulating banking systems and predicting contagion and policy implications. He suggests that behavioural features need to be incorporated into existing models.

4.2. General Model Description

Our modelling platform for financial simulations is based on agent-based modelling and it employs object-oriented features that imitate the behaviourist characteristics of economic agents, by simulating the transactions that can take place among them. Our agent-based system can perform multi-period simulations of the banking environment and includes four types of economic agents: the Banks, the Firms, the Households and the Regulator. Only one regulator can exist in the model, while the number of banks, firms and households can be set at will. The general model structure is based on Tsomocos (2003a) and Goodhart et al. (2004) and is demonstrated in Figure 11. It must be noted that such a setup is popular in agent-based models, such as Riccetti et al.

(2016), Gabbi et al. (2015) or Rashid et al. (2011). All types of agents share some common features and functions.

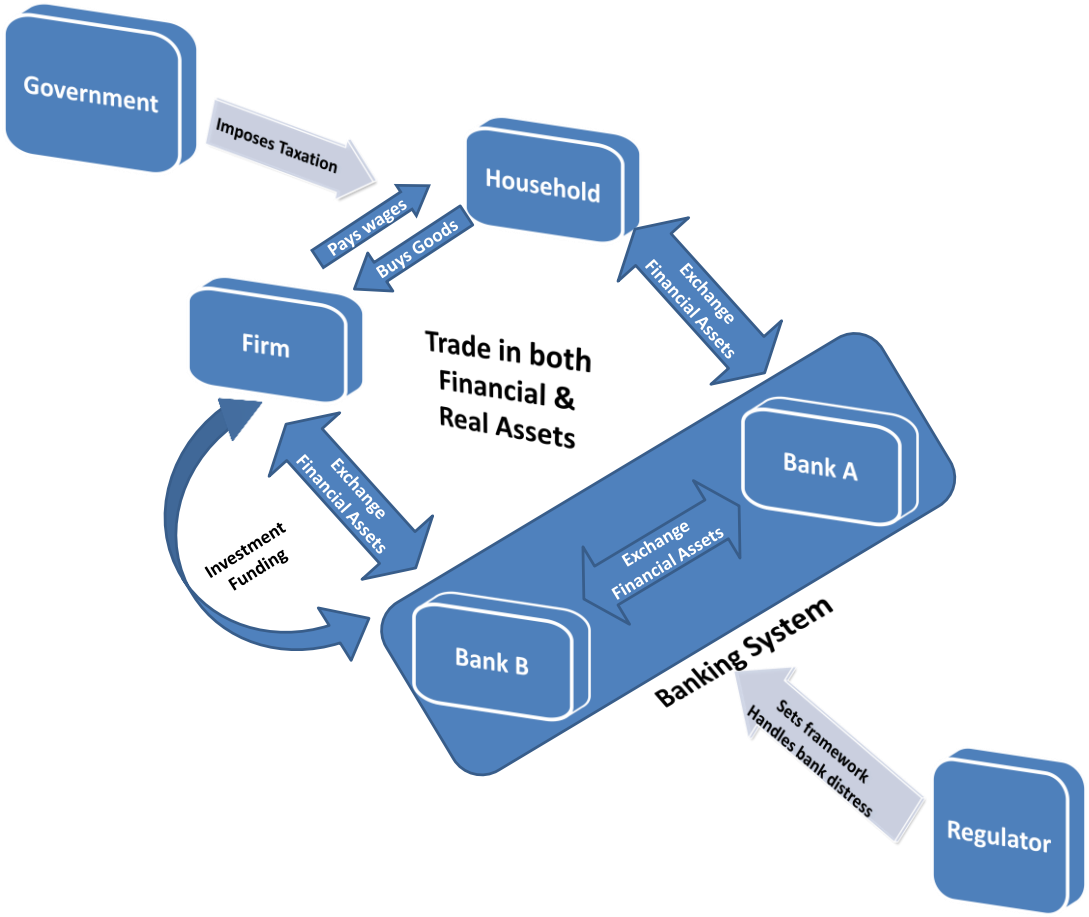


Figure 11. Graphical representation of the virtual economy

Banks can perform transactions with each other and with their customers (firms and households) using another object class, the Financial Asset. Agents (Banks, Firms and Households) trade in financial assets and in real assets (goods and services), under the regulatory framework set by the Regulator, with taxation being collected by the central Government. Households can trade only with Firms and Banks, while Banks can also trade with each other. With respect to Banks, Households deposit their cash there and can take out loans, if required. Also, Households receive money from Firms, in the form of wages, and Firms

receive money from Households in exchange for goods and services. It should be noted that Firms generate income for Households based on their productive capabilities, which depend heavily both on the Banks' willingness to finance investment projects and on the interest rate offered. The latter is affected by the general economic environment as well as by the status of the borrower.

Households spend money on each time period at an amount directly related to the wages paid on the previous time period and their personal preferences and characteristics. Additionally, negative output shocks can propagate to the banking system creating a downward spiral effect which can be dealt with using policy measures, such as banking regulations, monetary and fiscal tools. Output fluctuations also create a multiplier effect[23], which is not constant since it is dependent on the households' precautionary demand for money. The latter is influenced strongly by possible instability in the banking system.

In our model, we postulate that the role of the banking system is key to real economic growth. Additionally, negative output shocks can propagate to the banking system creating a downward spiralling effect which will need to be dealt with using policy measures, such as banking regulations, monetary and fiscal tools. The output model should exhibit internal effects through the multiplier effect, but this effect should not be constant since it will be dependent on the households' precautionary demand for money. The latter is influenced strongly by fluctuations in the banking system.

To simulate the real economy, we have included the Firms as separate economic agents. Their behaviour in the system is similar to that of households as far as

[23] This is the standard multiplier effect, where a dollar increase in the income of one agent in the system results to part of that increase being channelled to consumption, thus increasing the income of another agent, and so on. The percentage of the income increase that is spent and not saved, depends on the precautionary demand for cash of the particular agent.

their transactions with the banking system is concerned; they also deposit any excess cash, above their precautionary or transactional balances, and they seek financing in cases of cash deficits. However, their income endowments in each time period (that is the economy's output) will not be random but will be dependent on the banking system's behaviour in terms of financing capacity. Additionally, the production of these "corporate" agents directly affects the incomes of households and is also affected by their expenditure.[24]

The model incorporates a goods market which always clears and which causes for costs to be incurred to the firms, as suggested by Greenwald and Stiglitz (1993). These costs will be paid for either by the sale of goods or by financing. Firms will need to pay wages to households and these wages will be the source of households' income. Part of this income will be used to purchase goods from firms, generating income for the latters. Firms, similarly to other economic agents, can go bankrupt, in which case all of its assets will be liquidated in favour of its creditors. There will be imperfect information from the part of bank as to the firms' ability to handle their incurred debt, as we will see below.

The flow of funds between agents is hence stimulated either from the activity of firms (production, wages and investment projects) or from differences in income and spending for households. It is also affected by shifts in the households' precautionary balances. Excess balances for both firms and households are deposited in banks, where they are used as credit material, while negative balances result in loan demand from agents. Banks offer varying interest rates based on their cost of capital which is calculated in a process similar to the

[24] Note that the generalisation of firms and households as bank customers is consistent with the object-oriented nature of the model, where entities that exhibit similar behaviour are grouped into the same class (in this case, the Bank Customer class), which includes their common functions. In our case, firms and households are similar in the way they interact with banks but exhibit differences in their further behaviour.

Weighted Average Cost of Capital (WACC). In this setup, our modelling platform incorporates features that differentiate banks from each other, with the interest rate being the most important differentiating characteristic. In the earlier versions of the model, banks offered a uniform interest rate and hence the borrower was indifferent between the lenders.

The banks' cost of capital can be calculated given the cash drawn from depositors (note that deposit products may carry different interest rates) and the interest rate offered to the bank on the interbank market. This latter rate will be dependent on the bank's financial state (as denoted by its capital ratios) as well as on the willingness of the regulator to finance banks in distress. Now, the Regulator (which is financed by the central government) will, *ceteris paribus*, be able to finance banks at lower rates when the government can raise cash through taxation. This is supported by the findings of Hasman and Lopez (2011) and García-Palacios et al. (2014). Since we have not introduced a deposit guarantee system, we do not need to examine any moral hazard issues in the bank's lending behaviour.

Investment financing in the production sector follows Sengupta (2014) and Tobin (1969). Banks will choose which firms to finance, given a variable probability of default, unknown to the lender (Sengupta, 2014). Firms seek financing in order to fund new projects with a given expected return (above the interest rate) and a given (random) probability of success. The bank requests collateral, only a fraction of which may be recovered if the project fails. We assume that collateral is drawn from the firm's assets, which will be reduced in case the project is unsuccessful and the underlying loan is not serviced. There is a bankruptcy condition for the firms imposed here, which is dependent on the firm's nominal equity position (Greenwald & Stiglitz, 1993). In such a case, the lender recovers

the outstanding amount (or part of it), using assets pledged as collateral, and the firm's remaining assets are liquidated in favour of other creditors.

The probability of success of an investment project is not known to the lender, but a signalling feature has been implemented, whereby the past behaviour of borrowers can be used to infer the probability of success, similarly to a standard credit report drawn by banks. Given these conditions, the lender offers the loan with a given collateral and a given interest rate and the borrower chooses whether to accept the offer, given a positive net present value of the project, taking under consideration the collateral requested and the probability of loss in equity. In this setup, the transfer of funds from the banking system towards the real economy is not unconditional both from the part of the lender and from the part of the borrower. Given high interest rates, investments will not be carried out by firms and this may result in a loss of output, resulting in banking distress. Similarly, very low interest rates can lead to limited bank profitability, which can also harm the banking system, especially if matched with an increase in non-performing loans.

A loan results to payment obligations from the part of the borrower. Failure to meet these obligations leads to bankruptcy (for households and firms) and bank distress (for banks). The latter is handled by the regulator, who decides on the solution[25]. If a bank defaults, the consequences for the entire system are quite significant. The choices implemented with respect to how to handle bank distress are three, namely an immediate default, a bailout or a bail-in, and the actions taken at each case different.

[25] This is decided according to model's setup choice which is passed as a parameter to the simulation process.

In the first case, where the bank defaults, its loans are removed from the asset lists of other banks and any liabilities to households are cancelled. In the second case, where a bailout solution is implemented, the regulator uses money supply from the government account to cover the financing needs of the bank in distress and any outstanding obligations are covered immediately, without any further action from the part of the bank. In this case, there is an opportunity cost in terms of government spending on public goods.

Finally, the regulator may enforce the bail-in solution, that is the use of the funds the bank carries in deposit accounts or in investment products so that the bank is rescued from default. The bank firstly seeks to cover its needs through the use of the funds in securities, since these would normally not be part of any deposit guarantee system. If these funds do not suffice, then the bank will turn to the deposit accounts. Note that even in this case, a rescue is not certain, since the total funds in the bank's deposit accounts or high yield securities may not be enough to cover its financing needs. However, when a bail-in occurs, two events are recorded at the same time. First, depositors of the bank in question lose their money, since this is used to save the bank. Second, the bail-in alarms all depositors, raising their precautionary demand for cash, thus leading to a drop in total deposits in the next few periods.

Using this modelling approach, the transfer of funds from the banking system towards the real economy is not unconditional both from the part of the lender and from the part of the borrower. Given high interest rates, investments will not be carried out by firms and this may result in a loss of output, resulting in banking distress, in case of reverse contagion from the real sector to the banking sector. Similarly, very low interest rates can result in limited bank profitability, which, if matched by an increase in non-performing loans, can ultimately yield

the same result. The inclusion of this aspect of the economic system would not be possible without modelling the real economy, which we have described above. The government raises cash from taxing household incomes, so our model includes the money account of the central government. The cash raised will be used in the case where a bank is in distress and the amount raised (relative to the cash needs of the distraught bank) will be a key factor in selecting the solution. If the cash gathered cannot cover a sufficient portion of the bank's deficit, the bank will default. An increase of taxation results in an opportunity cost in terms of output but will mean that more cash is available to protect the economy from banking shocks[26].

The model uses data produced through a bootstrap of observed variables from publicly available sources regarding the European Union. For banks, we import asset values and financial ratios regarding capital requirements (most notably data regarding cash-equivalent capital sources). For firms, the model uses data regarding total assets and total output. In order to build the database of the firms' internal credit rating, we have constructed a data set describing how corporate loans are being serviced. We hand pick only those loans that would normally finance new investment projects (i.e. we have excluded short-term capital loans, such as overdraft facilities). Then, we calculate the percentage of these loans that were not being serviced properly[27] and use this to build a distribution that is sampled when assigning failure propensities to firms. Imported data is then calibrated to fit the number of agents in the system. All

[26] In future extensions of the model, cash raised from taxes will also be used for other purposes like correcting social problems (e.g. unemployment) or increasing household utility. Potentially, should a political stability factor be introduced, we could examine the motive of the central government to raise spending in an effort to maintain power. In further expansions of the model, taxation may also be used as a political tool.

[27] Note that re-financing a loan suggests that the loan was not serviced properly, since the underlying investment project did not bring in the necessary cash flows to enable the company to make the agreed payments.

the data used in this thesis has been collected by sources in Thomson Reuters Eikon.

Our framework allows for the collection of statistics, which can be used for further analysis of the simulations. The data produced and collected are based on variables proposed by Wong et al. (2011) in order to identify the particular banks that experience financial troubles. Banking crises are approached based on these indicators, as well as on the definition given by Demirgüç-Kunt and Detragiache (1998)[28].

4.3. Formal Model Definition

4.3.1 General Form

The model performs a series of algorithmic steps on the artificial economy. In this section we will present the notation used in our model and describe the steps in detail. The notation is as follows:

N1. $t \in T = \{1, \dots, T\}$

Time periods in the model of order $|T|$

N2. $h \in H = \{1, \dots, H\}$

Set of Households of order $|H|$

N3. $b \in B = \{1, \dots, B\}$

Set of Banks of order $|B|$

N4. $f \in F = \{1, \dots, F\}$

Set of Firms of order $|F|$

[28] A banking crisis occurs when nonperforming assets in the banking system exceed 10% of total assets, or when depositors run on banks.

N5. $bc \in BC = H \cup F$

The set of potential bank customers in the retail market (i.e. firms and households)

N6. $e \in E = BC \cup B = H \cup F \cup B$

Set of all economic agents

N7. $fa \in FA = \{1, \dots, FA\}$

Set of active financial assets

N8. $eb \in EB \subseteq E$

Set of bankrupt economic agents (banks, firms or households) This a subset of set E and it is initially empty.

It must be noted here that once an agent becomes bankrupt, she will not participate in any financial transactions in the artificial economy. Thus, in the simulation steps described below, sets E, H, F or B actually contain only the active agents of the corresponding sets. These sets are defined as the difference of the sets at time t=o from EB. Consequently, the active respective agent sets are:

N9. $h \in H = H - EB_H$

$f \in F = F - EB_F$

$b \in B = B - EB_B$

$e \in E = E - EB = (H_0 - EB_H) \cup (F_0 - EB_F) \cup (B_0 - EB_B)$

N10. $g \in G_t = \{1, \dots, G_t\}$

The set of goods available for sale at time t (and produced at time t-1)

N11. Total production (i.e. the total value of goods traded) at time t is equal to the total capacity of active firms at time t-1

$$Production_t = \sum_{\forall f \in F} Capacity_{f,t} = \sum_{\forall g \in G} Value_{g,t}$$

N12. $un \in UN \subseteq H$

The set of unemployed households. This is a subset of H and its members change on every period

Also, the following assumptions hold:

A1. $\forall\, e \in E : a \in A_e \subseteq FA$

For all economic agents, there exists a list of assets, which is a subset of FA.

A2. $\forall\, e \in E : l \in L_e \subseteq FA$

For all economic agents, there exists a list of liabilities, which is a subset of FA

A3. $\forall fa \in FA: \exists!\, e \in E: fa \in A_e$ and $\forall fa \in FA: \exists!\, e \in E: fa \in L_e$

For all financial assets, there exists exactly one agent that carries the item in her assets and there exists exactly one agent that carries the item in her liabilities.

We should note here that the banks' asset vectors are further divided into three subgroups according to the asset's liable agent. These groups can then be used to calculate the sum of weighted assets, since a different asset weight is assigned according to the type of the liable agent (bank, firm or household).

A4. $\forall g \in G_t: \exists!\, h \in H: g \in Exp_e \; and \; \forall g \in G_t: \exists!\, f \in F: g \in Production_f$

For all goods in the market at the end of time period t, there exists only one household that has purchased the item (and thus derived utility from it) and there exists only one firm that has produced it at time t-1 Price changes are not modelled and the goods market must clear domestically since foreign trade (as well as currency crises) is not handled for now.

The corollary of assumption A4 is that the goods market must always clear domestically at the end of each period since foreign trade (as well as currency crises) is not handled. Trade between the UK and the EU after Brexit is discussed in the following section. It should also be noted that price changes are not modelled.

The Regulator decides on a vector of market rules which includes the capital adequacy ratios (the basic Tier 1 ratio, the Capital Conservation Buffer[29] and the Countercyclical Capital Buffer[30]) as well as the Liquidity Coverage Ratio. The latter, when applicable, is calculated separately for each bank at each time period and is set equal to the total outflow of funds from deposit accounts in the last time period. The resulting rule vector imposes the minimum requirements for each banking institution, thus affecting the funds that the institution makes available to other agents in the system.

The rule vector is the following:

N13. $r_{b\in B,t\in T} = \{CapReqVector_t, LiqC_{b,t}\} = \{\{t1, CapB, CntCapB_t\}, LiqC_{b,t}\}$

The vector for each bank at each time period contains a Tier 1 capital requirement (t1), the Capital Conservation Buffer (CapB) and the Countercyclical Capital Buffer for the given time period (CntCapB) as well as the amount resulting from implementing the Liquidity Coverage Ratio on the given bank at the given time period (LiqC). This

[29] The Capital Conservation Buffer is an additional capital buffer introduced under Basel III and is equal to 2.5% of the bank's weighted assets.

[30] The Countercyclical Capital Buffer was introduced under Basel III and its implementation is at the discretion of authorities. It allows national regulators to require additional capital buffers which are accumulated during periods of economic growth. The Countercyclical Capital Buffer can equal at most 2.5% of the bank's weighted assets. According to Basel III, the Countercyclical Capital Buffer must be increased if the economy experiences three consecutive expansionary periods and must be reduced if the economy experiences three consecutive contractionary periods. The Countercyclical Capital Buffer is currently being be phased-in.

amount LiqC is calculated for each bank at each time step (see Step 1.2 below).

The rules are applied in sets.

If no banking regulations are imposed, then

$r_{b\in B,t\in T} = \{\{0,0,0\},0\}\forall t \in T, b \in B$

When a set of rules that is based on Basel II is imposed then

$r_{b\in B,t\in T} = \{\{0.08,0,0\},0\}\forall t \in T, b \in B$, since only the Tier 1 capital requirement is imposed.

When a set of rules that is based on Basel III is imposed then

$$r_{b\in B,t\in T} = \Big\{\{0.08, 0.025, CntCapB_t \in \{0.000, 0.005, 0.010, 0.015, 0.020, 0.025\}\}, \quad LiqC_{b,t}\Big\}$$

Note that when a Basel III rule set is implemented, the Countercyclical Capital Buffer is initiated at 0.005 (i.e. 0.5% of the bank's weighted assets), which is consistent with the gradual phasing in of the rule under Basel

The Countercyclical Capital Buffer is initiated at 0.005 (i.e. 0.5% of the bank's weighted assets), which is consistent with the gradual phasing in of the rule.

The regulator also implements the vector by which the assets of the bank are weighted. The weight vector depends on the type of rule set and is fixed throughout each simulation.

N14. $w = \{w_{b\in B}, w_{h\in H}, w_{f\in F}\}$

The weight vector contains potentially different weights for each type of asset.

N15. Hence, the sum of weighted assets of the bank can be calculated using the following equation:

$$wa_{b\in B,t\in T} = \sum_{\forall b\in B} \begin{cases} a_{b,t} \times w_b \; if \;\; \exists \, b' \in B : a_{b,t} \in L_{b',t} \\ a_{b,t} \times w_h \; if \;\; \exists \, h \in H : a_{b,t} \in L_{h,t} \\ a_{b,t} \times w_f \; if \;\; \exists \, f \in F : a_{b,t} \in L_{f,t} \end{cases}$$

The sum of the bank's weighted assets is the sum of the products of each asset in the bank's asset set with the corresponding weight (for that asset) from the weight vector.

The system is initialised using the algorithm described below.

0. System Initialisation:

0.1. Banks receive a random amount of initial cash equal to the product of a random variable times the number of households in the system

$\forall \, b \in B : CB_{b,t=0} = U(1,10) * |H|$

0.2. Firms start with an initial random productive capacity equal to the product of a random variable times the number of households over the number of firms in the system

$\forall \, f \in F : Capacity_{f,t=0} = U(1,10) * (|H|/|F|)$

0.3. Households receive a random amount of initial cash and are characterised by a random precautionary demand for money, which is the money they will keep outside the deposit accounts and is a fraction of their initial cash. The precautionary demand is important in the model, since it corresponds to the households' trust in the banking system (when there is mistrust in the banking system, the precautionary balance increases – Karas et al., 2013).

$\forall \, h \in H : CB_{h,t=0} = U(1,10)$

$\forall\, h \in\ H :\ PB_{h,t=0} =\ U(1,10)$

Additionally, some households behave in a risk-loving manner, opting for higher interest rates for their deposits even if the bank offering them is in distress. Finally, we have implemented a feature of increased vulnerability to financial crises, according to García-Palacios et al. (2014) and Giarda (2013). The latter suggests that this affects approximately 15% of the workforce. This feature is important, because we monitor the unemployment and happiness levels of the vulnerable group separately.

Steps 0.4 and 0.5 were implemented only in the earlier versions of the model, which correspond to the simulation results presented in sections 5.1 and 5.2.

0.4. The Regulator sets the money supply (equal to total cash) and initialises the rule set.

$$MoneySupply_t = \sum_{\forall e \in E} CB_{e,t}$$

Cash balances for households include precautionary savings.

0.5. A new economic cycle is instantiated with a random duration and a random direction

Before advancing to the next step, we must introduce some further notation.

N16. $\forall\, b \in\ B, t \in\ T$: $AvB_{b,t} = CB_{b,t} - \left[\sum_{\forall i \in CapReqVector_t}(CapReqVector_{i,t} \times wa_{b,t})\right] - LiqC_{b,t}$

For each bank, the available balance is given by adding the current cash balance and subtracting the funds required to meet the regulatory requirements. The sum in the statement above is the sum of the products of each imposed capital buffer rule (see N13 above) with the

sum of the weighted assets of the bank, as calculated in N15. This amount is subtracted from the bank's cash balance, since it cannot be used to purchase assets.

N17. $\forall\, h \in\ H, t \in\ T$: $AvB_{h,t} = CB_{h,t} - PB_{h,t}$

For each household, the available balance is given by the difference of the cash balance and the precautionary demand.

N18. The Growth Multiplier (GM) is used as a coefficient when calculating firm production, complementing the endogenous changes in firm capacity (step 1.13). Its calculation is random for each time period and uses as a basis the 2003-2007 growth average for OECD countries, for expansionary periods, and the 2008-2009 recession average for OECD countries, for recessionary periods.

The simulation steps follow the order given below:

1. Simulation Step at time t

1.1. The system checks if the economic cycle set up earlier has ended and, if so, a new economic cycle is instantiated with a random duration and a random direction.

1.2. The Liquidity Coverage Ratio is implemented for each bank and the required amount is calculated as the difference of deposit funds from the last period to the current one. If the outflow of funds is negative, the LCR is zero.

Assuming the deposits of a bank at any given time are given by

$d \in D_{b \in B, t \in T}\ \subseteq L_{b,t}$

the amount required to satisfy the Liquidity Coverage Ratio[31] rule is given by the equation:

$$LiqC_{b\in B,t\in T} = 100\% \times \begin{cases} 0\,, if\ outflow\ is\ negative \\ \sum_{d\in D_{b\in B,t\in T}} d_{b,t-1} - \sum_{d\in D_{b\in B,t\in T}} d_{b,t} \end{cases}$$

1.3. Interest is added to loans

$\forall\, \lambda \in \Lambda \subseteq FA: Amt_{\lambda,t} = Amt_{\lambda,t-1} + \left(Amt_{\lambda,t-1} \times ir_{\Lambda}\right)$

where Λ is the subset of financial assets that represents a loan asset, Amt is the amount remaining in the loan and *ir* is the interest rate for the particular security.

1.4. Add Household incomes (wages or unemployment benefits) and subtract expenditure

$$\forall\, h \in H: CB_{h,t} = CB_{h,t-1} + Wage\left(\stackrel{\text{def}}{=} f(Production_{t-1}, |H|)\right) + UnemploymentBenefit(if\ h \in UN) - Expenditure(\stackrel{\text{def}}{=} g(Wage))$$

Household wages are a function of last period's total production (by firms) and the number of households in the system. Also, it is important to note that unemployment benefits are paid from the government funds which are collected from taxation and the Tobin tax, if implemented (see step 1.13).

[31] Under our implementation, the Liquidity Coverage Ratio is always set to 100%, as will be the case under the full implementation of the rule.

1.5. Banks make payments for high risk securities

$\forall\, b \in B: \forall\, i \in I \subseteq A_{i,t}: Amt_{i,t} = Amt_{i,t-1} + \left(Amt_{i,t-1} \times ir_I\right)$ (interest is added to the amount)

Then the amount remaining is added to the CB of the asset holder and subtracted from the CB of the liable bank. When paying out a security yield, the liable bank uses its CB value, not the AvB value (see N16)

1.6. Economic agents (Banks, Firms and Households) pay their loan obligations

$$\forall\, \lambda \in \Lambda \subseteq FA: Amt_{i,t} = Amt_{i,t-1} - Pmt_{\lambda}$$

$$= Amt_{i,t-1} - InitialAmount \times \left(ir + \frac{ir}{(1+ir)^n - 1}\right)$$

The payment Pmt is subtracted from the CB of the liable economic agent and added to the CB of the asset holder (a bank). When repaying loans, liable economic agents use the CB value, not the AvB value, since the precautionary demand (which leads to the AvB value) is not taken into account when repaying a loan.

If CB (the cash at hand) does not suffice to cover the obligation, Households will go into their savings (the money they have in deposit accounts), until either all savings are withdrawn from banks or no more outstanding payments remain.

1.7. Households place their excess cash balance to a deposit account. Banks in need of cash will issue high yield securities. Risk loving households may opt to place the money on a security (if any banks are offering the product) or a deposit, with equal probability for each case, while risk averse households stick to normal deposit products. Once the choice of product is made, a random bank will be chosen, with banks offering a high interest rate having more chances of being picked.

Hence, the expected reward function of each asset for the depositor is as follows:

$$\text{(EQ1)} \qquad E(R)_{a,h\in H,t} = Amt_{a,t-1} \times ir_a \times \left(1 - PD_{b\in B:a\in L_b}\right)$$

where PD is the probability of default of the bank that carries the asset in her liabilities. The probability of default is different for each institution and also depends on the Regulator's solution to bank distress and is equal to:

$$\text{(EQ2)} \qquad PD_{b,t} = f_b\left(r_{b,t}\right)$$

Combining (EQ1) and (EQ2), we get:

$$\text{(EQ3)} \qquad E(R)_{a,h\in H,t} = Amt_{a,t-1} \times ir_a \times \left(1 - f_b\left(r_{b,t}\right)\right)$$

(EQ3) signifies the importance of regulation on the utility received by depositors in the banking sector, a setup similar to social planning in García-Palacios et al. (2014).

1.8. Bank Customers seek funds. In this step, any firms or households that have liabilities with missed payments or that have a negative available balance will seek funds from the marketplace. Banks are selected according to the lowest interest rate offered for loans and agents ask the full financing they need. Banks in turn offer the amount they can (i.e. their AvB figure at time t) and if the required amount is not covered, the next bank in the ordered list is chosen. Banks will finance the firm or household if the banking system can cover their full financing needs. If, at the end, the customer's financial needs are not met, then no loans are taken out.

1.9. Banks seek funds. In this step, any banks that have liabilities with missed payments or that have a negative available balance will seek funds from the marketplace. Financing banks are chosen in random

order and the initial bank will ask the full financing it needs. Financing banks in turn offer the amount they can (i.e. their AvB figure at time t) and if the bank is not covered, the next random bank is chosen to seek financing from. Banks will finance the initial bank if the banking system can cover their full financing needs.

1.10. Any agents that still have missed payments will be candidates for default. The default criteria are different for banks and households and naturally the consequences both for the specific agent and for the entire system are different. Banks that have one missed payment are immediately candidates for default while for firms and households the threshold has been placed at three missed payments. The criteria for banks are stricter, since it is not acceptable for a financial institution to be unable to make payments for its liabilities.

1.11. The government produces public goods, using the remaining funds gathered from taxation in the last period. In this way, there is a trade-off between bank bailouts, unemployment benefits and public goods. If the government chooses to rescue a bank, it has less to spend on public goods. However, if the bank fails and unemployment rises as a result of the ensuing crisis, there will again be less money available for public goods.

1.12. Banks re-examine their interest rate policy. The average weighted cost of capital is used as the main deposit rate, which is increased further, if the bank approaches the distress zone.

1.13. Firms propose investment projects. If a firm does not currently have an investment project underway, she will propose one to the banking

system. Investment projects carry a random return (this can be considered similar to the IRR), which will help her increase the productive capacity. In order for the project to be accepted, the firm must find a willing financier which will offer financing at a cost lower than the project's return. Each firm carries a random probability that the project will fail. If the firm is unable to find funding for the investment project, she gradually loses her productive capacity. In this way, high interest rates will tend to reduce long-term economic growth and will eventually lead to bank distress

Therefore, the productive capacity for each firm at any given time is expected to be equal to:

$$(\text{EQ}4) \quad Capacity_{f\in F,t} = Capacity_{f,t-1} + \begin{cases} U\big(\text{Min}(IRR), \text{Max}(IRR)\big) \times (-1), & without\ active\ investment\ project \\ IRR_{pr,f} \times \big(1 - PF_f\big), & with\ active\ investment\ project \end{cases}$$

If the firm fails to find financing for her current project, her productive capacity is reduced by a random amount, with uniform distribution between the minimum and maximum IRRs of all active projects in the system. We should note that firms produce the artificial economy's goods according to their capacity and taxes are collected on production, since the market always clears.

1.14. The regulator re-examines the Countercyclical Capital Buffer. The decision to increase the percentage for the Countercyclical Capital Buffer is taken when three consecutive growth periods have been achieved. Similarly, it is decreased after three consecutive recession

periods. This is a limited approach to the implementation of the policy (Drehmman et al., 2010)[32].

1.15. Individual and societal subjective well-being (SWB) is calculated. We have based our utility function on Giarda (2013), where it is the intertemporal change of variables and not their absolute levels which affect happiness. The function is defined it as follows:

(EQ5) $$SubjectiveWellBeing_{h\in H,t} = f'(\Delta GDP, \Delta Income_h, BankingCrisis_t, Employment_h, \Delta PublicGoods, \Delta NetWealth_h)$$

In order to avoid problems with the relative values of these heterogeneous components, each one of them contributes just 1 unit to SWB. So, if there is positive growth, SWB increases by one, while it decreases, if there is contraction in the economy. All variables affect SWB positively, except for banking crises which affect it negatively.

All variables contribute equally except for banking crises and spending on public goods. We have implemented a coefficient these two variables in order to shift societal preferences towards financial stability.

1.16. The system recalculates each household's employment status. There if we have experienced an economic downturn (i.e. a reduction of GDP), there is increased chance of a negative change in households' employment status (i.e. from employed to unemployed), while the opposite occurs for economic expansion. Also, there is increased

[32] Despite its limitations, this implementation is consistent with the basic motivation behind its introduction in Basel III whereby banks are forced to accumulate capital during expansionary periods in order to ensure liquidity under recessionary periods.

probability of a negative change for vulnerable households and a decreased probability for a positive change, similarly to Giarda (2013).

1.17. Statistics are collected

1.18. The system progresses to the next time period

4.3.2 Corporate Governance

The previous work is extended, in order to model the risk of financial institutions according to both their financial and their corporate governance characteristics. Each of the governance features influences the bank's behaviour in a different manner; this is something that the agent-based nature of our model allows us to implement. The financial features are calculated at a snapshot of the financial institution after some time periods have elapsed. It must be noted that the proposed methodology does not examine bank performance, efficiency or profitability. At the current stage, these are not handled by the extension of the model, since our goal in this part of the research was to examine the causes of failure, rather than the causes of success.

Extending our model, specific characteristics were introduced for each bank. These variables are monitored in order to link them with the end state of each financial institution and to try to deduce an underlying relationship. In terms of governance features, the first monitored variable in the simulation is the presence of a Credit Risk Officer (CRO) in the executive board. Aebi et al. (2012) suggest that when the CRO has an active say in the executive board, this generally results in better risk management. In the current implementation, the bank is more capable of discerning the probability of firms to default on their loans. Additionally, banks with a CRO in the board of directors have the capacity

to offer financing at customised interest rates, according to the credit status of the borrower[33].

Another variable implemented is the board size. Aebi et al. (2012) and Beltratti and Stulz (2009) show that a smaller board size can work in the benefit of flexibility allowing the bank to respond faster to changing market conditions. Both studies propose the use of further measures regarding the Board of Directors, such as the attendance of members to board meetings, but these were not included in our simulations. However, if the board size is too small, it is possible that the lack of polyphony will hinder effective risk management. In the proposed model, a large board size has a negative effect on the ability of the bank to offer the appropriate interest rate for each firm and to set its base deposit rate, which effects both its cost of capital and its earnings[34].

The board independence, which is the percentage of board members without further relation to the bank, is also an implemented variable. Additionally, we have included a variable measuring the director experience, which is calculated as the number of directors in the board with financial background. Aebi et al. (2012) have implemented this variable as the percentage of directors with experience as an executive officer in a bank or insurance company. Both these variables tend to improve risk management as they increase.

In terms of ownership, three variables have been included, namely the percentage of total equity owned by the CEO[35], the percentage owned by the public sector and the percentage owned by institutional investors. It has been shown (Barry et al., 2011) that institutional investors tend to enforce riskier

[33] See step 1.13 of the basic model, where the active firms seek financing from banks from their proposed investment projects.
[34] This is handled at step 1.12 of the basic model.
[35] CEO: Chief Executive Officer.

strategies when their ownership percent permits them to exert managerial control. On the other hand, Barry et al. also show that public sector ownership is associated with lower risk, while other research (Iannotta et al., 2007) suggests lower loan quality and higher insolvency. Ownership concentration is associated with better risk management (Iannotta et al., 2007) while a high CEO ownership seems to reduce overall risk (Sullivan and Spong, 2007).

The monitored financial variables include the bank's ratio of assets to liabilities[36] and the ratio of loans to deposits as shown below:

$$\text{(EQ6)} \qquad Assets\ to\ Liabilities_{\ b} = \frac{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}}{\sum_{l \in L_{b,t=10}} Amt_{l,t=10}}$$

$$\text{(EQ7)} \qquad Loans\ to\ Deposits_{\ b} = \frac{\sum_{a_{b,t} \in A_{b,t=10}} Amt_{a,t=10}}{\sum_{l_{b,t} \in L_{b,t=10}} Amt_{l,t=10}\ \ where\ l\ is\ of\ type\ Deposit}$$

In terms of the bank's position in the marketplace, we compute the ratio of the average interest rate of deposits and the ratio of the average interest rate of loans over the market average.

$$\text{(EQ8)} \qquad Average\ Interest\ Rate\ (Loans)_b = \frac{\frac{\sum_{a \in A_{b,t=10}} ir_{a,t=10} \times Amt_{a,t=10}}{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}}}{Market\ Average}$$

$$\text{(EQ9)} \qquad Average\ Interest\ Rate\ (Deposits)_b = \frac{\frac{\sum_{l \in L_{b,t=10}} ir_{a,t=10} \times Amt_{ba,t=10}}{\sum_{l \in L_{b,t=10}} Amt_{ba,t=10}}}{Market\ Average}$$

$$where\ l\ is\ of\ type\ Deposit$$

Also, the model uses the average spread (denoted by the average interest rate of loans minus that of deposits) and the profit margin, which is the average interest rate of loans less the cost of capital. The latter is the weighted average of the interest rates of the bank's liabilities.

[36] Note that this ratio will differ greatly from the expected values of a real-world bank since we are only simulating part of a financial institution's balance sheet.

(EQ10) $$Average\ \text{Spread}_b = \frac{\sum_{a \in A_{b,t=10}} ir_{a,t=10} \times Amt_{a,t=10}}{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}} - \frac{\sum_{l \in L_{b,t=10}} ir_{a,t=10} \times Amt_{ba,t=10}}{\sum_{l \in L_{b,t=10}} Amt_{ba,t=10}}$$

$$where\ l\ is\ of\ type\ Deposit$$

(EQ11) $$Profit\ Margin_b = \frac{\sum_{a \in A_{b,t=10}} ir_{a,t=10} \times Amt_{a,t=10}}{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}} - \frac{\sum_{l \in L_{b,t=10}} ir_{a,t=10} \times Amt_{ba,t=10}}{\sum_{l \in L_{b,t=10}} Amt_{ba,t=10}}$$

Note that (EQ10) and (EQ11) differ in the fact the latter takes into account all liabilities of the bank (i.e. includes interbank loans), while the former only considers deposits.

With respect to the particulars of the banking sector, we monitor the amount of cash over the weighted assets[37], the percentage of non-performing loans on total loans and the interbank exposure of the bank, which is the percentage of interbank loans over on loans. Increased interbank exposure has been shown to deteriorate a bank's expected viability due to increased contagion risks (Drehmann and Tarashev, 2013).

(EQ12) $$Cash\ to\ Weighted\ Assets_b = \frac{CB_{b,t=10}}{wa_{b,t=10}}$$

(EQ13) $$NPLs_b = \frac{\sum_{a' \in A_{b,t=10}} Amt_{a',t=10}\ where\ a'\ has\ missed\ payments}{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}}$$

(EQ14) $$Interbank\ Exposure_b = \frac{\sum_{a' \in A_{b,t=10}} Amt_{a',t=10}\ \ such\ that\ \ a' \in L_{b',t=10}\ \ b' \in B}{\sum_{a \in A_{b,t=10}} Amt_{a,t=10}}$$

The governance features were assigned to each bank at the start of the simulation. Their values are random and the probability distribution has been manipulated to follow the findings of Aebi et al. (2012), who recorded these variables over a large sample of international banks. Each bank is logged in the

[37] This could be considered an approximation to the Tier-1 capital.

system with these variables at the start of each simulation. The financial variables were recorded at period 10, when the banks had enough time to interact with firms and households, in order to build their asset and liability list. The final state of the bank was then recorded, given four alternatives, as follows:

i. Bankrupt: In this state, the bank has gone bankrupt. Note that in this case, the Regulator was unable to rescue the bank, using the deposits the bank carries.

ii. NeedsFinancing: In this state, the bank is still working but is unable to meet the requirements of the regulatory framework and will need a cash injection.

iii. Balanced: This is the initial state of the bank. This state will be assigned to banks in all cases where they cannot be included in any other state.

iv. Prosperous: This is the ideal state of the bank. In this case, the bank's total assets including its available cash exceed its liabilities. This state is an indication that the bank is well equipped to deal with financial distress.

The final state of the bank is the dependent variable on our regression analysis. We have examined which of the above variables are significant in the prediction of the final state and built a forecasting model to predict the outcome of the simulations. This methodology is similar to Aebi et al. (2012), the difference being that the data is generated from the simulations of our model. Following this process, the model was executed again to verify the predictive efficiency of our model.

4.4. Robustness Checks

Table 1. Robustness Checks with Two Sets of 10,000 Simulations

	First Simulation Set	Second Simulation Set	Divergence
Bank Defaults	0.297	0.283	0.0135
Bank Default Attempts	0.558	0.528	0.0296
Non-Performing Loans	0.164%	0.159%	0.0051%
Money Supply	3,294.188	3,303.773	9.58
Deposits	1,603.449	1,602.629	0.82
High-Yield Securities	48.539	48.880	0.34
Consumer Loans	6,194.376	6,188.699	5.68
Interbank Loans	83.934	81.634	2.30
Outstanding Loans	7.286	6.906	0.38
Availably Liquidity	2,637.023	2,649.714	12.7
Recovery Periods	0.005	0.003	0.002
Deposits Standard Deviation	743.963	743.656	0.30729
High-Yield Securities Standard Deviation	48.652	48.829	2.01
Consumer Loans Standard Deviation	5,453.590	5,451.582	2.59
Interbank Loans Standard Deviation	119.476	116.884	0.18
At least 1 Default	1,016.0	969.0	47.0
At least 2 Defaults	569.0	536.0	33.0
Contagion Ratio	56.004%	55.315%	0.689%

***Note**: This table includes the results of two consecutive simulation sets of 10,000 simulations each. The simulations were executed with the same parameter sets in order to examine if the results of the simulations are random and to confirm the number of 10,000 simulations as an adequate number of repetitions for the simulation set.*

In order to verify the model's robustness, we ran simulations with the same parameter values in two sets of 10,000 simulations. This check was aimed at confirming that the model results are not random and that they stem from the

workings of the agent-based model. Indeed, the results produced where similar for each one of the simulation sets. They are provided in Table 1.

We also ran plausibility robustness checks for the model where we executed 10,000 simulations, before working on the empirical results. This set of robustness checks was aimed at verifying the relationship of our virtual economy to a real capitalist market, such as the United States. We selected the US economy as a benchmark mainly due to its size and its developed financial sector, which give a leading position in the global financial system. These characteristics of the US economic system permit us to run simulations for both markets, namely the financial market and the real economy. Even in the cases where we examined other economic systems (e.g. UK or the Eurozone), the skeleton of the US economy is ideal as the base of any modelling platform which aims to simulate financial and economic systems.

Table 2. Results of Robustness Checks

Variable	Average Value (Standard Deviation)
GDP Growth	2.48% (3.12%)
Unemployment Rate	5.98 % (2.68 %)
Subjective Well Being	25,141.95 (11,902.05)
Public Goods Spending	41,241.99 (16,757.76)

The results of the robustness checks are demonstrated in Table 2. As a comparison indicator, the average unemployment rate in the US for the period 1998-2017 was 5.91%, according to the US Department of Labour. For the same time period, the World Bank records an average growth rate 2.23% in real terms.

These results are similar to our model. In addition, the standard deviation is relatively low, when compared to the respective average values of the variables, which means that the results of our simulations are fairly constant and do not fluctuate heavily with each repetition.

Part B - Empirical Work

Chapter 5. Empirical Findings

5.1. Banking Sector

Table 3. Average Values for the Monitored Variables for Each Set of Rules

	No Rules	Basel II	Basel III
Bank Defaults	0.179	0.489	1.383
Bank Default Attempts	0.442	0.978	5.191
Non-Performing Loans	0.1406%	0.4315%	3.0796%
Deposits + High-Yield Securities	1,659.92	1,562.79	1,226.51
Total Loans	6,356.38	5,886.59	4,301.40
Outstanding Loans	5.568	25.515	192.458
Availably Liquidity	2,662.50	2,322.37	1,838.27
Rescue Costs	116.16	167.87	404.28
Recovery Periods	0.005	0.155	2.160

The first part of the simulations focused solely on the banking sector and on financial stability, completely ignoring the real economy[38]. We ran the model 10,000 times for each available combination of rules and default solutions (9 possible combinations, i.e. 90,000 totally simulations). This number of simulations was selected as optimal in order to smooth out divergences in the recorded values of variables in cases of "extreme" simulations (e.g. a generalised banking system failure). In each simulation, there were 100 households in the

[38] This section discusses the findings of Samitas and Polyzos (2015).

system and 5 banks and the model ran for 100 time periods. Each one of the simulations produced a set of statistics which included the values of all the variables at each time period, while the model also collected summary statistics for each simulation, so as to facilitate any further data manipulation and analysis.

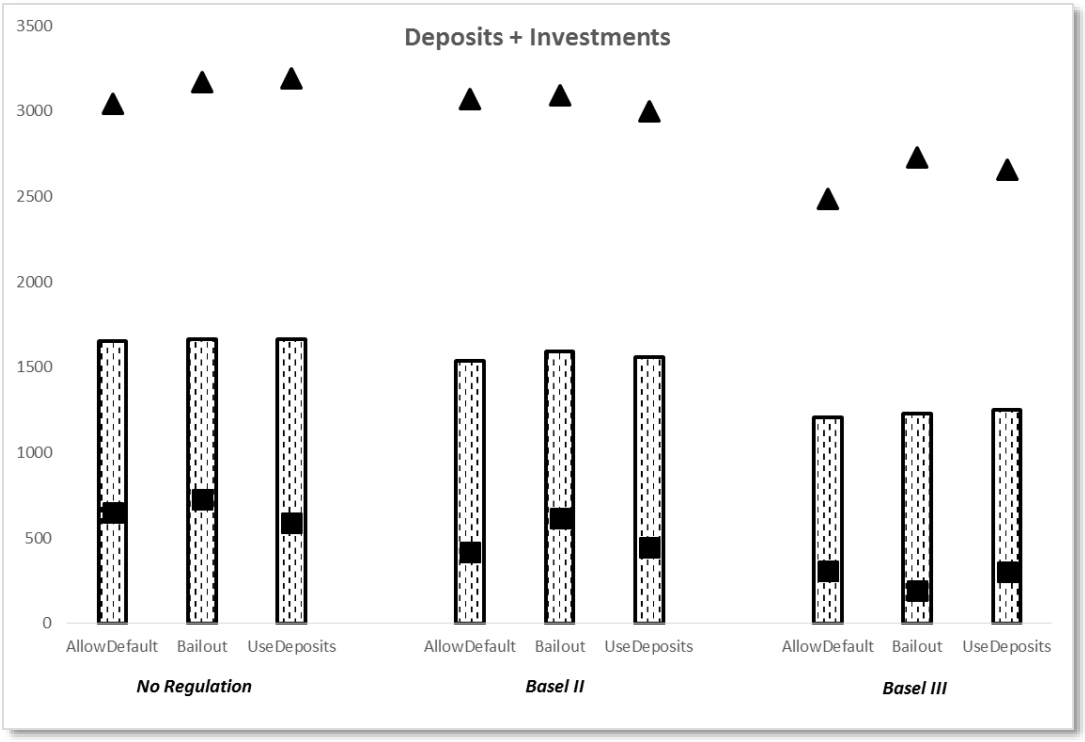


Figure 12. Average of Total amounts of Assets

This figure shows the average of total amounts of assets deposited at banks for each simulation set. The triangle marks the highest value in the simulation set and the square marks the lowest value.

The simulation procedure for the 90,000 simulations lasted approximately 35 hours, that is a little under 4 hours for each simulation set. In total, 5.02 gigabytes of data were produced, which is equal to 5,390,183,956 characters or 1,916,850 pages of text. The data was the further analysed to produce the tables we will present in the current section.

Table 3 shows the average values for the monitored variables for the simulations of each regime. The first two rows essentially signify the probability that a bank will default (or attempt a default, i.e. ask the regulator for assistance) in each of the set of rules. The last row shows the periods required under each regime for the economy to recover from a banking crisis. The values shown below have been calculated over the total of 30,000 simulations for each set of rules. The information for deposits and investments is also shown in Figure 12, where we have also included the minimum and maximum values of the data.

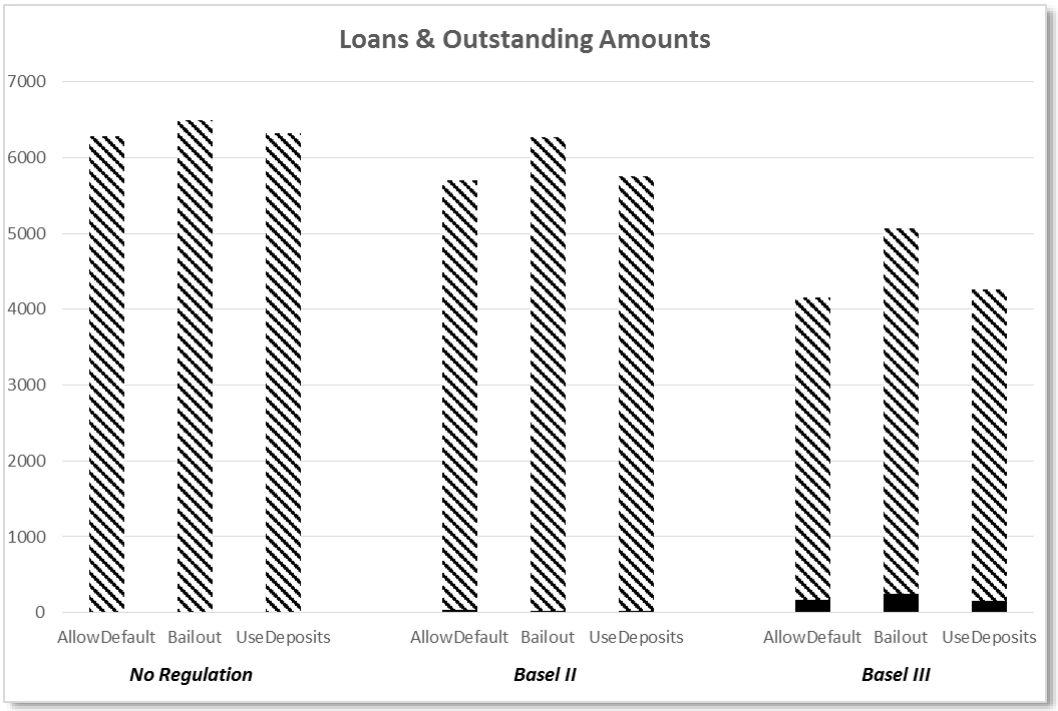


Figure 13. Loans & Outstanding Amounts

This figure shows the average of the total amount of loans for each simulation set, as a stacked bar over the amount of outstanding loans (solid coloured). The outstanding loans for the unregulated sets are negligible, with respect to the total loans.

Our first impression of the summary data is the far greater number of banking defaults in the case of Basel III, when compared to the other two regimes. It is

obvious that the strict banking rules and the increased capital requirements place a great strain on the economic system and limit the capabilities of the financial institutions. The value of the default attempts under Basel III, when compared to the number of banks in the simulation (five) shows us that, on average, every bank will seek assistance from the regulator at least once, when these rules are imposed.

The increased strain in the banking system is supported by the rest of the data that has been recorded. Deposits and investment products are much lower, as are loans, both private and interbank. On the other hand, non-performing loans are much higher under Basel III, despite the fact that less loans are being delivered to the economy. The available liquidity is much lower under Basel III and it is important to note that the difference in the first two columns is greater than 8%, which is essentially the only capital requirement imposed in our system for Basel II. The rescuing costs are far greater in Basel III, as we will discuss later. Finally, the economy will need more periods to recover from a crisis in the case of Basel III, which is one more indication that the strict regime limits the flexibility of the system and the capability of the banks to overcome any issues they may be facing. The decrease in banking activity due to the increased regulation is a result favoured by the relevant literature (Cosimano & Hakura, 2011; Allen et al., 2012).

Another interesting observation relates to the contagion effect and the relevant information is depicted in Table 4, which shows the number of simulations where the system experiences at least one or at least two defaults. The information relates to 20,000 simulations under the regimes where a default is possible (i.e. immediate default or attempted rescue by bail-in). The Contagion Ratio shows the contagion effect in the system as the percentage of cases where

a default was followed by a second. The last row in the table shows the percentage of cases over the total number of simulations where at least one default occurred.

Firstly, the percentage of cases where a default will occur is tripled from the first to the second column and it is further increased radically in the third column, under Basel III. The contagion effect is also much stronger under Basel III, even when compared to Basel II. It is definite that our findings on this issue cannot be regarded as encouraging with respect to the effectiveness of Basel III against banking crises. The fact that the funds of the financial institutions are significantly limited since they are tied up in capital requirements seems to yield destructive results. The contagion ratio, which is simply the ratio of the first two rows in Table 4, is much higher in Basel III, which is surely a negative implication of the new regime. With a probability as high as 81%, when a bank defaults under Basel III, a second is likely to follow.

Table 4. Analysis of Bank Defaults

	No Rules	Basel II	Basel III
At least 1 Default	1,941.0	5,460.0	12,269.0
At least 2 Defaults	1,040.0	3,405.0	9,992.0
Contagion Ratio	53.58%	62.36%	81.44%
Defaults over Total Simulations	9.71%	27.30%	61.35%

Table 5. Percentages of Contagion in Banks

	Default	Bailout	Bail-in	Average
No Rules	55.31%	0.00%	51.85%	**53.58%**
Basel II	65.09%	0.00%	59.75%	**62.36%**
Basel III	82.65%	0.00%	80.23%	**81.44%**
Average	67.69%	0.00%	63.94%	**65.81%**

Table 5, which presents a further analysis of the contagion effect under each regime and for each of the default solutions proposed, confirms that the problems with contagion under Basel III are not influenced by differences in the type of solution implemented in the case of a default. The contagion ratios are similar both in the case of immediate default and in the case of the bail-in, with the latter, which is being examined currently by policymakers as a response to banking crises, not showing any added benefits against contagion. The failure of Basel III to effectively limit contagion, despite the increased capital buffers that decrease counterparty risk, is consistent with the relevant literature (Georg, 2011 Ojo, 2011).

In terms of economic stability, Table 6 depicts the average values of the standard deviations of the monitored variables for each the simulation in the simulation set. Note that these values do not represent the standard deviation over the entire set. On the contrary, we calculate the standard deviation for each variable at each simulation and then we calculate the average of this figure for all simulations in the set. This value is indicative of the volatility in the variable's distribution and has been used in the literature as a means to describe economic stability (McConnel et al., 1999; Dambolena & Khoury, 1980).

The results here are important and, to some extent, unexpected. We can see that the values in the regulated regimes (i.e. Basel II and Basel III) are lower than in the case of the absence of banking rules. To the extent that these figures can signify economic stability or, in a more general sense, a smooth path for the banking figures, the regulated regimes seem to outperform the unregulated case in this case. Given these figures, we can argue in favour of Basel III since it seems to add significantly to the system's stability, even when compared to Basel II.

This is an important finding and one that definitely permits us to support Basel III for this purpose.

Table 6. Standard Deviation of Monitored Variables

	No Rules	Basel II	Basel III
High-Yield Securities	748.42	640.24	448.89
Deposits	5,545.75	5,007.63	3,246.64
Loans to Households	127.32	71.11	59.52
Loans to Banks	48.78	53.20	50.23

Another important issue that must be discussed is the rescuing costs, which are presented for each regime in Table 7. This table shows the average values for the rescuing costs and the average values of deposit accounts and investments (securities). The rescuing costs are essentially the total financing needs of the financial institution that is rescued by the regulator and the statistics used in this table relate only to the case of a bailout. In effect, this table shows the costs incurred by the economy (essentially by the taxpayers) in the case of a bailout under each of the three regimes

Table 7. Rescuing Costs and Total Deposit Products

	Rescuing Costs	Deposits + Investments	Percentage
No Rules	348.49	1,664.04	20.94%
Basel II	503.60	1,593.08	31.61%
Basel III	1,212.84	1,225.53	98.96%
Average	688.31	1,494.22	50.51%

As was expected, given the large number of defaults, these costs are quite high in Basel III and in fact are more than double the respective costs under Basel II. In Basel III, the costs of the bailout are almost equal to the total amount of funds placed in banks, either through deposit accounts or other investments. This figure suggests that the solution of a bailout is a costly one and perhaps there are political issues to be examined, given the comparability of the deposited funds to the rescue costs. One can easily argue that a much fairer solution would be to ask those using the banking services to pay for their rescuing, as is proposed in the bail-in solution.

5.2. Real Economy

In the first part of our work, our purpose was to test for the adequacy of Basel III as opposed to Basel II. In this version of the model, where production followed a random pattern, we tested for the immediate criticism of the new measures proposed by Basel III, which suggested that they did little to deal with the problems of their predecessor and in particular those that were regarded as root causes of the crisis (Quignon, 2011, Allen et al., 2012)[39].

However, an improved model setup allowed us to examine the propagation effect of a banking crises on the real economy, whilst confirming once more our initial findings with respect to the drawbacks of Basel III. The propagation effect, termed Real Contagion (Table 10 below), was defined as the number of times that an output loss followed a banking crisis.

We executed the model 10,000 times for each available combination of rules and default solutions (9 possible combinations, i.e. 90,000 totally simulations). Our

[39] This section deals with the findings of our study, as presented in Polyzos and Samitas (2015).

virtual economy now consisted of 10 banks, 25 firms and 250 households[40] and the simulations lasted 100 periods each. Again, the simulations produced a statistics file with the values of all the variables at each time period, while the software also collects summary statistics for each simulation, so as to facilitate any further data manipulation and analysis.

Table 8. Average Values for the Monitored Variables of the Banking Sector for Each Set of Rules

	No Rules	Basel II	Basel III
Bank Defaults	4.81	5.35	5.43
Bank Default Attempts	8.79	11.49	15.80
Non-Performing Loans	3.915%	12.074%	19.815%
Deposits + High-Yield Securities	24,224.68	38,772.65	70,394.09
Consumer Loans	209,559.77	107,414.70	105,412.57
Interbank Loans	20,434.99	29,667.94	45,582.34
Available Liquidity	20,784.94	13,676.35	5,020.63
Rescue Costs	75,121.93	22,094.05	14,480.31
Recovery Periods	0.77	1.27	3.42

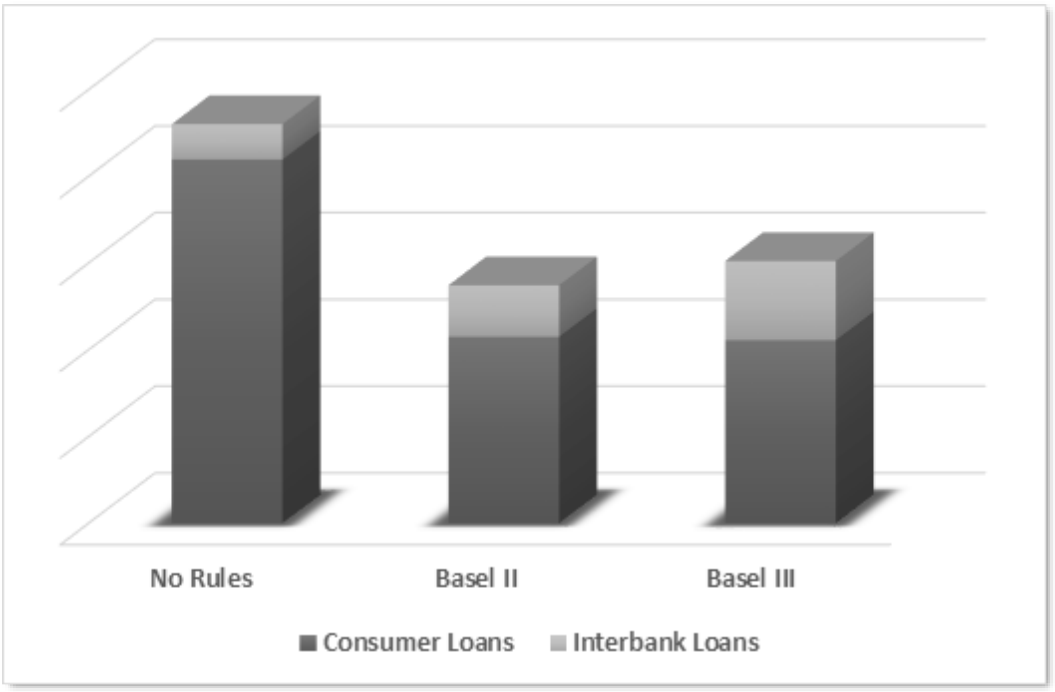
Table 8 shows the average values for the monitored variables for the simulations of each regime. The first two rows essentially signify the probability that a bank will default (or attempt a default, i.e. ask the regulator for assistance) in each of the set of rules. The last row shows the periods required under each regime for the economy to recover from a banking crisis. The values shown in this table

[40] It must be noted that the selection of the number of banks, firms and households relates solely to market depth and should not be analysed in isolation from the model results. In theory, the model could consist of one bank, one household and one firm and the interactions would still be the same. However, should one of the agents fail (i.e. go bankrupt), this would stop the simulation from completing. Thus, for each setup, we select the appropriate number of banks, firms and households to ensure adequate market depth for the simulations to complete successfully. Additionally, the number of banks must be such that allows for a non-trivial interbank market. The number in each case is selected by bootstrapping.

have been calculated over the total of 30,000 simulations for each set of banking rules (no regulation, the Basel II framework and the Basel III framework).

The results confirm our earlier findings whereby the number of bank defaults is higher in the case of Basel III and Basel II, when compared to the absence of regulatory framework. It is obvious that the strict banking rules and the increased capital requirements place a great strain on the economic system and limit the capabilities of the financial institutions. The value of the default attempts under Basel II and Basel III, is greater than the number of banks in the system which means that every bank seeks assistance from the regulator at least once, when these rules are imposed.

Figure 14. Asset Portfolio Mix for Banks under Each Regime



***Note**: This figure demonstrates the total amount of loans in the banks' asset portfolio, separating the respective amounts for consumer loans and interbank loans. Total loans are lower in Basel II and Basel III, but the portion of consumer loans is higher under Basel II and Basel III.*

The increased strain in the banking system is supported by the rest of the data that has been recorded. Amount placed in deposits and securities is higher but total loans are lower. This means that cash should be available to the economy, but, in reality, it is tied up in regulatory requirements. This is shown by the lower figures in available liquidity.

Additionally, the asset portfolio mix, as shown in Figure 14, is significantly different, with bank loans amounting to a much greater portion of the total assets. This can be regarded as a negative effect of regulation on the real economy, since banks use their available cash to finance each other and do not make these amounts available to the production sector. Interestingly enough, this effect is heightened under Basel III, where interbank financing is much higher than the other two regimes. Also, it must be noted that even though less loans are made available to households, the percentage of non-performing loans is much higher. Finally, the economy seems to need more periods to recover from a crisis in the case of Basel III, which is one more indication that the strict regime limits the flexibility of the system and the capability of the banks to overcome any issues they may be facing.

Table 9. Average Values for the Monitored Variables of the Real Economy for Each Set of Rules

	No Rules	Basel II	Basel III
Production	48,089.12	15,359.51	6,453.96
Wage per Household	251.80	85.89	44.21
Real Contagion	73.87%	76.13%	68.39%

Table 9 shows the values of the monitored values on the real economy. We can see that production is much lower when regulatory restrictions are placed on the banking sector. It is evident that banks are inadequate in financing the increase

of the productive capacity of firms, when they are faced with increased regulation. This is particularly evident under Basel III where total productive capacity is only approximately double the initial average capacity of firms[41]. The negative effects on total production are naturally also demonstrated in the average wage figures, with the average wage being much lower in Basel II and Basel III.

On the other hand, the findings on the real contagion effect are encouraging with respect to the adequacy of Basel III. As stated earlier, we have defined real contagion as the percentage of cases when a banking crisis was followed by a loss in total production. We expect a time lag on this negative propagation effect and our simulations show that one can expect that in *most* cases, when a banking crisis occurs, a contraction in output will ensue.

Table 10. Percentages of Real Contagion

	Default	Bailout	Bail-in	Average
No Rules	93.14%	53.89%	74.58%	73.87%
Basel II	92.99%	55.79%	79.61%	76.13%
Basel III	83.38%	47.51%	74.27%	68.39%
Average	89.84%	52.40%	76.15%	72.79%

However, over the three sets, the real contagion effect is lower under Basel III but higher under Basel II. This would suggest a valid argument for the adequacy of an increased regulatory framework, as opposed to a more limited set of banking rules, like those implemented under Basel II. The strict regulatory

[41] The initial total capacity of firms is set at random and in our current setup of the virtual economy, this figure averaged at around 2,500 units over the entire simulation set.

requirements function as a shield on the real economy, protecting it from the negative effects of a financial crisis.

Table 10, which presents a further analysis of the real contagion effect under each regime and for each of the default solutions proposed, confirms that the problems with real contagion are handled better under Basel III. Additionally, it seems that bailouts, using cash gathered from taxation, are better in protecting the real economy from a banking crisis. Even though taxation in our artificial economy will generally be increased after a bailout in order to gather the cash spent, the fact that the bank is rescued functions as a positive force in the real economy.

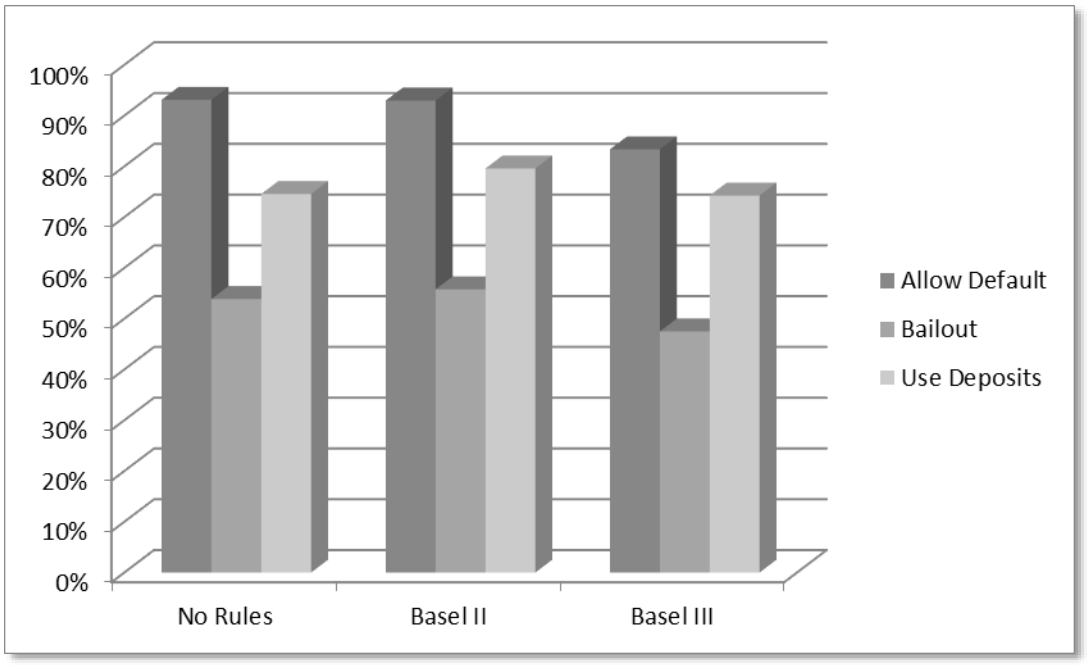


Figure 15. The Real Contagion Effect under each Regulatory Regime

Additionally, in this context, the solution of a bail-in is not more preferable to the bailout, since the contagion effect is significantly higher, albeit lower than the corresponding figures if banks are left to default. Note that the bail-in

performs approximately with the same efficiency under each of the three regulatory frameworks. The analysis of the real contagion effect for each set of rules and each solution to distress is shown graphically in Figure 15.

5.3. Welfare & Subjective Well-being

Our model can also simulate the results of banking crises on the subjective well-being of individuals that are affected by it. We were able to quantify the welfare loss of financial instability and to propose solutions, according to relative preferences of the society. We also showed that using public money to bail out banks is, in some cases, less costly in terms of welfare as opposed to dealing with a bank failure.

Table 11. Number of Simulations for Each Policy-Preference Combination

	With Tobin Tax			Without Tobin Tax		
	Allow Default	Bailout	Bail-in	Allow Default	Bailout	Bail-in
Public Goods	1,000	1,000	1,000	1,000	1,000	1,000
Equal	1,000	1,000	1,000	1,000	1,000	1,000
Financial Stability	1,000	1,000	1,000	1,000	1,000	1,000

***Note**: This table demonstrates the number of simulations executed according to the different policy responses to bank distress, to the different societal preferences and the implementation of the Tobin tax.*

We designed an artificial economy with 40 banks, 80 firms and 3,000 households. We executed 18,000 simulations with varying combinations of the regulator's policy mix and the population preferences. More specifically, the policy mix included the implementation of a Tobin tax and the three types of response to bank distress. The Tobin tax is a tax on withdrawals during a banking crisis. The

funds collected here are used by authorities for unemployment benefits, public goods and/or bank bailouts.

Table 12. Policy Mix for Best & Worst Result

	Public Goods		Equal		Financial Stability	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Subjective Well Being	Default	Bailout	Default (TT)	Bailout (TT)	Bail-in	Bailout (TT)
Subjective Well Being (Vulnerable)	Default	Bailout	Default (TT)	Bailout	Bail-in	Bailout (TT)
Subjective Well Being (Non-Vulnerable)	Default	Bailout	Default (TT)	Bailout (TT)	Bail-in	Bailout (TT)
Unemployment Rate	Bailout	Default	Bailout (TT)	Default (TT)	Bailout (TT)	Bail-in
Unemployment Rate (Vulnerable)	Bailout	Default	Bailout (TT)	Default (TT)	Bailout (TT)	Bail-in
Unemployment Rate (Non-Vulnerable)	Bailout	Default	Bailout (TT)	Default (TT)	Bailout (TT)	Default (TT)
Public Goods Spending	Bail-in (TT)	Bailout	Bail-in (TT)	Default	Default	Bail-in (TT)
Rescuing Costs	Bail-in	Bailout (TT)	Bail-in	Bailout (TT)	Bail-in	Bailout
Periods to Recover (Banking Crisis)	Bailout	Default	Bailout (TT)	Bail-in	Bailout (TT)	Bail-in
Periods to Recover (Welfare Crisis)	Bailout	Default	Bailout (TT)	Default	Bailout (TT)	Default
Average Wage	Bail-in (TT)	Bailout	Bail-in (TT)	Bailout	Default	Bailout (TT)
Tax Rate	Default	Bailout (TT)	Default (TT)	Bailout	Bail-in (TT)	Bailout (TT)

***Note**: This table shows the policy mix that yields the best and worst outcomes of the monitored variables according to societal preferences. When (TT) is added to the bank distress solution, a Tobin tax was implemented. The underlined results are the best outcome for each variable.*

Additionally, we implemented different types of preferences which, for simplicity reasons, we assumed to be uniform across the population. Households could either value public goods higher or they could value financial stability. We also implemented a third option where households value both public goods and

financial stability equally. Table 11 shows the number of simulations executed for each combination of policies and preferences. The detailed results for each simulation set are shown in the Appendix.

Table 13. Average Values of Monitored Variables by Tobin Tax Policy

	Without Tobin Tax	With Tobin Tax
Subjective Well Being	25,251.90	25,032.01
Subjective Well Being (Vulnerable)	3,494.03	3,470.91
Subjective Well Being (Non-Vulnerable)	21,757.87	21,561.09
Unemployment Rate	5.90%	5.89%
Unemployment Rate (Vulnerable)	7.54%	7.52%
Unemployment Rate (Non-Vulnerable)	5.61%	5.60%
Public Goods Spending	39,527.73	42,956.25
Rescuing Costs	247,264.38	310,536.22
Periods to Recover (Banking Crisis)	2.17	2.02
Periods to Recover (Welfare Crisis)	2.31	2.21
Wage	116.74	114.62
Tax Rate	8.40%	8.40%
Real Contagion	65.68%	67.29%
Welfare Contagion	23.58%	22.19%

This form of setup allows us to examine the effects of the policy mix on the monitored variables, according to the different preferences of the population. A summary of the best and worst result for each variable is shown in Table 12. This table is interpreted as follows: if, for example, policy makers aim to minimise the unemployment rate, when faced with a banking crisis, they should bail out banks which are in distress, since this mix achieved the lowest possible outcome in all cases of population preferences. Additionally, if they believe that households value financial stability at least as much as public goods, then a Tobin tax should also be imposed as a preventive measure. It is interesting to note that the same

policy strategy also achieves the highest possible value in terms of subjective well-being (both in total terms as well as for the different employee classes), even though it does not maximise government spending on public goods and does not minimise the tax rate. However, it does seem to maximise the average wage.

This would suggest that subjective well-being is not directed by government spending, but instead by employment and by financial stability, either directly or indirectly. Before examining these results in further detail, we present the effects of the Tobin tax on the average values of the monitored variables. It must be noted here that the Tobin tax described here is similar to Hasman and Lopez (2011), meaning that it is a tax implemented once a banking crisis is imminent. Table 13 shows that the effect of the Tobin tax is minimal on both subjective well-being and on the unemployment rate.

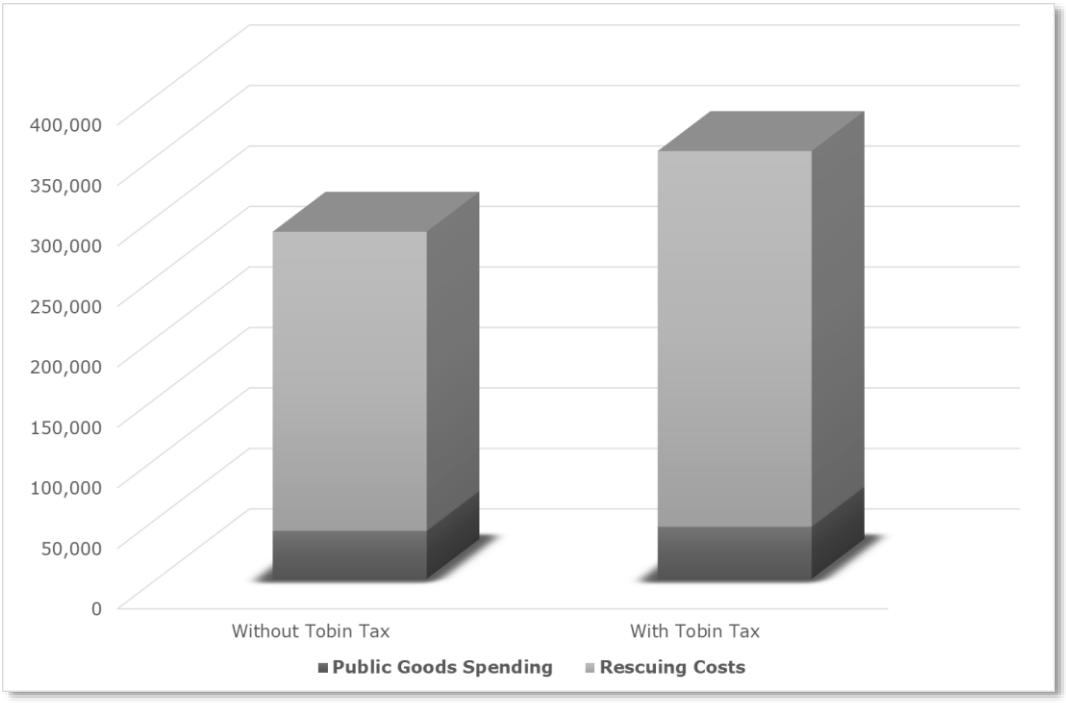


Figure 16. Public Fund Spending

The Tobin tax policy does improve welfare spending but also increases rescuing costs, since the implementation of the tax seems to lead more banks to distress. In other words, it does not appear to work as a deterrent to bank runs but, instead, it seems to burden the banking sector even more. This finding is in contrast to previous findings (García-Palacios et al., 2014; Poledna and Thurner, 2016) and needs to be explored further. A graphical depiction can be found in Figure 16, where we see that the total government spending is higher when the Tobin tax is enforced but the extra amount is channelled to the banking system. Other variables are also similar between the two policies. In other words, our appraisal of the Tobin tax seems to be negative since it does not help in limiting the crisis and, even though it helps authorities collect more funds, these funds are channelled into bank bailouts, rather than public goods.

Table 14. Variations in Subjective Well-Being

		Public Goods	Equal	Financial Stability
Bail-in	**Total**	1.45	1.00	0.55
	Vulnerable	*1.49*	*1.00*	*0.52*
	Non-Vulnerable	*1.44*	*1.00*	*0.55*
Bailout	**Total**	1.58	1.25	0.65
	Vulnerable	*1.64*	*1.28*	*0.62*
	Non-Vulnerable	*1.57*	*1.24*	*0.65*
Default	**Total**	1.18	0.91	0.58
	Vulnerable	*1.21*	*0.92*	*0.55*
	Non-Vulnerable	*1.18*	*0.91*	*0.58*

***Note**: This table shows the variations in subjective well-being (total and by employee class) according to the different solutions to bank distress and the differences in societal preferences. We use the case of the bail-in and of indifference between public goods and financial stability as the benchmark (value 1) and calculate the proportionate changes of the SWB according to the different scenarios.*

We now examine the effects of the various solutions to bank distress given the societal preferences regarding financial stability and public goods. In Table 14, we see the variations in subjective well-being. As we noted earlier, in Table 12, the best outcome for societal happiness is the bailout solution, which maximises total SWB across all preference scenarios. Also, it is interesting to note that with the bailout solution, the vulnerable class enjoys the biggest welfare gain when compared to the gain of the non-vulnerable class.

The second-best solution is the bail-in, but only if society does not favour financial stability over public goods. If society favours stability, then allowing banks to default yields better results in terms of total well-being. This suggests that the financial turmoil that results from the bail-in will cost more to society in terms of welfare than a bank bankruptcy, when societal happiness is based on financial stability.

Table 15. Variations in the Unemployment Rate

		Welfare	Equal	Stability
Bail-in	**Total**	5.95%	5.93%	5.96%
	Vulnerable	*7.58%*	*7.56%*	*7.62%*
	Non-Vulnerable	*5.66%*	*5.64%*	*5.67%*
Bailout	**Total**	5.73%	5.63%	5.73%
	Vulnerable	*7.35%*	*7.20%*	*7.30%*
	Non-Vulnerable	*5.45%*	*5.35%*	*5.45%*
Default	**Total**	6.12%	6.00%	6.03%
	Vulnerable	*7.80%*	*7.65%*	*7.70%*
	Non-Vulnerable	*5.82%*	*5.70%*	*5.73%*

***Note**: This table shows the variations in the rate of unemployment (total and by employee class) according to the different solutions to bank distress and the differences in societal preferences.*

This is an important implication regarding the social outcomes of the different solutions to bank distress. Our model shows that using public money to bailout banks helps society in general but favours vulnerable employee classes to a bigger extent. It is also interesting to note that the welfare loss when moving preferences towards stability is greater for the vulnerable class. This means that when society in general favours financial stability over public goods, the lower social class experience a loss in well-being, since their consumption is based more on public goods

Moving on to unemployment (Table 15), the solution of bank default generally seems to yield better results. This would suggest that the repercussions of a banking crisis if the bank is allowed to default are more easily handled by the economy, if no resources (either private or public funds) are channelled to the banking sector. This is a clear sign that the real economy is more harmed by the outlay of funds to save banks, than by the actual bank default.

Table 16. Contagion Effects

		Public Goods	Equal	Financial Stability
Bail-in	**Real**	58.78%	52.18%	65.27%
	Welfare	25.90%	22.29%	17.98%
Bailout	**Real**	49.99%	45.51%	51.22%
	Welfare	27.74%	25.50%	15.83%
Default	**Real**	88.42%	87.09%	99.89%
	Welfare	24.43%	23.19%	23.16%

***Note**: This table the contagion effects according to the various scenarios simulated. The real contagion is defined as the percentage of financial crises which were followed by an output loss (a real crisis). The welfare contagion is defined as the percentage of financial crises which were followed by a loss in societal well-being (a welfare loss).*

Also, as we see in Table 16, the real contagion effect (the spillover of the crisis from the banking sector to the real economy) is much higher if banks are left to go bankrupt. Real contagion is also higher when households favour financial stability. On the other hand, welfare contagion is lower when financial stability is preferable. This is an intuitively unexpected result, because we would expect that in that case, it would be more likely that a welfare loss came after a financial crisis. However, this finding is an indicator that, even when stability is preferable, any well-being loss incurred because of the crisis is offset by the other components of (EQ5).

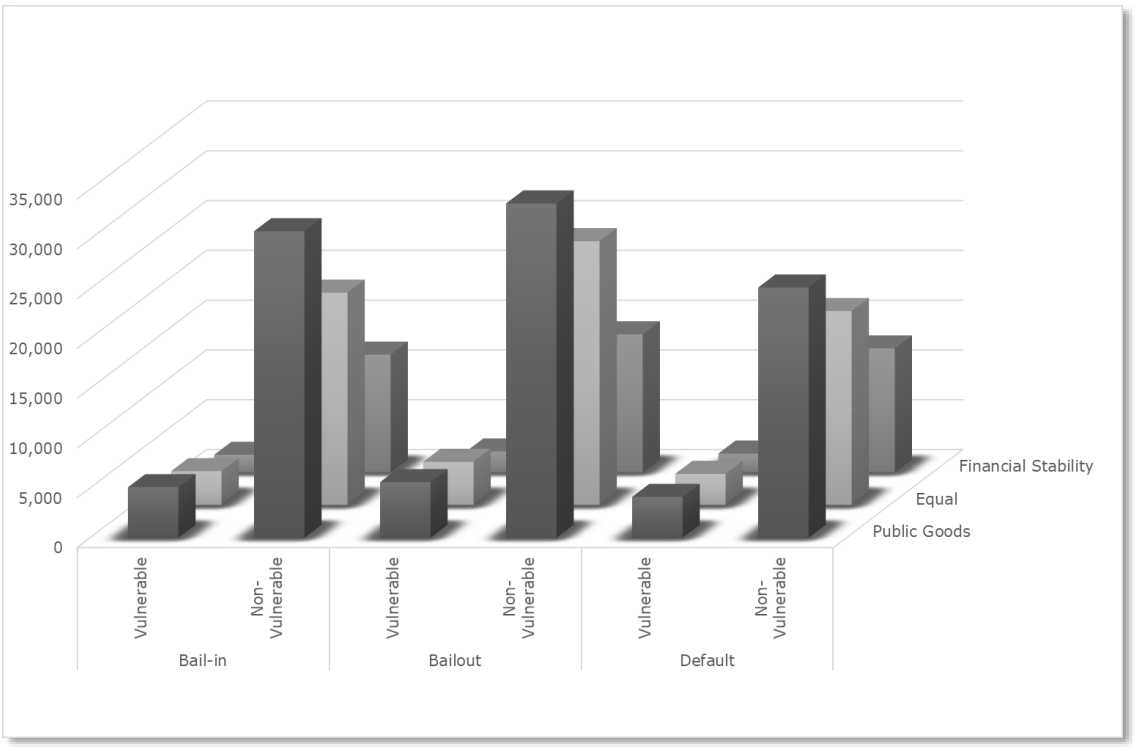


Figure 17. Subjective Well-Being by Employee Class

***Note**: This figure demonstrates the outcomes in subjective well-being by employee class for the different combinations in bank solvency and societal preferences.*

Finally, in Figure 17 we see the differences in subjective well-being for the different employee class. It is evident from the graph that the bailout solution is the best in terms of welfare, both for the society as a whole and for the separate employee classes. We believe this to be one of the most important findings of our work. Bank defaults or bail-ins result in heavy income losses to individual agents, which result to a significant drop in total SWB. This loss cannot be compensated by public goods spending, even in the cases when society values public goods more than financial stability.

5.4. Corporate Governance

Our model is also able to simulate corporate governance features, such as those proposed by researchers in section 3.5. After the implementation of the variables in the proposed agent-based model, a virtual economy is designed, consisting of 1,000 households, 10 banks and 40 firms. Basel III was enforced as a regulatory framework for the banking system and a bail-in was the solution of choice for the Regulator to save a bank in distress. The time span for each simulation was 30 periods and 10,000 simulations were executed[42].

Table 17 shows a summary of the monitored variables for each of the four final states. The sample is 100,000 banks (10,000 simulations with 10 banks each) with random governance features, as described earlier. This table shows the distribution patterns for each of the variables over the entire sample of 100,000 observations, according to the final states. The table is indicative of the firm link between the bank's final state and both its governance and financial features.

[42] The results of this section are similar to those of Polyzos et al (2018).

Table 17. Summaries of monitored variables for each Final State

	Bankrupt	Needs Financing	Balanced	Prosperous
No CRO In Board	66.0%	61.0%	53.0%	53.0%
CRO In Board	34.0%	39.0%	47.0%	47.0%
Board Size (Independent/Dependent Members)	12 (8/4)	13 (8/5)	13 (9/4)	13 (9/4)
CEO Ownership	20.5%	23.7%	25.2%	25.2%
Public Ownership	28.6%	28.1%	37.2%	30.5%
Institutional Ownership	20.9%	23.2%	22.6%	24.3%
Assets to Liabilities	1,221%	1,098%	73%	691%
Loans to Deposits	3,702%	2,165%	156%	1,494%
Deposit Rate to Market Average	101.8%	97.4%	93.7%	93.9%
Loan Rate to Market Average	102.3%	97.2%	94.2%	95.3%
Spread	6.41%	5.95%	5.88%	5.91%
Profit Margin	5.28%	5.42%	5.58%	5.42%
Non-Performing Loans	9.88%	15.38%	1.59%	9.16%
Interbank Exposure	28.7%	54.4%	1.4%	39.3%
Cash to Weighted Assets	25.6%	24.6%	36.1%	31.8%

Note: This table includes the summaries of monitored variable of the simulation set, for each of the final states of banks. The summary for the CRO variables is the percentage of the banks where the particular feature was true, except for the board size, which shows the average number of members. The summaries for the financial variables, as well as of ownership variables (CEO Ownership, Public Ownership and Institutional Ownership) represent the average values recorded at the snapshot period (period 10), linked with the end state of the bank after the end of the simulation.

Firstly, it is clear that CRO presence improves the bank's final state, since the worse-off states show lower average CRO presence in the board of directors (Figure 18). The board size does not seem important in determining the final state, but it seems that an increased number of independent members is beneficial (Figure 19).

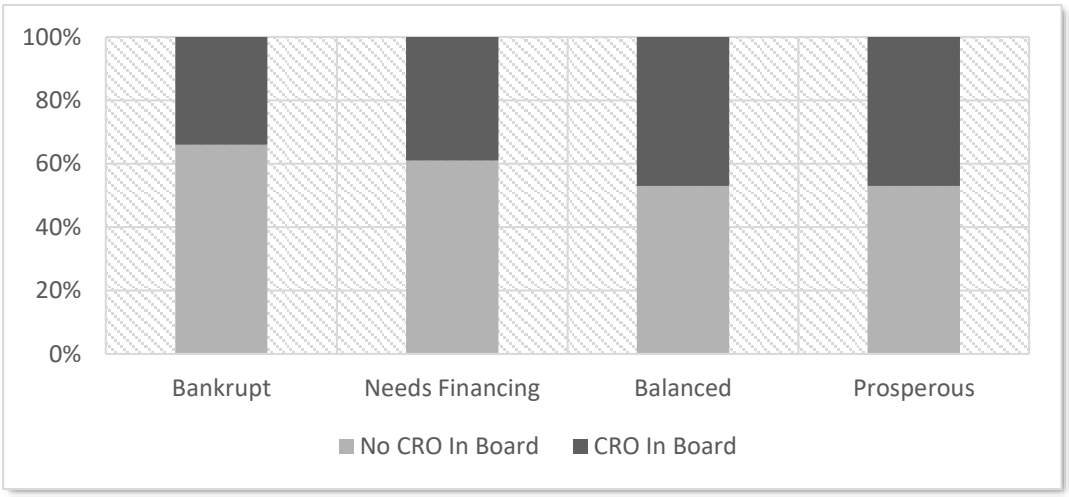


Figure 18. CRO Presence for each of the four final states

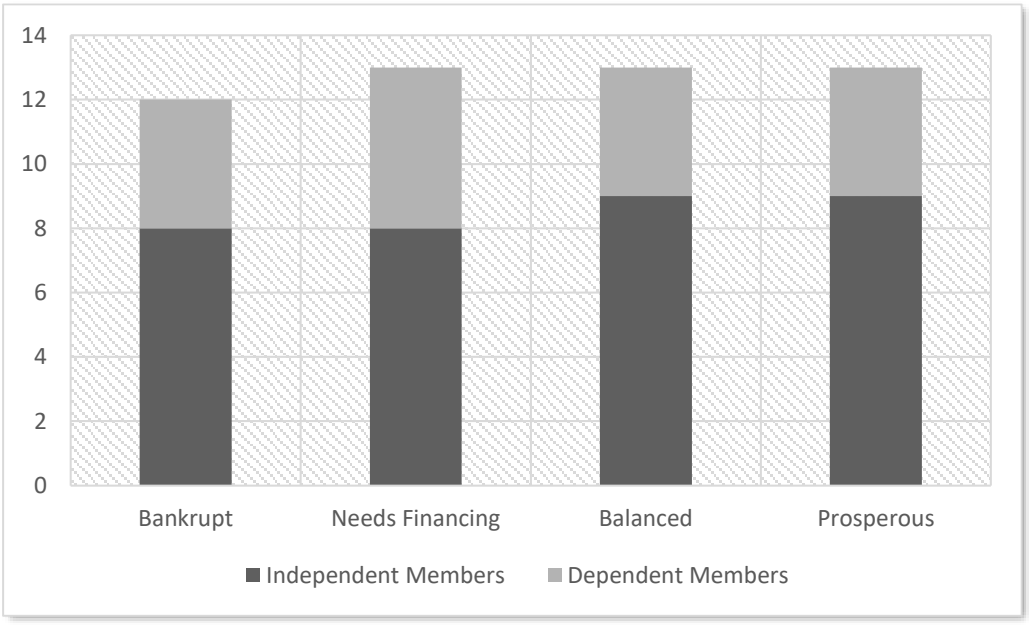


Figure 19. Dependent and independent board members for each of the four states

In terms of the ownership structure, it is evident that a larger value in CEO ownership as well as in institutional ownership will tend to improve the bank's future. On the other hand, greater public ownership seems to lead the bank to the balanced state more often, which is an expected result since publicly owned banks tend to exhibit lower risk and lower profitability. The latter variable

(public ownership) does not seem to exhibit a liner relationship with the dependent variable (final state).

Moving on to financial information, it is important to note the existence of "extreme" values for all states except the balanced state. It must also be noted that the amount of loans that bankrupt banks carry in their asset list is substantially higher than the other states. However, the existence of extreme values in the prosperous state leads us to deduce that banks cannot prosper if risks are not assumed. Nevertheless, it must be made clear to investors and depositors that these risks may result in bank failure. Risks must also be assumed by the financing department, where interestingly enough data for the NPLs and the interbank exposure at the snapshot period (period 10, as mentioned earlier) are similar for banks which ended up in the bankrupt and prosperous states, albeit interbank exposure is somewhat higher for the prosperous state.

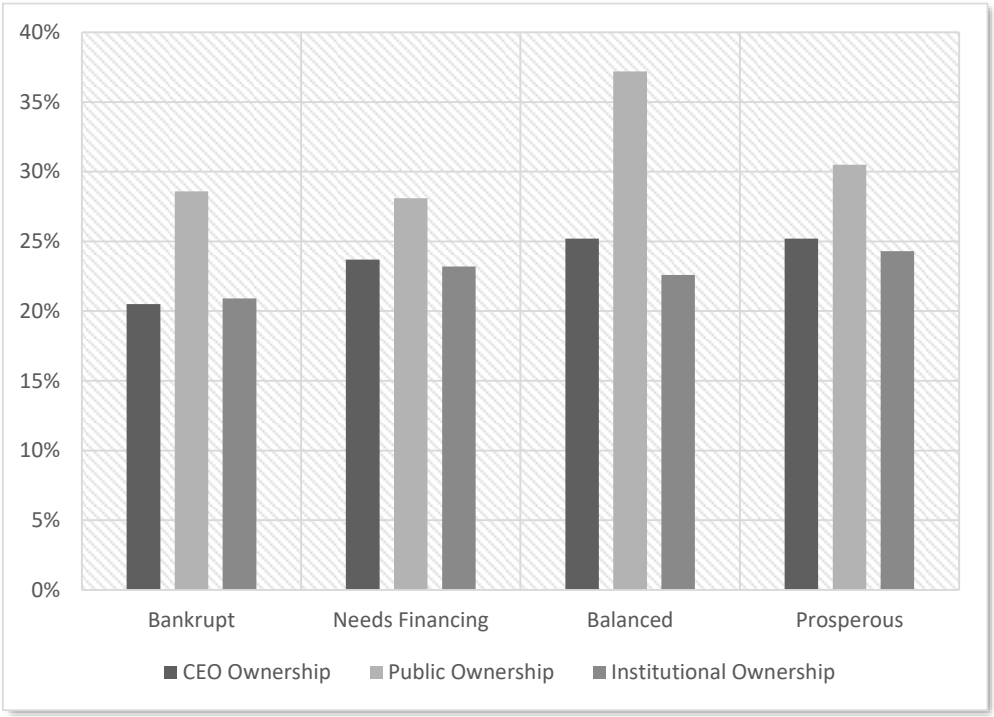


Figure 20. Average ownership percentages for each of the final states

With respect to the market position, it must be noted that the simulations appear to suggest an interest rate strategy for banks. The findings show that offering lower interest rates, vis-à-vis the market average, both for deposits and for loans, will improve the bank's future, the particulars of the prisoner's dilemma notwithstanding. A lower interest rate spread is also advisable, as is the use of a lower profit margin, even though the results are not clear on the latter.

A simple linear regression on the results shows that the important variables are the presence of the CRO in the board (similarly to Aebi et al., 2012), the ownership variables (similarly to Barry et al., 2011) and the interest rate strategy variables. These were included in the final prediction model.

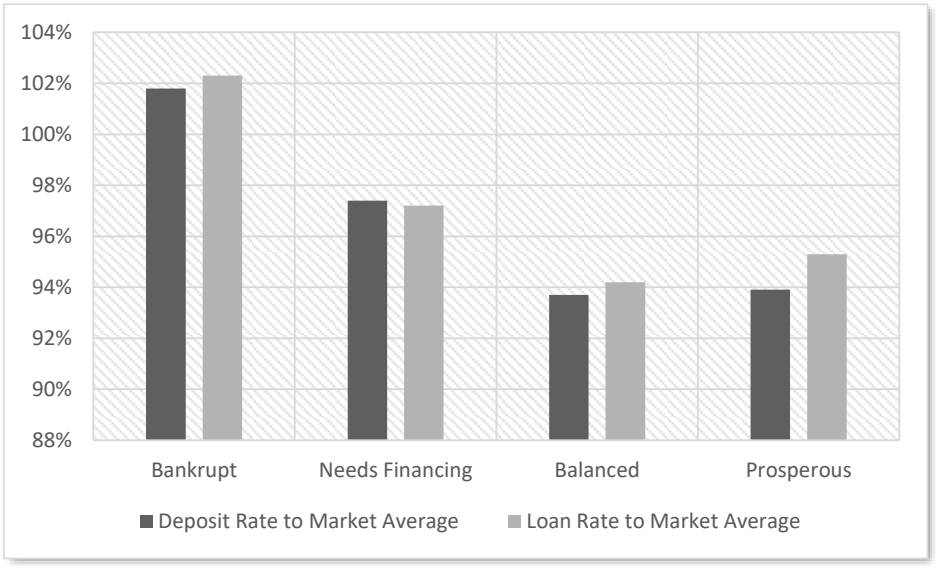


Figure 21. Interest rates over the respective market average

It is not surprising that the public ownership variable does not exhibit high correlation, since, as was shown earlier, its relationship with the final state is not a linear one and consequently a linear regression of these variables will fail to describe the dependent variable's values. Admittedly, the use of a linear regression is simplistic and is one of the shortcomings of our current work.

However, as we will see below, the linear regression is successful in describing the model and the resulting forecasting system can predict the bank's final state with a fair amount of certainty.

Table 18. Regression linear regression model for the prediction of the final state of the bank

	B	*Standard Error*
(Constant)	-1.82	0.018
CROInBoard	0.65	0.006
LoansToDeposits	-0.02	0.000
PublicOwnership	-0.28	0.012
InstitutionalOwnership	0.32	0.013
CEOOwnership	0.19	0.013
DepositRateToAverage	-0.15	0.014
LoanRateToAverage	-0.36	0.029

***Note**: The model's R^2 value is 0.62, which means that an important proportion of the variance in the dependent variable (FinalState) can be predicted from the given set of independent variables. The specific value (0.62) shows that the model is a good fit for the given data set.*

Table 18 shows the coefficients for the variables in the proposed prediction model, which are significant at the 95% confidence level. This regression model has a satisfactory R^2 value and was implemented in our model in an effort to predict the final state of the financial institution. Once the prediction model was implemented, we executed the simulations 1,000 more times to verify robustness and the outcome (displayed in Table 19) was encouraging. On the snapshot period, we calculated the financial variables and used them in conjunction with the governance variables in order to compute a prediction for the bank's final state. We let the simulation complete and compared the predicted state to the actual final state.

In most cases, the prediction model was successful in forecasting the bank's final state, since in only 35% of the simulations the prediction was false. In these latter cases, only 42% would be damaging to the investors, since the final state of the bank was worse than the predicted one. Consequently, even though one can argue that a prediction of a worse state than the final one can also prove damaging, only a mere 15% of predictions could make an investor or depositor worse off if they followed it.

Table 19. Robustness check of the prediction model over 1,000 simulations

	Percentage
Successful prediction	64.25%
Unsuccessful prediction	35.75%
Better State than predicted	*57.98%*
Worse State than predicted	*42.02%*

Chapter 6. Special Cases

6.1. Capital Controls in Greece

The surprising developments in Greece, in the summer of 2015, which brought the country on the brink of a Grexit, i.e. an exit from the Eurozone, caused for the implementation of banking capital controls on the outflow of funds, a policy decision not uncommon, especially in emerging markets. However, the structural weaknesses of the Greek economy, which seemed to stem from weakness of the governing institutions but had been passed on to the banking sector, posed a unique challenge to researchers.

Globalisation in the modern economic system has resulted in increased capital flows, across international border and locally as well. Authorities often attempt to tweak the efficiency of monetary policy tools by implementing restrictions on capital flows (both outgoing and incoming), which are generally referred to as capital controls. In this section of our work, we present a particular set of capital controls, which limit the circulation of cash inside the borders of the economy, an issue still at hand in Greece. We employed our agent-based model to examine whether these restrictions were implemented in a timely manner in the Greek banking sector and to attempt a forecast as to the persistence of these measures, based on the relevant literature and using data on the capital requirements of Greek banks in the days preceding the crisis.

Our work in the section contributes to three aspects of the existing literature. Firstly, we propose an empirical implementation of the theory on cash capital controls, where research appears to be limited since a significant portion of the relevant literature focuses on restrictions imposed on the inflow of capital, a

common solution in developing and emerging markets. Secondly, we propose the optimal point (in terms of the financial and output costs) during a bank run where controls should be enforced. Lastly, we used the aforementioned findings to examine the timeliness of the implementation of capital controls in the Greek banking sector in the end of June 2015.

6.1.1 Relevant Literature

Capital controls have been used historically as a response to financial crises. The first well known use dates as far back as World War I. More modern instances of capital controls can be found in Malaysia, Iceland, Cyprus and, more recently, Greece. What is particular to the Greek case is that in the first three economies, the causal crisis was the financial crisis. On the contrary, in Greece the financial crisis that called for the implementation of capital controls was subsequent to a lasting fiscal and political crisis, which has driven the economy into a recessionary slump and has thus put further strain on the banking sector. Capital controls, in various forms, have also been used to limit capital inflows, which may impede the use of monetary policy and may also cause currency appreciation, over the short term. A notorious form of regulation against capital inflows was the Chilean *encaje*, a short-term, interest-free, mandatory deposit with the country's Central Bank, which was required for foreign investors.

Despite their relatively infrequent use, capital controls have been the subject of academic research due to the fact that they are usually the foremost solution to a banking system that is in a critical state of cash haemorrhaging, even though they are considered detrimental to the efficiency of the financial system. Additionally, existing literature seems to reach contradicting conclusions as to the efficiency and adequacy of capital controls, particularly when used in the context of a recessionary economy. Furthermore, as Magud et al. (2011) point

out, researchers have failed to agree upon a unified framework for examining capital controls. Finally, each country which has implemented restrictions in capital flows seems to be a unique case to such an extent that existing studies cannot even agree on a single measure of what a successful implementation entails.

Eichengreen and Rose (2014) present a thorough discussion on capital controls in modern economies. They show that capital controls are persistent, staying in place for long periods of time, exhibiting similar behaviour to international trade policy regulations. Their use is linked with limited financial depth, weak political institutions and lower quality of financial regulation.

One of the most prominent supporters of capital controls is Paul Krugman, who has argued in favour of capital controls, as a short-term tool to limit capital outflows that would prevent the economy from bouncing back to a positive path (Krugman, 1998). Johnson and Mitton (2003) suggest that imposing restrictions on capital flows may also limit cronyism, due to the similar extent that capital resources would be limited to politically connected and non-connected firms alike.

Both Bhagwati (1998) and Rodrik (2000) argue in favour of capital controls in particular cases and especially over the short term. They also point out that capital market liberalisation may make the financial system more vulnerable to speculative attacks, which have been an issue in many smaller economies, such as Greece. Finally, Montiel and Reinhart (1999) examine regulation enforced on capital inflows in the Asian economies during the 1997 crisis and show that they were mostly effective in limiting the volume of capital, while in some instances they affected the composition of capital, which shifted away from long-term investments towards short-term capital.

On the other hand, some researchers remain unconvinced by the above arguments. Goodman and Pauly (1993) argued that capital controls had become obsolete as early as the start of the 90s, due to the globalisation of the financial markets and the abundance of evasion strategies from firms. Mitchener and Wandschneider (2015) show that capital controls enforced in the 1930s US economy limited the effectiveness of monetary policy instruments and slowed down economic recovery. Danielsson (2008) supports the same argument, but in reference to the Icelandic economy and points out that the opportunity cost in terms of corporate investment exceeds the benefits of long-lasting capital controls.

Edwards (1999) and Schmidt (2001) examine the effectiveness of regulation on both inflow and outflow of capital and show that such policy measures carry a significant administrative cost and are often ineffective and prone to corruption. Edwards however points out the partial effectiveness of policy measures in Chile in increasing the maturity of foreign debt. Both introduce the idea of a Tobin tax on capital flows, which seems to be a more effective tool. Both also agree that policy measures that aim at improving banking supervision and decreasing moral hazard in the banking sector should be regarded as first-best policies.

Eichengreen and Rose (2014) argue against capital controls also, suggesting that such measures should be used as a last resort, after first-best policies have been exhausted. Forbes et al. (2011, 2012) show that the use of capital controls raises negative externality issues to neighbouring economies and that this effect should be taken into account in policy decisions. It should be noted that the decision to implement policies that limit capital inflows or outflows is a rather difficult one, since these flows tend to be unpredictably volatile, challenging policy makers even more (Broto et al., 2011).

Alesina et al. (1993) argue that limiting capital outflows permits the local economy to run under increased inflation, since individuals can no longer hold capital in foreign funds and assets. In general, they show that controls favour distortions in domestic policy, but allow greater independence of government policies, with respect to financial trade neighbours. Finally, Fernández et al. (2013) argue that capital controls are irrelevant when dealing with real economic crises and show that output and exchange rate fluctuations cannot be dealt with using capital controls.

In general, the views of researchers seem to be contradicting both in methodology and in the conclusions reached. In this context, we proposed the application of our simulation framework to test for the effects of capital controls on the banking sector of a hypothetical economy.

6.1.2 The Economic Environment

We collected data from the Bank of Greece and from the European Central Bank, regarding deposits and loans in Greece and the Eurozone. The data clearly demonstrates the deteriorating state of Greek financial institutions. Additionally, it is interesting to point out that a mere glance at the graphs yields many conclusions regarding the timing of the political developments in the country, both in terms of expectations and in terms of actual events. Note that the use of integrated banking data for the Eurozone, despite the heterogeneity of the banking sectors at the national level, is acceptable, since there exists evidence that national markets behave as a single European Market (Bos & Schmiedel, 2007).

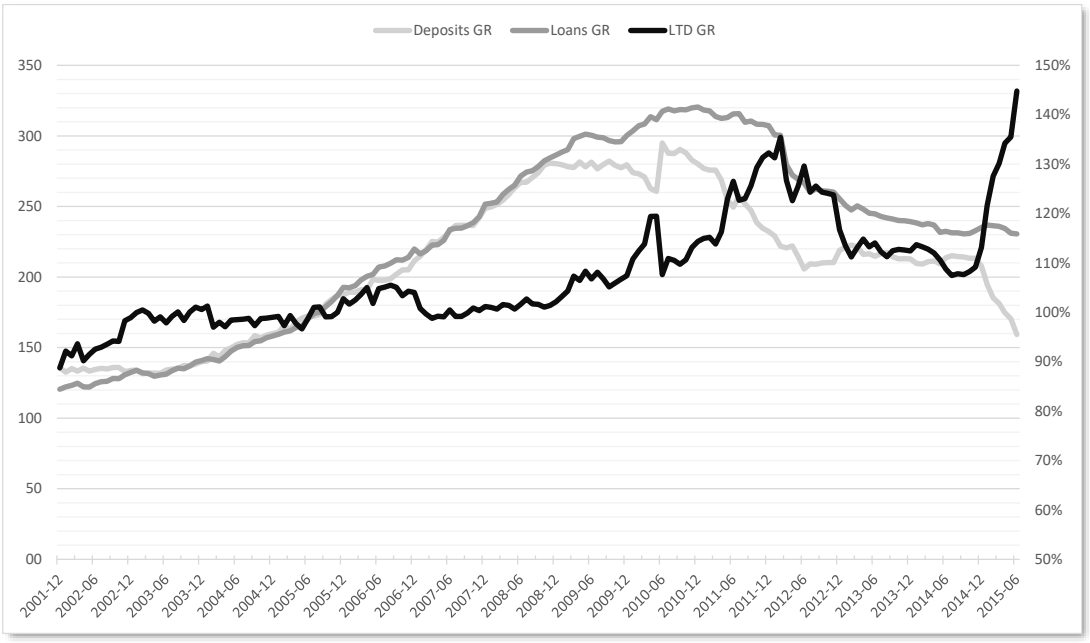


Figure 22. The Banking Sector in Greece

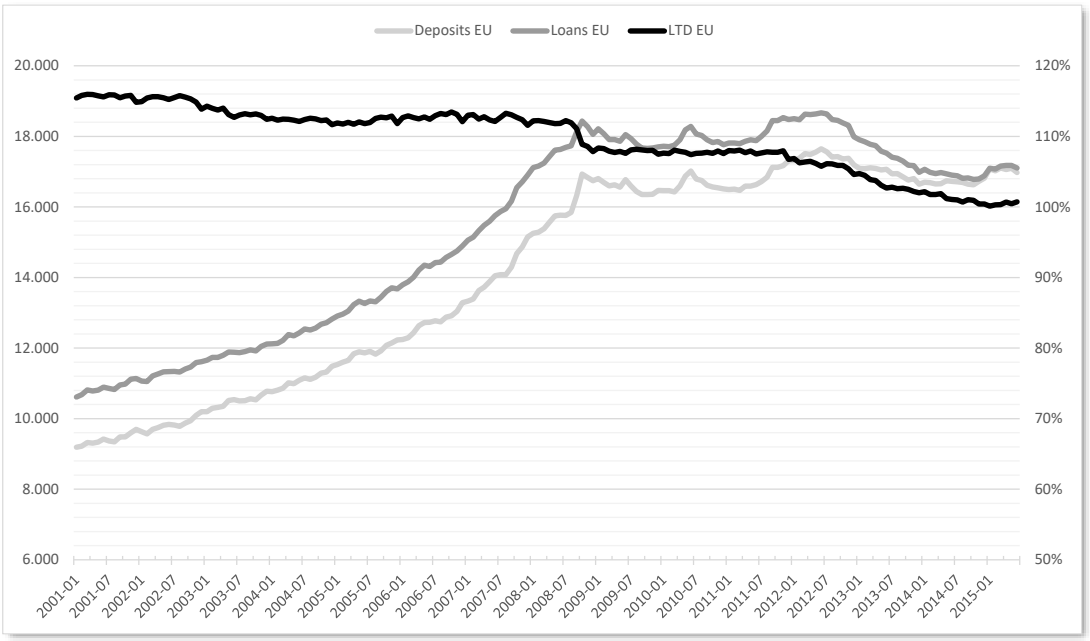


Figure 23. The Banking Sector in the Eurozone

***Note**: These figures demonstrate the total deposits, the total loans (in billion Euros) and the corresponding Loans-To-Deposits (LTD) ratio for Greek and European Banks since 2001.*

The data paints an astonishing, yet not unexpected picture. Following the Greek government's inability to refinance public debt from private creditors, the country entered a strict austerity regime, coupled with extensive market reforms, in April 2010. Both deposits and loans (Figure 22) follow a downward path after that point. What is more, we see a sharp drop in deposits as we approach the 2012 elections, when there was increased restlessness among depositors due to fear of a Greek default. After the end of the elections, deposits seem to have recovered somewhat, only to experience a new drop in the months leading to the elections of January 2015 and the referendum of July 2015. In June 2015, the LTD value for the Greek banking sector reached 145%, when "normal" values should not exceed 120% (Van den End, 2014).

At the same time, banking business in the Eurozone follows a smooth trajectory (Figure 23). Despite slowing down after the 2008 financial crisis, deposits and loans remained at their pre-crisis levels. The LTD ratio for banking in the Eurozone follows a path converging towards 100%, where loans are equal to deposits. The fact that the European banking sector exhibits such smooth behaviour in its activities can be seen as a sign of robustness, taking under consideration the difficulties faced by banks in the PIIGS[43].

Put together, the above figures demonstrate the distress of the Greek banking sector and show that the system is in fact in crisis. Additionally, it is evident that a bank run is taking place, albeit at a slower pace than what we might be seeing if depositors were faced with widespread panic. These figures help us examine

[43] A commonly used acronym for countries in the European South (and Ireland) that have been experiencing public debt issues. More specifically, PIIGS stands for Portugal, Ireland, Italy, Greece and Spain.

whether capital controls were enforced in time according to the empirical results of our simulations.

6.1.3 Methodology Particulars

As Eichengreen and Rose (2014) show, capital controls are usually not being enforced in response to macroeconomic shocks in output or in response to exchange rate or financial incidents. Instead, they focus on regulatory quality, on the political regime and on the depth of the financial market. In our modelling approach, the latter is not applicable since we examine the same financial system. We have however introduced a political stability factor which can cause distress on the financial system. Note that the particular causes of deterioration in political stability are not of interest to us; we simply postulate that a political crisis can bring about anxiety in the financial sector (Asteriou and Siriopoulos, 2000) and may consequently cause a bank run. This was the case in Greece, when the government decided to put Europe's proposed bailout plan to a referendum, which was seen by some as a first step towards the exit of Greece from the Eurozone.

In their general definitions, capital controls can be any policy which aims at limiting or redirecting capital account transactions. This is a relatively broad definition which covers all the forms that these policies may take. In our approach, however, capital controls aim at stopping a bank run, by limiting the amount individuals (firms and households) can withdraw from their bank accounts at any given time. In effect, regulatory authorities fear that sudden outflows of funds deposited in banks may endanger economic stability. Bank runs can be initiated by political instability, banking crises or any sudden drops of depositor confidence. Authorities take action at some point during capital outflow, using two key criteria: the percentage loss of deposits from the

beginning of the bank run and the loans-to-deposits ratio (LTD) in the banking sector. The latter is an important indicator of liquidity mismatch risk (Van den End, 2014) and can be used to signify general system health. Van den End shows that a generally acceptable upper limit for the LTD ratio is 120%.

As far as modelling bank runs, our implementation follows Diamond and Dybvig (1983), Bryant (1980) and Uhlig, H. (2010). Diamond and Dybvig showed that a bank run may be the result of rational behaviour by depositors who seek to maintain increased liquidity. Bryant urges the importance of incomplete information and proposes some solutions, including deposit insurance, which is not implemented here. A bank run can be the result of a series of events that affect the confidence of depositors in the banking sector. The causality of these events is not studied in this paper since our aim is to examine capital controls in response to these events; we model reactive measures, not proactive ones.

Once the bank run begins, bank customers (Households and Firms) withdraw amounts from their deposit accounts. They are also unwilling to undertake increased risk in investment products, even if the expected payout is higher. Note that not all customers withdraw their funds from banks. We implement a subgroup of economic agents (termed "Bank Runners") who make withdrawal tenders for the full amount of deposit and investment products. Tenders are satisfied at each time period but the probability that an agent enters the Runner group increases at each period the cash hoarding mindset kicks in. Note that Banks do not participate in the bank run (as customers).

Once the bank run starts, firms and households randomly start to enter the Bank Runners group. Agents in this group choose to hold no deposits in banks. Additionally, all active agents do not deposit any excess funds to banks. At some point during this process, the Regulator implements capital controls, limiting the

amount of funds that can be withdrawn as cash from banks. The cash distinction must be made since we allow Firms and Households to withdraw funds in order to pay their obligations (loans and wages).

We utilise our platform's ability to run consecutive repetitions of the same simulation and examine the optimal point where controls must be enforced. The regulators will use the deposit loss or the LTD ratio as a signal in order to enforce limits on deposit outflows. The cut-off values for these signals (i.e. the point at which the controls will be put in place) are different on each simulation. After the end of the bank run (a certain number of periods later), we examine which of these signals is more efficient as to the final outcome in terms of the costs incurred by the real economy and the financial system. Additionally, we attempt to locate the optimal value for each of the two signals which will result in the best result.

6.1.4 Empirical Results

Our model setup for this particular issue consisted of 40 unique simulation sets. Each set was characterised by the capital control enforcement criterion (LTD or loss of deposits) and by the alert-health pair values[44]. The alert value signifies the benchmark value for the given criteria where the Regulator imposes capital controls in the banking sector. The health value is the value where the economy is considered healthy again and capital controls are eliminated. It is important to examine both these values since our assumption is that the longevity of capital restrictions on the economy is as damaging as the restrictions themselves. Each simulation set was repeated 1.000 times and statistics were collected for each simulation separately.

[44] This section discusses the results similarly to Samitas and Polyzos (2016).

Table 20. Average Number of Periods under Capital Controls for the Loans-To-Deposits Criteria

		System Health At				
		100%	**105%**	**110%**	**115%**	**Average**
Alert At	**125%**	21.279	21.525	21.240	20.973	**21.254**
	130%	21.774	21.924	21.936	21.378	**21.753**
	135%	22.272	22.113	21.849	21.702	**21.984**
	140%	22.266	22.251	22.182	21.903	**22.151**
	145%	22.989	22.617	22.752	22.455	**22.703**
	150%	22.542	22.905	22.611	22.518	**22.644**
	Average	**22.187**	**22.223**	**22.095**	**21.822**	**22.082**

Table 21. Average Number of Periods under Capital Controls for the Deposit Loss Criteria

		System Health At				
		90%	**95%**	**100%**	**105%**	**Average**
Alert At	**60%**	40.390	42.596	42.839	87.166	**53.248**
	65%	34.641	34.843	35.366	79.167	**46.004**
	70%	26.302	29.689	31.333	76.459	**40.946**
	75%	11.195	16.857	24.293	67.943	**30.702**
	Average	**28.132**	**30.996**	**33.458**	**77.684**	**42.567**

In Table 20 and Table 21, we see the average number of periods that the economy remained under capital controls, for each simulation set. Our first outcome is the significantly longer period that the economy must remain under restrictions if the deposit loss criteria are used. When faced with the panic of a bank run, even under capital controls, it is far more difficult for the banking system to reclaim the lost deposits. Furthermore, the longer authorities wait to enforce the restrictions (a higher LTD or a lower deposit loss alert value), the longer it will take for the system to return to a healthy state. This outcome is not surprising. What is interesting, however, is that this effect is further exacerbated for the

deposit loss criteria, where a lower deposit loss alert value results in a significantly longer period under restrictions.

Table 22. Average Values of Monitored Variables under Capital Controls for the LTD Criteria

Alert LTD	125%	130%	135%	140%	145%	150%	Average
Periods In CC	21.254	21.753	21.984	22.151	22.703	22.644	**22.082**
NPL %	23.81%	24.88%	25.36%	25.79%	26.78%	27.00%	**25.60%**
Consumer Loans	8,339.60	8,464.11	8,423.69	8,456.14	8,553.68	8,513.78	**8,458.50**
Interbank Loans	57.86	64.62	75.01	114.04	106.25	130.16	**91.32**
Δ Deposits	-65.29%	-68.55%	-70.86%	-72.62%	-75.29%	-76.65%	**-71.54%**
Δ Production	-16.35%	-18.67%	-19.31%	-20.49%	-22.33%	-22.70%	**-19.97%**
Δ Wages	15.90%	2.71%	-0.20%	-0.85%	-17.19%	-34.80%	**-5.74%**

Table 23. Average Values of Monitored Variables under Capital Controls for the Deposit Loss Criteria

Alert Deposit Loss	60%	65%	70%	75%	Average
Periods In CC	53.248	46.004	40.946	30.072	**42.567**
NPL %	7.23%	6.76%	5.79%	4.76%	**6.14%**
Consumer Loans	4,727.82	4,833.42	4,712.45	4,304.81	**4,644.63**
Interbank Loans	781.13	624.80	523.20	319.55	**562.17**
Δ Deposits	23.51%	17.89%	17.10%	26.59%	**21.27%**
Δ Production	30.52%	31.37%	26.11%	18.51%	**26.62%**
Δ Wages	1.93%	4.96%	1.82%	-5.52%	**0.80%**

***Note**: The tables above demonstrate the results of the simulation sets for each of the parameter values. Table 22 includes the values of the monitored variables when capital controls are enforced according to various values of the LTD ratio, while Table 23 includes the corresponding values when capital controls are enforced according to loss of total deposits held in banks. Each line is computed using the average values of the variables recorded on the simulations executed for each of the four health values of the corresponding criteria (i.e. 4,000 simulations for each line).*

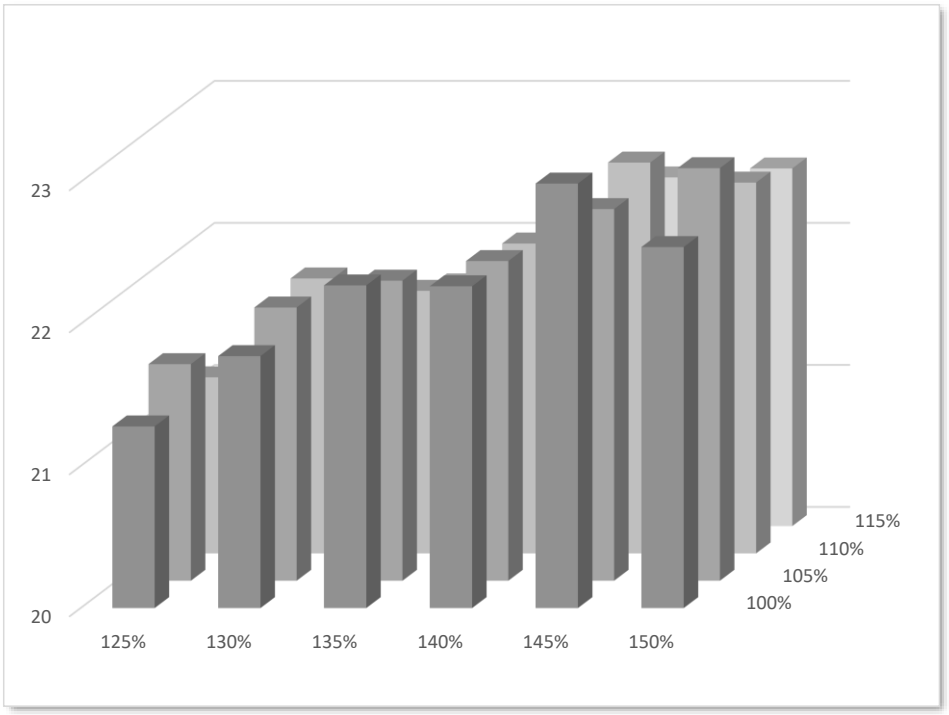


Figure 24. Periods under capital controls for combinations of values for the alert and health LTD criteria

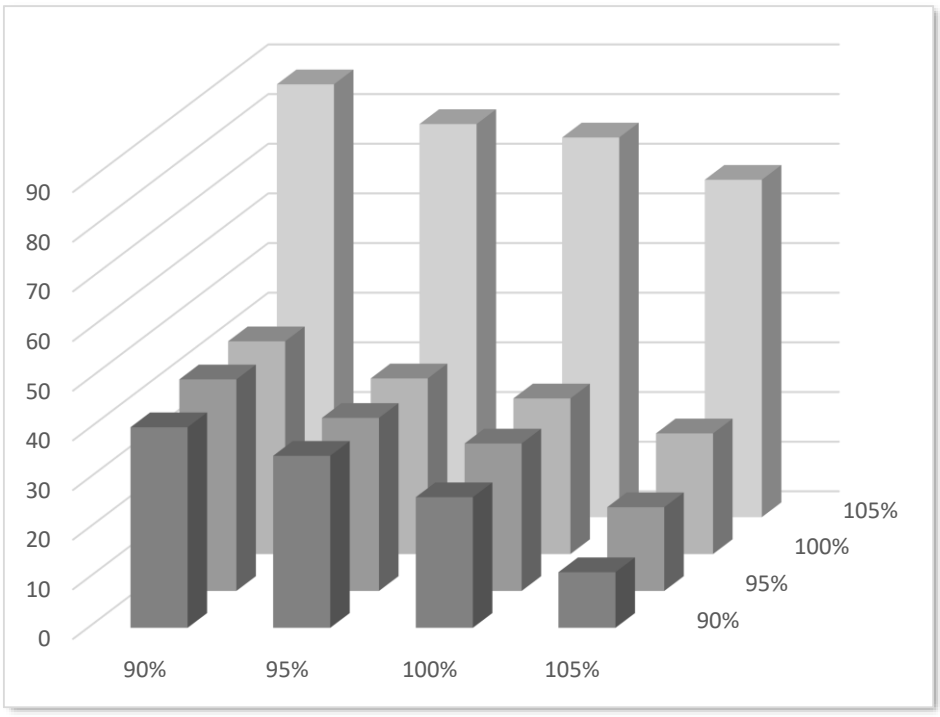


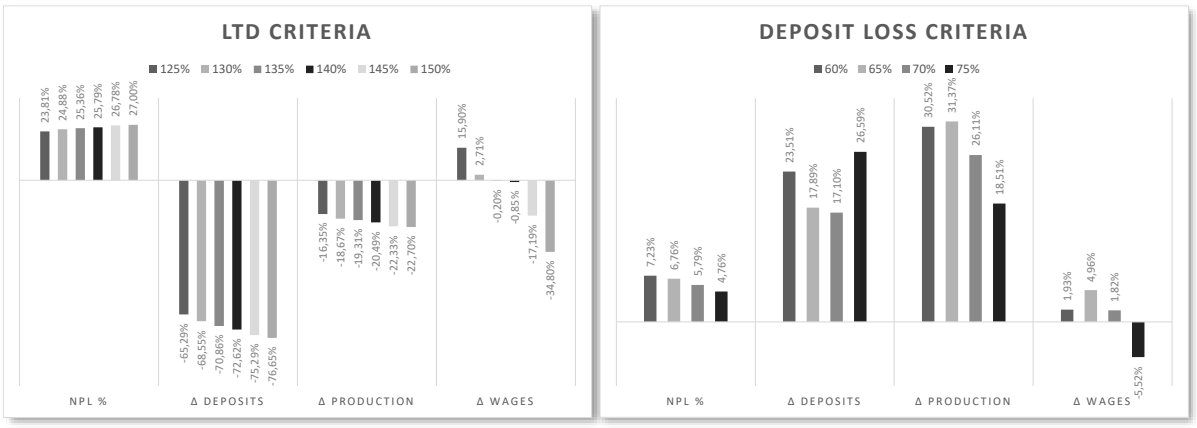
Figure 25. Periods under capital controls for combinations of values for the alert and health deposit loss criteria

***Note**: These figures demonstrate the periods that the economy was under capital controls for all combinations of values for the alert (x-axis) and health (z-axis) criteria for the LTD ratio and for deposit loss.*

Furthermore, there is an important finding for the deposit loss criteria. Authorities may choose to overcompensate for the loss in deposits to balance out negative business climate or adverse expectations by depositors that may result in a steep but short deposit loss after capital controls are lifted. Should the regulator opt for this choice (i.e. select a system health benchmark value of 105%), then one can expect an extremely long time period under capital controls. Our findings show that this decision would put the economy under strain for much longer and should be avoided.

Table 22 and Table 23 show the average values of monitored variables under Capital Controls for the simulations we executed. The last three rows (Δ Deposits, Δ Production and Δ Wages) calculate the percentage change in these variables from the beginning of the capital controls to the end.

Figure 26. Percentage values in key variables for the two criteria regimes



***Note**: This figure depicts the percentage values of non-performing loans (NPL%), the changes in deposits (Δ deposits), the changes in total production (Δ Production) and the changes in wages (Δ Wages), under the different values of the alert criteria. Values calculated as averages over 4.000 simulations in each alert value (one for every health value selected).*

Our first observation is that the percentage of NPLs is much lower for the deposit loss criteria. However, this could be attributed to the significantly lower amounts that banks lend to households and other banks under this regime. On the other hand, the banks' asset mix is different under the deposit loss criteria, since it appears that a much greater percentage of the banks' balance is spent on consumer loans, rather than interbank loans. In general, interbank loans are considered a waste in terms of economic fuelling since they do not finance investment projects or consumption (Goodhart et al., 2004, and also section 5.2).

Another interesting observation relates to the changes in monitored variables when the economy is under capital controls. For this analysis, we will assume that the values for the LTD criteria signify the short-run effects of the restrictions while the values for the Deposit Loss criteria show us the long-run effects. This is justified since the economy functions in exactly the same manner under the two regimes (the only difference being the benchmark values) and the average number of monitored periods is almost half for the LTD benchmarks.

The simulation results show that the short-term effects of capital controls are detrimental to the economy, with a significant loss in deposits, production and wages. However, given enough time, the real economy will bounce back even under the limited flexibility of capital restrictions. The banking system on the other hand does not bounce back; the drop in total loans given out is significant when capital controls remain in place for longer time periods. One could argue that the lower percentage of non-performing loans is a positive outcome in the long run, but the negative effects on the banking sector are too strong to ignore. Additionally, the increase in the variables of the real economy, such as wages and production, cannot be regarded as an argument in support of capital restrictions, since an unhindered economy would definitely outperform these figures.

We must note at this point that the loss in deposits will bring about fluctuations in the economy, both on the demand and on the supply side in the money market. The effects on the supply side are evident: bank loans drop sharply under capital controls and the banking system can no longer finance the growth of the real economy. However, there should exist a demand-side effect that has not been analysed here. Households and firms find themselves with an abundance of cash, well beyond their transaction requirements. In Greece, it was reported that this sparked a short-term surge in consumption, even though there have been no empirical studies examining this. Nevertheless, over the long term, it is still unclear whether the demand surplus will have a lasting positive effect on the output levels, since negative expectations could thwart the short-term benefits. This could be the basis for a future implementation of the model which would take into account empirical results on the reactions of consumer behaviour to economic and political events.

Additionally, our findings seem to favour early adoption of capital controls, rather than a sit-and-watch approach. Under both regimes, the average values of the monitored variables seem to improve as the benchmark values for the criteria signify an earlier intervention by regulatory authorities[45]. Exceptions to this sequence are the production and wage changes under the deposit loss criteria, as discussed earlier, where the longer time spent under capital controls seems to allow economic recovery for the real economy. We cannot overlook, however, the fact that the banking system seems to be functioning at a lower intensity in this regime, as signified by the lower amount of loans given out by financial institutions.

[45] Note the inverse order of the alert criteria: earlier adoption of capital controls is indicated by a lower LTD value but by a higher deposit loss value.

6.2. Brexit & Financial Stability

The news that Brexit won in the referendum of June 2016 came as a shock to most, since predictions and exit polls had foreseen a clear victory for Remain. The referendum results immediately triggered heavy discussion in the news, with respect to the anticipated results of Britain leaving the EU, with most analysts predicting a significant cost to both the EU and the UK, focusing particularly on the banking sector.

In this section, we attempt to quantify these results and link them to financial stability, by simulating the effects of Brexit using our agent-based approach but in a setup similar to Riccetti et al. (2016). Our aim here is to examine if Brexit will have an impact on financial stability and also how it will influence the real economy, through the financial sector channel. We build a virtual unified economy, which includes banks, firms and households with unimpeded goods and capital flows between them, and implement a sudden separation of a particular subset of agents, which can no longer trade freely with the rest. We must note that our modelling approach focuses on the effects driven by the banking sector and, as such, offers a different perspective from research based on the trade channel (e.g. Dhingra et al., 2016a).

In this manner, we are able to contribute to three aspects of the existing literature. First, to the best of our knowledge, our work is the first to examine the effects of Brexit through the financial sector channel, both on bank stability and on the real economy. Second, we add to the discussion linking the financial sector to the real economy (De Bandt et al., 2008, Costeiu and Neagu, 2013). Lastly, our work adds to recent findings on the cost of Brexit, by taking into account financial stability.

6.2.1 Relevant Literature

The likely effects of a potential Brexit have been in the spotlight in academic literature in the past years, even before the official referendum was announced. Describing the process as a debate between economics and politics, Jensen and Snaith (2016) analyse the political side of the process and suggest that the decision for the referendum has been a political one. From the economic point of view, most researchers explained how such a scenario would be harmful for both sides of the Channel. Gropp (2016) linked pre-election poll data to stock market returns and showed a negative link between share returns and Brexit votes, particularly in bank shares. However, it seems that markets did not doubt Britain's capability of handling the Brexit fiscally, since Gropp concluded that increasing pro-Brexit poll data resulted in increasing demand for UK government bonds[46].

Most researchers consider the real economy effects. Dhingra et al. (2016a) focus on trade restrictions (tariff and non-tariff barriers) and show that a significant loss in GDP can be anticipated, which they estimate to be between 1.3% and 2.6% for the UK and between 0.12% and 0.29% for the EU. The estimates of Ottaviano et al. (2014) are similar for the UK (between 1.23% and 3.09%), but the income loss could be as high as 9.5% in the pessimistic case, once dynamic long-term losses are factored in, while Ebell et al. (2016) estimate the GDP loss to 2.7%. Note that all the above figures do not take into account the cost of trade negotiations with non-EU countries, which are currently governed by the EU common policy (e.g. the USA or BRICS). Similar conclusions can be found in Boulanger and Philippidis (2015).

[46] Interestingly, this "flight-to-safety" effect is only visible with UK government bonds and not with other "safe" bonds, like for example the German government bond.

Barrett et al. (2015) focus on FDI[47] and the energy sector and describe a series of issues that may need to be addressed due to the diminishing attractiveness of the UK in FDI. They propose that the Brexit deal may reduce UK access to the EU market by 25% to 50%. The loss in FDI is estimated to be as high as 22% (Dhingra et al., 2016b), an effect further exacerbated by the financial sector multinational enterprises. Uncertainty may also be an important parameter here. Jones and Olson (2015) examine the effects on the UK and Japan of uncertainty in the US and show that, among others, uncertainty shocks tend to reduce foreign output and induce depreciation of domestic currency. It is not unreasonable to expect similar effects on the EU, stemming from Brexit uncertainty in the UK.

Outside the UK, Oliver (2016) presents a thorough review of relevant views from all sides, including the US and other non-EU states. Even though the analysis is pointed mainly on the political economy of Brexit, the central idea is that one can anticipate negative economic effects. Similar conclusions are reached in the presentation of individual country views in Möller and Oliver (2014), with most analyses focusing on the adverse economic effects of Brexit. Regarding Italy, in particular, Bagnai et al. (2017) simulate a potential exit from the EU and show that it would have a short-term cost of a 1.1% loss in GDP, which would be recovered in approximately five years. Developing countries in the EU are also likely to suffer from the loss of capital inflows, with the banking sector taking some of the burden (Slesman et al., 2015).

In general, economists have always notoriously favoured globalisation as a method of maintaining financial stability and improving efficiency (Samuelson, 1939[48]). Costinot and Rodriguez-Clare (2014) show that trade barriers can be

[47] FDI: Foreign Direct Investment.
[48] Samuelson (1939) discusses the positive effects of free trade. The reference has been added here to support globalisation in general and is not particular to financial markets.

beneficial domestically only when they are imposed unilaterally; in other cases, they need to be unrealistically high to achieve positive results. Ghosh (2016) uses an exhaustive data set and demonstrates that globalisation in the banking sector significantly lowers the risk of a banking crisis. Kose et al. (2003) also show that globalisation favours stability but may increase consumption volatility up to a certain point.

On the other hand, Broner and Ventura (2016) showed that the actual effect of globalisation is dependent upon the particulars of each economy. However, they do note that for developed economies, the outcome is most likely to be positive. Edison et al. (2002) showed that even though financial integration is not *per se* linked to economic success, we should be careful in rejecting openness as a means to achieve economic growth. Specifically in the EU, Bayoumi and Eichengreen (2017) show that member countries do not experience output disturbances symmetrically, suggesting that there are issues that could result in a suboptimal currency union. Other researchers (Gourinchas and Jeanne, 2006) have shown that globalisation in the financial sector does not benefit growth directly, particularly in developing countries, but can have indirect long-term positive effects through the productivity channel.

6.2.2 Methodology Particulars

The main model setup was developed for a single, unified economy. To implement Brexit, we needed to consider a scenario where agents are split into two groups and are unable to perform transactions without any barriers between these groups. The group of agents splitting from the main economy must reflect the relative strength of the UK economy with respect to the EU. Figure 27 and Figure 28 display UK GDP and the total assets of UK banks as part of the respective EU totals. We use this information to split the Banks, Firms and

Households into two distinct groups. The UK group includes banks that hold up to the UK percentage of total assets and households and firms with incomes up to the UK percentage of GDP. These percentages are 30% for bank assets and 15.1% for GDP, as recorded in 2013 by Thomson Reuters.

The main features of Brexit, as implemented in our updated model are as follows:

1. Bank customers (firms and households, as well as other banks) in one group can no longer borrow from banks in the other group
2. Households deposit excess funds in banks that belong to their own group
3. Firms pay wages to households in their own group
4. Trade between firms and households of different groups takes place according to the trade function (equation (EQ15) below)

Most authors (Barrett et al., 2015, Dhingra et al., 2016a) consider "optimistic" and "pessimistic" scenarios regarding Britain's access to the EU single market after Brexit. The optimistic scenario is based on Norway's status, which is not a member of the EU but has been granted full access to the single market. However, given that non-tariff barriers still exist, it has been shown (Campos et al., 2015) that there are considerable trade costs, even in the optimistic scenario. The choice of considering two scenarios is necessary since the particulars of the Brexit implementation are still being negotiated. Hence, any assumption that would lead to a model based on a specific scenario could soon be refuted, as the Brexit deal is being discussed. Even today, a long time after the referendum, analysts cannot safely guess about the UK's post-Brexit status.

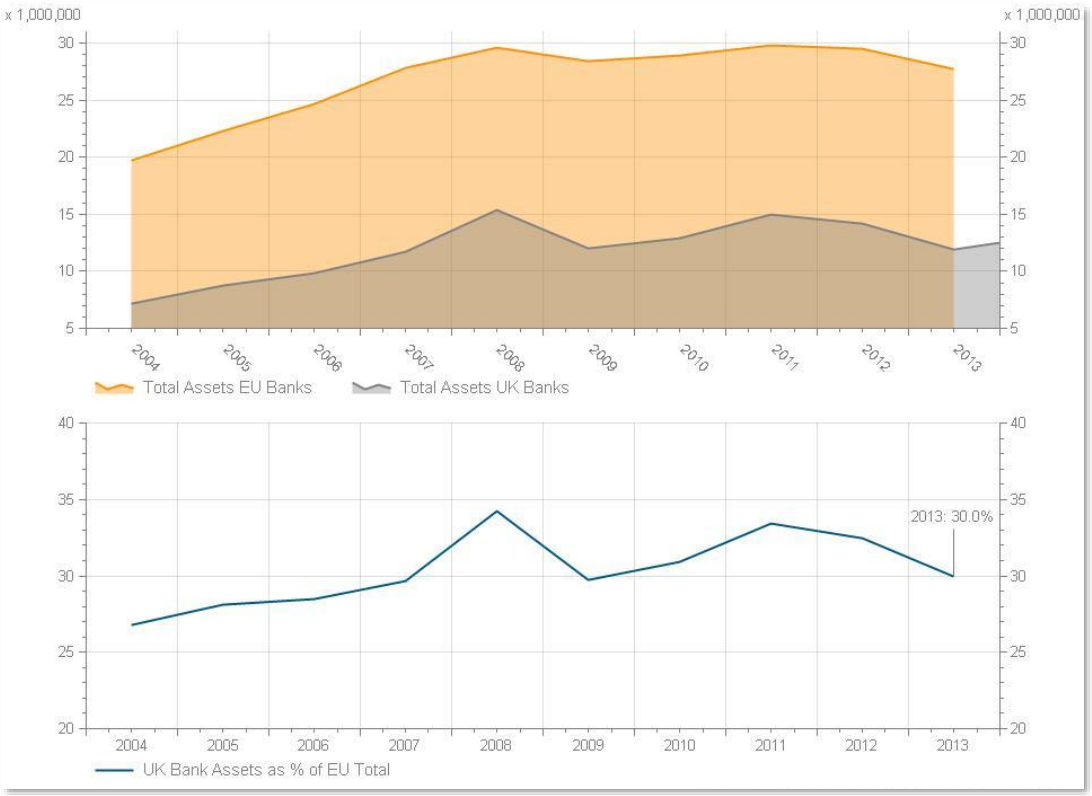


Figure 27. UK and EU bank assets

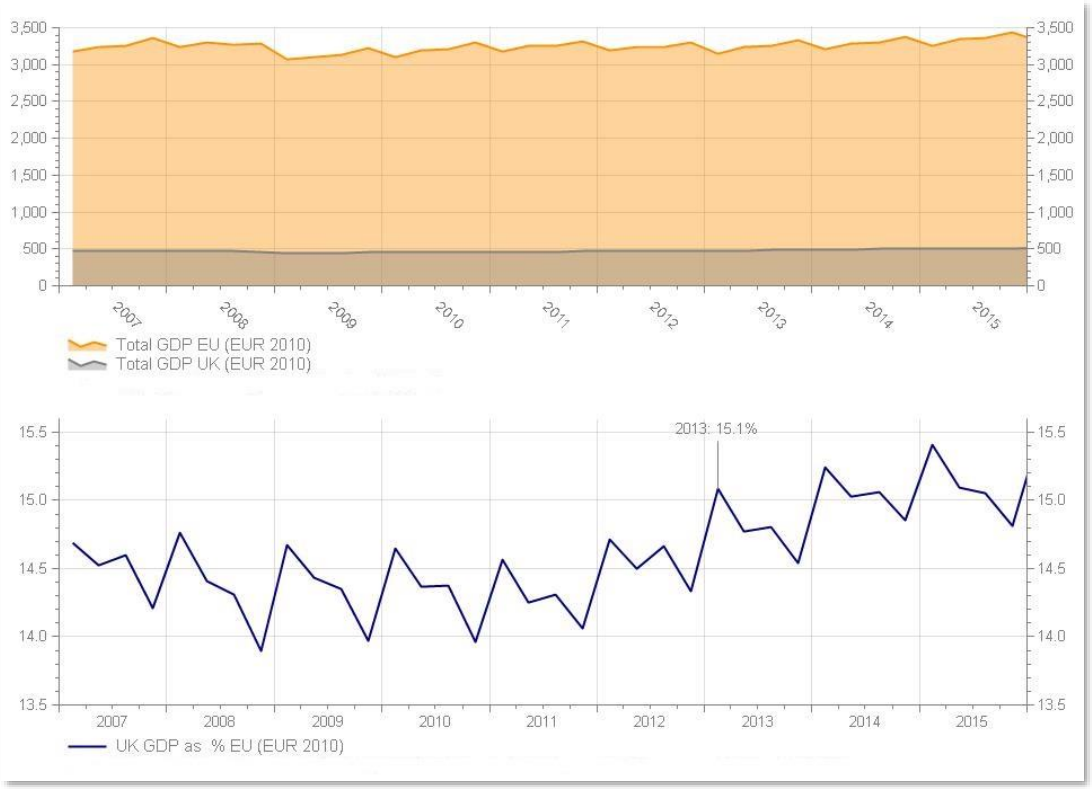


Figure 28. UK and EU GDP

Consequently, we need to consider both the optimistic and pessimistic scenario in trade restrictions. We have stretched the optimistic scenario to the point where no restrictions are imposed on goods trade between the UK and the EU. In this case, the effects of Brexit are solely caused by the segmentation of the financial sector. In the pessimistic scenario, UK access to the single market is reduced by 50% (Barrett et al., 2015).

Hence, in the pessimistic scenario, we need to consider a border effect in EU-UK trade. We employ the equation proposed by Borraz et al. (2016). The authors use

$$(\text{EQ15}) \quad Q_n\left(\left|p_{i,t} - p_{j,t}\right|, q\right) = a + \beta \times D_n + \gamma \times B_n + \delta_1 \times B_n \times D_n + \delta_2 \times Firm_n + \varepsilon_n$$

to calculate the effects of market segmentation both with and without the presence of borders. In the equation above, Q_n represents the price difference between different locations, D_n measures distance, B_n is a dummy variable for locations in different countries and $Firm_n$ is a dummy variable showing whether the different locations belong to the same chain. Hence, γ is the factor that shows the (linear) effect of borders on market prices. We use this as a proxy to determine the effect on goods trade after Brexit and assume that market barriers will increase by 50%, as suggested by Barrett et al. (2015). As prices are not modelled, the γ factor denotes the probability that goods produced in one group are sold to agents in the other group. After Brexit, this probability drops by 50% in the pessimistic scenario, while it is not changed in the optimistic scenario.[49]

[49] Computationally, this is implemented when calculating firm income for each group.

Table 24. Pessimistic Scenario: Average values of monitored variables for the two economies, at the three snapshot periods

	UK			*EU*		
	Brexit	**Short Term**	**Long Term**	**Brexit**	**Short Term**	**Long Term**
Banking Crisis After		1.14			8.46	
Real Crisis After		1.59			5.60	
Attempted Defaults		1.34			31.75	
Banks In Operation	6.52	6.26	5.62	13.45	8.47	3.34
Firms In Operation	16.76	16.73	16.56	63.25	60.92	54.47
Active Projects	16.64	15.91	15.54	63.01	51.31	39.80
GDP	10,293.48	37,586.98	49,400.72	54,540.43	212,595.24	190,131.50
Total Deposits	3,160.32	7,505.83	10,236.93	12,795.16	41,375.69	34,397.34
Total Consumer Loans	15,233.58	69,569.44	117,675.99	83,697.13	273,237.38	181,384.38
Total Interbank Loans	1,003.92	14,621.77	5,664.87	10,008.74	48,043.14	25,217.51
NPL %	0.19%	10.55%	8.62%	0.22%	17.99%	28.11%
Bank Available Balance	97,341.20	77,850.29	53,255.88	198,494.29	36,116.95	9,581.23
Wage Per Household	8.09	179.79	149.38	8.05	75.92	88.04

Table 25. Optimistic Scenario: Average values of monitored variables for the two economies, at the three snapshot periods

	UK			*EU*		
	Brexit	**Short Term**	**Long Term**	**Brexit**	**Short Term**	**Long Term**
Banking Crisis After		1.80			8.40	
Real Crisis After		5.04			7.02	
Attempted Defaults		2.18			33.49	
Banks In Operation	6.58	6.23	5.25	13.41	8.29	3.20
Firms In Operation	17.18	17.11	16.84	62.82	60.02	53.54
Active Projects	17.09	16.52	16.07	62.65	50.01	38.72
GDP	8,964.39	44,495.76	46,218.44	51,595.31	255,608.51	250,123.67
Total Deposits	3,097.99	16,440.94	17,445.98	11,890.87	37,424.64	30,093.97
Total Consumer Loans	14,417.39	78,502.76	128,504.39	80,710.97	247,143.08	187,506.74
Total Interbank Loans	798.41	13,932.03	6,849.45	9,600.63	43,715.52	25,137.78
NPL %	0.17%	11.55%	11.29%	0.22%	15.88%	31.47%
Bank Available Balance	96,728.12	73,679.45	44,560.65	199,145.48	37,340.95	8,892.66
Wage Per Household	7.76	112.96	102.65	7.78	80.21	78.49

***Note**: The tables above demonstrate the results of the simulation sets for each of the two scenarios regarding UK's trade with the EU after Brexit. Table 24 includes the values of the monitored variables for the pessimistic scenario, where UK access to single market drops by 50% while Table 25 includes the corresponding values for the optimistic scenario where UK has full access to the single market. Variables are recorded at three time periods: at Brexit, 15 periods later (short/medium run) and 30 periods later (long run).*

Note that our analysis does not take into account uncertainty relating to Brexit, which might bring about a sharp short term (negative) effect. Additionally, we do not account for the fiscal benefits of the UK leaving the EU. However, Dhingra et al. (2016a) show that the net fiscal contribution to the EU budget is 0.53%[50] of GDP and it may be as low as 0.09% of GDP, if Brexit negotiations for full access to the single market result in a contribution similar to that of Norway.

6.2.3 Empirical Results

With the setup proposed above, we executed 1,000 simulations for each of the scenarios, the pessimistic and the optimistic. We took a snapshot of the variables at the period before Brexit and then again 15 periods later and 30 periods later. We assert that the first post-Brexit snapshot shows the short- to medium-term effects, while the second shows the long-term outcome[51].

Table 24 and Table 25 show summaries of the monitored variables at each of the three snapshots over the 1,000 simulations for the two scenarios. The general remark is that the effects of Brexit are heavier for the EU economy than for the UK economy. After Brexit, EU banks show increasing distress signals, with a

[50] Even this figure can be disputed by further examination. See Dhingra et al. (2016a, pp 4-5) for a detailed analysis.
[51] The results of this section can be found in Samitas et al. (2018).

reduction of the banking sector and a significant number of banks in distress (approximately one bank in distress every time period).

Table 26. Average values of monitored variables for the unified economies, compared to the average figures after Brexit

	No Brexit		Brexit	
	Short Term	**Long Term**	**Short Term**	**Long Term**
Attempted Defaults		16.85		34.38
Banks In Operation	18.35	17.84	14.63	8.71
Firms In Operation	78.25	71.55	77.39	70.71
Active Projects	70.11	65.60	66.88	55.07
GDP	282,896.96	318,158.64	275,143.25	267,937.17
Total Deposits	52,965.55	54,872.66	51,373.55	46,087.11
Total Consumer Loans	308,565.90	337,498.68	334,226.33	307,535.75
Total Interbank Loans	15,605.65	21,158.92	60,156.23	31,434.81
NPL %	6.25%	8.18%	27.99%	39.75%
Bank Available Balance	157,658.32	192,985.52	112,493.82	58,145.21
Wage Per Household	228.95	232.07	224.44	209.28

***Note**: The table above demonstrates the results of the simulation sets when Brexit does not occur and the corresponding totals of the UK and the EU, averaged over the two scenarios. Results without Brexit were recorded at the middle and at the end of the simulation (equivalent to the short run and the long run period in the Table 24 and Table 25).*

Table 26 demonstrates the results of the monitored variables, as recorded over 1,000 extra simulations where Brexit did not occur. The values were recorded for the unified economy at the middle and at the end of each simulation, at periods equivalent to the "short run" and the "long run" periods of the Brexit simulations. The results are a clearer indication of the long run costs of Brexit, both on the financial system and the real economy. In the short run, there are few differences between the recorded values, showing how the short run costs of Brexit could be perceived as trivial. However, in the long run Brexit figures, there are fewer

banks in operation, but with less total assets, more of which are interbank loans. In the real economy, firms are unable to finance investment projects to improve their productive capacity, resulting in a total GDP loss of approximately 15%. In this context, the GDP loss persists in the long run, a finding consistent with Bassi and Lang (2016).

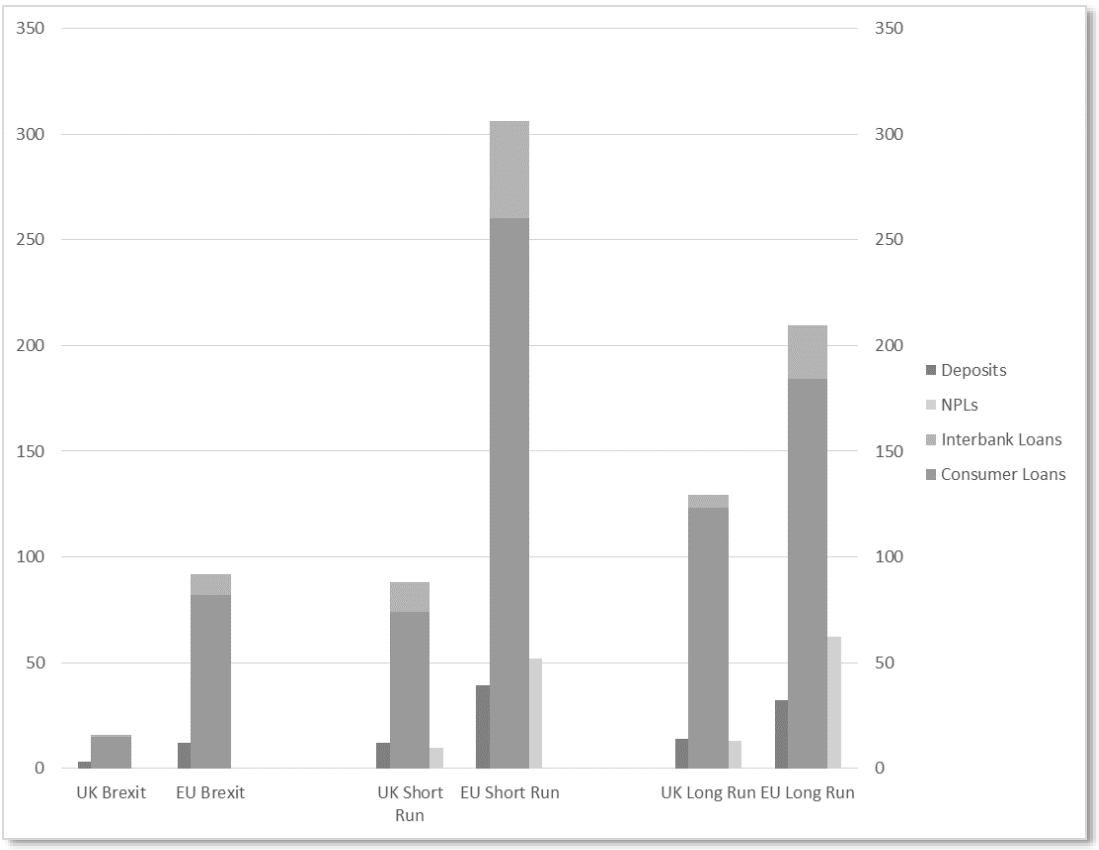


Figure 29. The UK and EU banking sector at the snapshot periods

***Note**: This figure is representative of the changes in the banking sector due to Brexit. Note that at Brexit, NPLs are negligible, but as time passes NPLs grow, with the acceleration being higher in the EU. Additionally, on the long run, the UK banking sector has grown, as compared to the short run, while the EU banking sector has contracted.*

Even though Brexit appears to be heavier on the EU, its effect seems to hit the UK more quickly. A banking crisis, as defined by Demirgüc-Kunt and Detragiache (1998), will occur in the UK almost immediately, while for the EU it

may take as much as 8 periods, even after the crisis in the real economy. In the UK, the economic downturn follows the banking crisis closely, but the results are different for the optimistic scenario, where the continuation of trade with the EU helps support the domestic economy and the recession is delayed by almost 4 periods.

Nevertheless, both the short term and the long-term damage are heavier on the EU economy. The banking sector suffers heavy losses in the long run, with a significant rise in NPLs and a reduction in the total volume of financing (Figure 29). The strain on the EU banking sector is also evident by the smaller figures in the banks' available balance. This variable shows the amount of available funds that banks have at the given time period. Finally, it is interesting to note that in the UK NPLs approximately equal deposits in banks, even in the long run, while in the EU deposits are lower than NPLs. This would suggest that UK banks have enough funds available to cover possible losses even if all NPLs fail, while in the EU, banks are at risk if such a case occurs. This is also an indication of the relative resilience of UK banks after Brexit, with respect to EU banks.

The real economy in the EU suffers too; GDP does not grow in the long run, as compared to the short run period and wages in both economies drop as a result of contractionary pressures. It is interesting to note that the only case where the model shows a rise in long term wages is in EU in the pessimistic scenario. This may serve as an argument in favour of trade barriers when the economy (EU) is larger than that of its trading partners (UK).

Even though the relevant literature predicts damaging effects for both the UK and the EU, no existing work predicts a heavier burden on the EU. We can assume that the reason for such an unexpected result is the relative power of UK banking institutions *vis-à-vis* their EU counterparts. As we saw earlier, in 2013,

UK banks owned 30% of the EU bank assets, while UK GDP accounted for little over 15% of EU total output. This means that in case of a separation, UK banks have more assets than what would normally be required to service the domestic economy. It is critical to note however that this will take place only if the numerous financial institutions currently based in London, enjoying up to now easy access to the single market, choose to remain in the country despite its departure from the Eurozone. The aforementioned excess liquidity of UK banks can also be seen in the high available funds these banks exhibit after Brexit. This assumption is examined further below.

The most useful finding of our empirical work is the observation that long-term figures are far worse than short-term figures, both for the EU and the UK. A common argument of Leave supporters in the UK was that the county would have to endure some pressure in the short run to enjoy benefits in the long run. However, our results show this is not the case. After the outbreak of the banking and real crises in the UK, the economy immediately recovers. In the short-term figures, the economies of both in the UK and the EU have not yet had time to adapt to the new status quo and seem to function with the momentum they had before Brexit. Over the longer term however, both economies are hit with the consequences of the separation and both domestic and European figures seem to collapse.

It is evident that such an event is not one where recovery is simply a matter of time; specific policy measures will need to be implemented in order to smooth the negative impact of Brexit. The banking crisis is more evident in the EU, where NPLs are extremely high and banks are unable to finance investment projects by firms. It is notable that the percentage of firms with currently active investment projects is declining continuously and so is the total number of firms

in the economy, a signal for a contracting economy (Figure 30). Additionally, total deposits in EU banks are decreasing, a trend that is not present in UK banks where post-Brexit deposits seem to be relatively stable. In both cases, on average one European bank is in distress at each time period, a figure that should definitely worry EU policy makers.

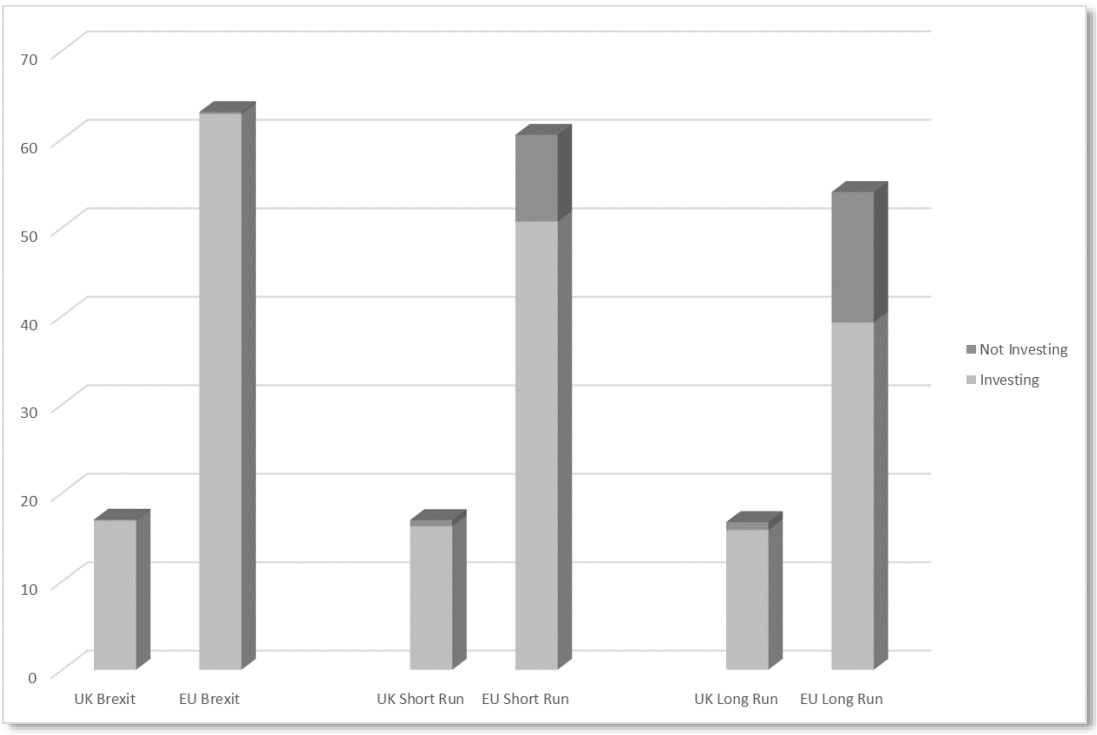


Figure 30. Average number of firms with and without active investment projects

***Note**: This figure depicts the average number of firms operating in the EU and UK economies at the three snapshot periods. The firms are distinguished between those with an active investment project and those without one. This distinction is important because these projects improve the firms' productive capacity. On the other hand, when a firm cannot find financing for investments, her productive*

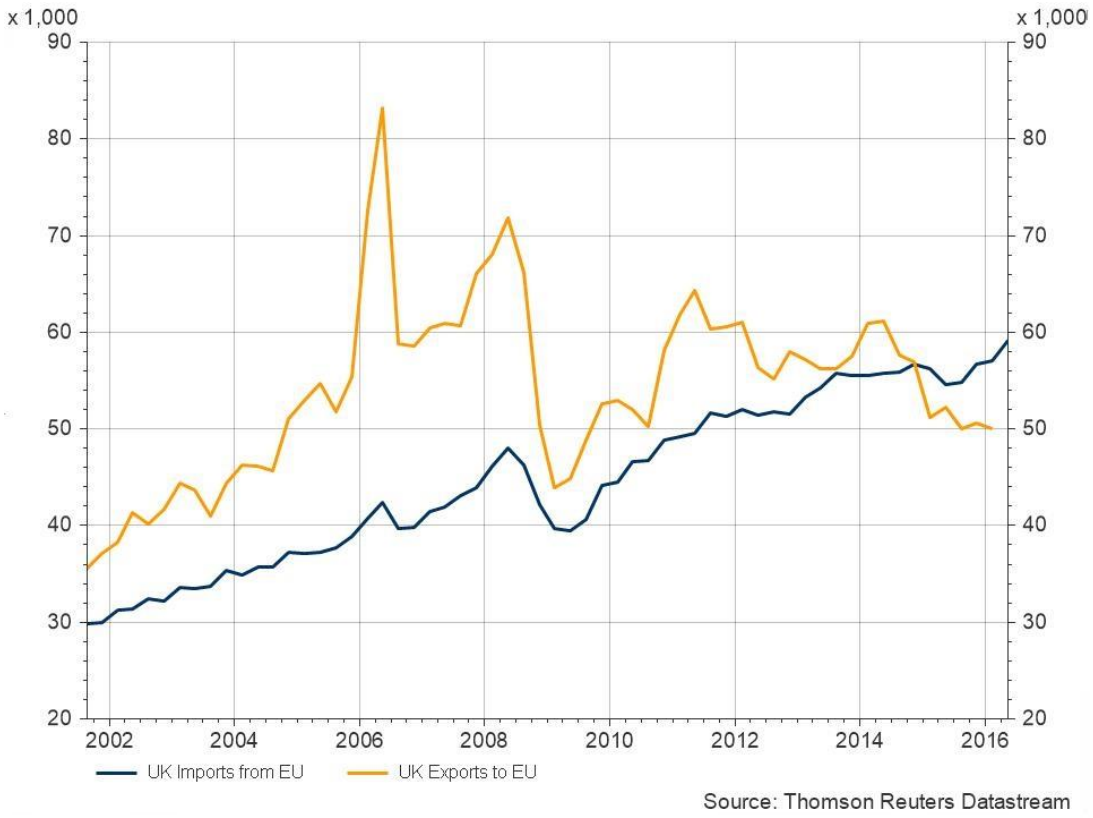


Figure 31. UK trade with the EU

Interestingly, the post-Brexit figures for the UK economy are a little worse for the optimistic scenario, presumably due to the contagion effect from the EU real economy to the UK. This effect is demonstrated in the somewhat lower figures for the long-run post-Brexit GDP as well is the higher percentage of NPLs in that time period. In the optimistic scenario, UK will manage to secure full access to the single market, similarly to the current situation, even after departure from the Union. In such a case, recessionary pressures in the EU will propagate to the UK economy, through the balance of payments. Analysts (e.g. Jensen and Snaith, 2016) suggest that the UK can use its balance of payments deficit (Figure 31) with the EU to leverage a deal that will allow its firms unhindered access to the single market. In such a case, authorities in Britain will need to incorporate domestic measures that respond to EU GDP changes.

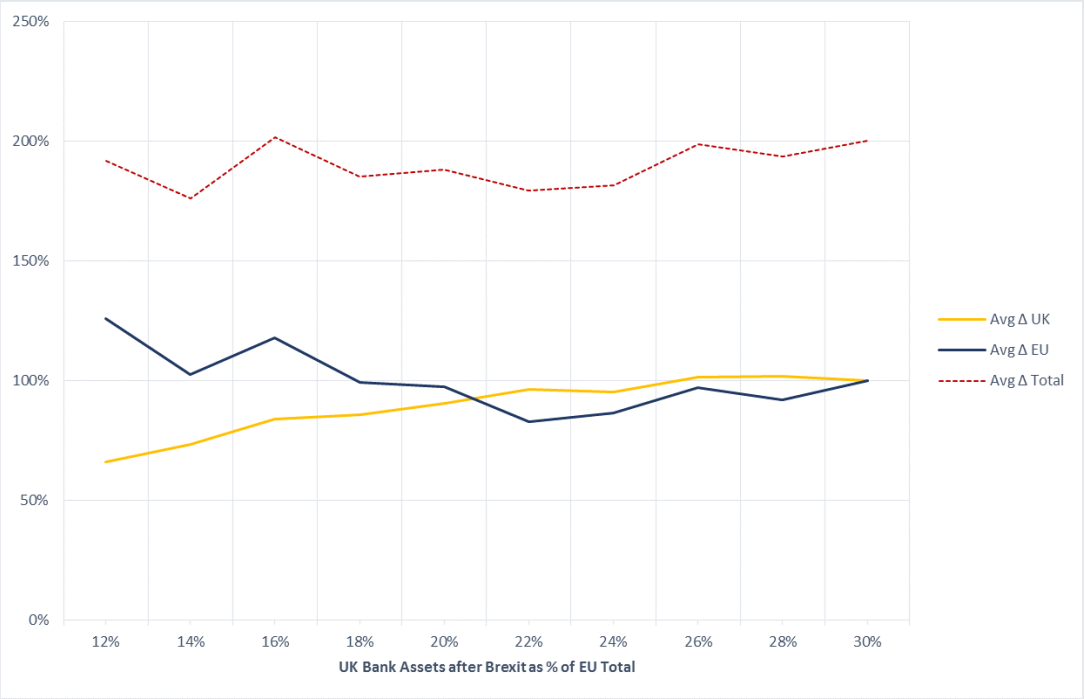


Figure 32. UK, EU and global economy end states at varying percentages of UK bank assets, as compared to the current percentage

***Note**: The end states of the economies at different percentages are normalised with respect to the current percentage (30%=100). We note that the social optimum is when UK banks hold 16% of EU total assets after Brexit.*

As stated earlier, the UK financial sector seems to be better equipped to deal with the consequences of Brexit, presumably due to the relative strength of the banking sector over the real economy. In keeping with our aim to focus on the financial sector, we examined this assumption further by executing 2,000 more simulations using a variable (declining) percentage of UK bank assets at the Brexit period, under both the optimistic and the pessimistic scenarios. We then compared the end state of the UK and EU economies *vis-à-vis* the Brexit snapshot using a simple normalised index[52]. We assert that if financial institutions in the

[52] For all monitored variables, we normalised the Brexit figure to 100 and calculated the change at the end of the simulation. We then proceeded to compare the improvement between the current state (UK bank assets at 30% of EU total) and alternative scenarios.

UK choose to move away from London, due to the departure of the UK from EU, then the post-Brexit figures for the UK will not be as reassuring.

Indeed, our findings confirm our assumption that as the percentage of UK bank assets diminishes, the end state of the UK economy deteriorates and the end state of the EU economy improves (Figure 32). It is important to note that if the percentage falls below the percentage of UK GDP, there are significant costs for the UK which are translated into gains for the EU. Additionally, even though the current percentage is Pareto efficient, the optimum point for total prosperity is achieved if approximately half of UK bank assets move to the EU. Finally, it is interesting to note that the UK can handle (and maybe even benefit from) losing some of its bank assets (up to approximately 15%) since it is clear that current assets are more than what the real economy can use effectively. This is important since it may be a sign of post-Brexit overcrowding in the banking sector, especially if the pessimistic trade scenario is confirmed.

Chapter 7. Policy Implications

In the concluding section of this paper, we will present the policy implications of our findings. Each part of the empirical work will be described separately, in order to achieve a clearer presentation of the conclusions drawn from each of the simulation sets that we executed. In addition, in this manner, we are able to demonstrate the links between our findings and existing literature more clearly. We will discuss our policy suggestions for each section of our empirical work and then conclude with our final remarks.

7.1. Banking System

The analysis of our findings with respect to the banking system lead us to a series of useful policy implications, regarding banking supervision and bank stability. It is obvious that the strict financial regime of Basel III adds pressure to the financial institutions and leads to the deceleration of the circulation of money to households and, potentially, businesses. The simulations show that Basel III makes the banking practice far more difficult and limits the available liquidity in financial markets. Additionally, it does not go a long way to protect banks from contagion effects, which are far stronger in Basel III than in looser regimes.

On the contrary, the limitations and the increased capital requirements reduce the flexibility of financial institutions and further hinder their ability to respond to any banking crisis, thus delaying the recovery of the system in such a case. We have shown that Basel III results in a deterioration of the economy's performance with respect to the recovery from a crisis and its contagion effects. This is definitely an argument against the effectiveness of Basel III in the context of the banking union in the Eurozone, where it is suggested that the strict rules it

encompasses will safeguard the European banks from contagion of banking crises. This finding has been often supported by the relevant literature (Pakravan, 2014).

Moreover, the pressures applied to the banking system seem to lead banks to distress quite more often and force the intervention of the regulator. The cost of that intervention is quite high and, when it is financed by the tax payers' money, it is often disproportionate to the economy's capabilities, which should definitely be taken under advisement, particularly in the European economies today, where tax income is needed for a far greater number of purposes than in the past. On the other hand, a bail-in, that is the rescue of a bank using the depositors' funds, does not seem to offer any added advantages in terms of contagion. Additionally, the market's response to a bail-in could be detrimental for other financial institutions as well. Given the fact the policy makers in Europe are currently examining the implementation of a permanent bail-in solution as a response to bank distress, the aforementioned conclusion has added importance.

On the other hand, we must point out the effectiveness of stricter regimes with respect to economic stability. On this matter, it appears that the stricter the set of rules, the greater the stability in the system. Our findings showed lower standard deviation figures for the key economic figures for Basel II and Basel III and this can definitely be used as an argument in favour of the proposed measures of the latter. The restrictions and the added capital requirements seem to limit the reckless use of funds without a long-term strategic target. On this assumption, Basel III seems to meet, at least in part, its goals of improving economic stability through regulation in the banking sector, even though the proposed measures may temporarily reduce the banks' profitability, until they have had the chance to adapt to the new regime.

Our two main conclusions suggest the strict regime can definitely be regarded as useful when it improves economic stability. In Basel III, the rigorous measures proposed seem to meet this goal. However, their implementation should be matched by other actions to moderate their negative effects on liquidity, since the increased pressures seem to lead the banks to distress more often. Taking into consideration the increased contagion effect under Basel III, protecting each bank individually should be the main focus of the regulating authority and of the government officials as well. The protective measures should be proactive and not reactive, since the existing or proposed rescuing solutions (the bailout using taxpayers' money and the bail-in using depositors' money) do not appear appropriate, albeit for different reasons each.

The banking system and its stability should be safeguarded with measures not specifically targeted to financial institutions. Banks do not operate separately from the rest of the economy, but they carry a distinctive role in maintaining both stability and economic prosperity, albeit not always successfully. Any regulatory measures should support this double role, without overlooking that the banks' shareholders often keep their eye on the bottom line, i.e. profitability. Basel III seems to support the former role of the financial institutions in maintaining stability but neglects the latter in supporting economic progress. Consequently, governments should make it their prime objective to enhance the latter role, in the context of the strict financial regulation.

The fact that our findings, when comparing Basel III to Basel II or to the absence of a regulatory framework, incorporate such vast differences should function as a starting point for further analysis of the implications of the proposed measures on the economy. It is obvious that Basel III puts banks in a more difficult position than before, especially when the full set of the proposed rules will be applied.

Thus, we should see political measures aimed at countering the loss in liquidity due to the increased regulation. Nevertheless, Basel III has important positive effects on stability that cannot be neglected. However, the proposed measures should be implemented collectively with a series of protective measures, targeted at all economic parties, whose ultimate purpose should be stable economic growth and prosperity.

7.2. Real Economy

With respect to the effects of banking crises, our findings are along similar lines. Again, we have shown how the rigid financial regime of Basel III limits the manoeuvrability of financial institutions, which in turn favours a credit crunch, thus hindering the flow of funding from the economy's depositors to the borrowers. This has negative effects on total output.

Our simulations confirm once more that Basel III makes the banking practice far more difficult and limits the available liquidity in financial markets, by tying funds in regulatory requirements and interbank financing. The limitations and the increased capital requirements reduce the flexibility of financial institutions in cases of banking crises, which come more often under increased regulation, and delay the recovery of the banking system. Additionally, when the bail-in is used as the solution to bank distress, this does not seem to offer any added protection to the real economy as opposed to a bank default.

On the other hand, we must point out the effectiveness of Basel III with respect to real contagion, which we have defined to be the propagation of a banking crisis to the real economy, as signified by a loss in total output. On this matter, it appears that only a strict set of rules can shield the economy from this effect. If

combined with bailout, meaning that banks in distress are saved using taxpayers' money, this regime appears to offer the best defence to the real economy when dealing with banking crises.

Again, our finding suggests that Basel III meets its goals of improving economic stability through regulation in the banking sector, but only partially. In addition, the proposed measures may have some negative effects on the banking sector. The positive results of Basel III on the protection of the real economy against banking crises should not hide its negative results on the banking business from the view of policymakers. The difficulties of banks to finance firms and households will need to be dealt with before Basel III is put into full effect since the crisis-stricken Eurozone may not be able to handle the significant output cost of the strict measures.

7.3. Welfare & Subjective Well-being

In our research on the happiness of individuals, our findings propose different policy mixes to accommodate societal preferences, while targeting specific variables. We showed that subjective well-being is maximised and unemployment is minimised when authorities bail out banks in distress and that a Tobin tax should additionally be implemented in all cases except when society prefers public goods to financial stability. Additionally, we show that, if society prefers financial stability to public goods, then the vulnerable employee class will experience a loss in total well-being, regardless of the policy mix. This occurs because their consumption is based more on public goods.

Additionally, we showed that bank bailouts should be the preferred solution of policymakers when dealing with banks in distress. Our findings suggest that the

financial consequences of a bail-in or of a bank default result in a higher welfare cost than a bank bailout. This is an argument in favour of implementing bailouts and against the adoption the new fad in bank distress, which is the bail-in, contrary to the findings of García-Palacios et al. (2014). The welfare loss due to the income damages incurred is greater than the cost of the bail-in, even when society values public goods over financial stability. We should note however, in line with García-Palacios et al. (2014), that the guarantee of a bank bailout increases the morale hazard in the banking sector. Finally, our assessment of the Tobin tax is not *a priori* positive, since it does not seem to help limit the consequences of the crises under all circumstances. We show that this type of policy should be implemented selectively, according to societal preferences.

7.4. Corporate Governance

In our research on corporate governance in the banking sector, we have shown that both governance and financial variables need to be taken into account when discussing bank viability and when predicting whether the bank has enough potential to handle a financial crisis. Our findings agree with the relevant literature (Barry et al., 2011; Aebi et al., 2012) which places emphasis on the presence of a CRO in the board of directors, on board independence and on the ownership structure of the financial institutions, when discussing bank performance and hence viability.

Additionally, we propose the introduction of a low interest rate strategy, which needs further verification though, since it appears to be a case of prisoner's dilemma. If all banks follow this strategy, then it will simply be ineffective. Consequently, a bank will need to be careful when using this strategy as a tool for better results.

Our findings have also led to a simple, linear prediction model for the bank's end state, but it must be noted that the effectiveness is limited to the economic system of our agent-based model in its current version. The model seems to fail to predict a worse-off final state in only 15% of cases.

The empirical results have some important policy implications. Banking supervision pays little importance to the corporate governance features of the financial institutions. Additionally, authorities seem to focus more on capital requirements, which have been shown to hinder banking activity, with negative effects on the real economy and society, as we have showed in the previous sections.

The results of our simulations suggest that regulators should take into account management characteristics of each bank as well. Policy makers can use this information to improve their stress testing systems in order to yield better results. The lack of statistical significance for commonly quoted figures, such as the NPLs and the interbank exposure, implies that banking authorities need to evolve their models and include more characteristics which might not have been taken previously into account. In today's corporate environment, where the role of banks is not limited to financial services but extends to many aspects of the modern society, bank failure can have severe adverse effects in community prosperity.

7.5. Special Cases

7.5.1 Capital Controls

Capital controls were implemented in Greece in the end of June 2015 in effort to halt a likely bank run due to the political instability in the country. However,

banking data from the ECB and the Bank of Greece show that Greek banks suffered a significant loss in deposits and a deterioration of the loans-to-deposits (LTD) ratio as early as the last quarter of 2014. Despite the evident crisis, authorities were sluggish to take action and implemented the restrictions at an LTD ratio of 150%, a value considerably higher than the maximum acceptable value of 120% (Van den End, 2014). Our simulations showed that an early adoption of limits to capital flows can limit the negative effects of the restrictions to the banking system and to the real economy. Our optimal value for the implementation of capital controls, when the economy is faced with a bank run, is an LTD ratio of 125%.

Additionally, our empirical findings indicate that when authorities monitor the loss of deposits as a criterion to implement or withdraw the capital controls, the restrictions remain in place for a much longer time span than when the LTD ration is used instead. In case of the deposit loss criterion, however, the simulation results show a positive change in total production, which occurs over a longer period of time. Nevertheless, this finding is not enough to favour the deposit loss criterion over the LTD ratio, since the recovery evidently takes much longer in an economy under pressure than if the flow of funds is unhindered.

In total, we have shown the detrimental effects of capital controls on the financial system. These negative effects are channelled to the real economy, through a drop in corporate investment, which brings about a loss in total production. Despite the fact that early adoption limits these effects, authorities should avoid capital controls altogether, when dealing with a banking crisis. Policy makers need to focus on developing other first-best policy instruments and implement capital controls only as a last resort.

7.5.2 Brexit

We examined the effects of Britain's expected departure from the EU, through the financial system, using an object-oriented simulation model. Our empirical findings take into account the relative size of the UK banking sector and the UK economy as compared to the EU, by employing calibrated data. We show that both the UK and the EU economies will suffer as a direct result and that, in the long run, both sides of the Channel are worse off. Contrary to expectations, the short- to medium-term results do not show high negative consequences, since the impact of Brexit has not yet hit the financial system and the economy still operates with momentum gained previously. In the long run, figures for all monitored variables are worse off both for the EU and the UK.

Contrary to the findings of other researchers, we show that the cost of Brexit will not be borne solely by the UK, since our results suggest a significant cost to the EU as well. Our agent-based model shows that the cost in the EU is more evident in the long run, as the banking system fails to carry the weight of the real economy. The results are more severe in the pessimistic scenario, where the UK is assumed not to have access to the EU single market.

These results carry significant policy implications, particularly with respect to the Brexit negotiations expected to commence shortly. The most critical outcome for the EU is that its financial authorities should not be absent from the negotiating process. The repercussions of UK's departure could incite instability for the EU banking sector, which will be called upon to carry a relatively higher burden in order to support the real economy. The difficulty of banks to finance the expansion of the economy's productive capacity means that it is imperative for EU authorities to either finance these projects directly or implement expansionary fiscal policies, in order to boost the economy through

consumption. Additionally, the EU efforts to improve its banking system, through the banking union, will surely be a factor that may significantly improve the results for EU banks. In terms of strategy, any excess bank liquidity in the UK may be channelled to outside the EU, while EU banks may contract their activities outside the EU in order to save funds for European firms.

On the UK side, our findings show that the banking sector is strong enough to handle the crisis, without much distress. However, it is important for authorities to implement measures that will balance the loss incurred by the possible post-Brexit relocation of financial institutions to the EU due to the lack of access to the single market. Note that the negative effects for financial institutions in the UK may be further aggravated by the possibility of a strict Brexit deal in immigration laws and in human capital mobility, a result which has not yet been discussed to full extent. If a significant number of banks move their operations to the EU, the outcome for the UK economy will not be that encouraging, with the end state of the economy deteriorating as bank assets move to the EU, as we have shown. In response, UK authorities may choose to increase integration in the banking sector with other countries, in an effort to relieve possible negative effects due to the loss of bank assets.

Our findings demonstrate clearly the clash of conflicting interests in the Brexit negotiations, with the success of one side resulting in damage for the other. In this difficult and unprecedented process, it is important for both sides to try to reach a collectively optimum point, rather than handle the negotiations as independent agents.

7.6. Future Research

The modelling platform that we have presented is versatile and expandable. In this context, there can be many ways in which it can be expanded to produce further research. The first application would be to apply the welfare model to simulate the effects of Brexit and its consequences on happiness in the UK and the EU.

In the welfare subsystem, a possible extension could be to implement non-uniform preferences across the population and measure the results of the crises on each preference group. This would be a good way to examine if the effects of the policy mix are symmetric over the different preference groups, since we have shown that they seem symmetric over the employee classes. Also, the amount of the Tobin tax has not been examined exhaustively. Researchers could possibly examine the optimal value of the Tobin tax and assess whether different values help prevent banking crises. Additionally, the model setup could be extended to include the Systemic Risk Task described by Poledna and Thurner (2016).

However, the model can also be extended in order to be used for further research into different type of simulations. The first could be to use the modelling platform to examine alternative financial systems. For example, we could implement the principles of Islamic banking and then examine the benefits *vis-à-vis* western banking. The benefits could be focused on financial stability, economic performance or, even, happiness. Another financial model that could be examined is the peer-to-peer lending model. Proponents of this new form of lending are raving about its efficiency; our platform could examine the accuracy of their claims.

Finally, our modelling approach can be modified to include more features that would improve its accuracy. A first possibility would be to add expectations into our model. Expectations play an important part in forming the credit policy of banks, in household decisions regarding spending or saving and in formulating the business policy of firms. They are not included in our current model and they could be a useful addition. Also, commodity prices are not modelled. This is due to the fact that our model is based on the financial system and prices relate to the real economy. However, the fluctuations caused by the financial system could bring about inflationary or deflationary pressures in the commodity markets.

Furthermore, the artificial economy in the model is a closed economy, with the exception of the particular implementation in Brexit. Foreign currency and foreign trade shocks are thus not modelled. They could prove a very useful addition to the model, since the financial system has close relations with the foreign exchange market. Lastly, the system could be expanded to cover political or social simulation, including the effects of political instability, of improving education or of changing demographics.

7.7. Concluding Remarks

We conclude this work by discussing the lessons learned from our research. After reviewing the most important financial crises in history, we presented the relevant literature discussing the causes of financial instability and the variables that any pertinent research should monitor. We also discussed possible ways in which researchers suggest that financial systems should be modelled.

We then presented the fundamentals of agent-based modelling, which is the technique that we believe is better suited to creating accurate simulations of the banking sector. We then proceeded to discuss our model, describing in detail each one of its functions and showing how they relate to the literature presented earlier. The formal model definition was given along with the algorithmic steps of the simulation process. We also discussed the robustness checks that we executed for our model in order to verify the accuracy of the design and thus of the simulation results.

We then proceeded to present our empirical findings for each part of our research and briefly discuss what these findings mean. We also demonstrated our findings with respect to two particular implementations of our modelling platform, namely on the capital restriction imposed in the Greek banking sector and on Brexit. We also discussed the literature relevant to each topic and presented the specifics of the methodology implemented. Then, we examined some possible policy implications of our findings and proposed some paths for future research.

Summing up our work, we have demonstrated that banking crises exhibit important similarities in their manifestation. They begin by an asset bubble that the banking sector picks up on and helps expand with a credit boom, often fuelled by financial innovation. As the asset bubble and the credit boom feed into each other, regulatory authorities are either unable or unwilling to intervene. Unwillingness can usually be attributed to political reasons, putting further significance on the arguments for the independence of financial regulation.

When the asset bubble bursts, the effect on the economy is twofold. First, it causes an abrupt loss in personal and/or corporate wealth, instigating an

immediate recession and also a significant loss in welfare. Second, it has a detrimental effect on the financial system, which, depending on its exposure to the collapsing market, produces severe credit crunch, deepening the recession that has already began from the bubble burst. Interestingly enough, researchers and academics focus on what went wrong, only to allow the same mistakes to occur again in later years, in a somewhat different setting which is, however, all too familiar.

With respect to our findings, we must stress the transmission of financial crises into every aspect of the economic system. In this sense, the prevention of the crisis is extremely important for economic stability and prosperity. Consequently, bank bailouts should be considered taboo, but they must be reconsidered as they have shown to limit the negative consequences of financial instability. The alternative solutions seem to be targeted at solving the issue of moral hazard, but they cost much more to the economy and to societal welfare than a bailout.

Our research coincides with the rise of populism in politics worldwide. Whether populist governments are left-wing or right-wing is of little importance to the economic perspective. Bad political decisions are costly and this cost cannot be easily recovered. The near-sightedness of voters in selecting political leaders that claim to fight the economic powerhouses, while at the same time turn a blind eye to clear financial transgressions, has been a source of harm for too long. Financial innovation is only partly to blame for the inability of authorities to monitor the markets. It is the inability of authorities to keep up with the advancements in financial instruments that must be tackled in the most urgent manner.

Financial regulatory authorities must be left to the hands of (adequately reimbursed) financial professionals, who are properly educated and are safe from political aspirations. Politicians, and populist ones in particular, are unable to understand the full extent of the long-term consequences of their policies and, often, they believe that they know best. Michael Gove, the Conservative Justice Minister, said before the 2016 Brexit vote that "people [...] have had enough of experts" (Financial Times, 2016). Actually, it is now more important than ever to let the experts do their job, without political constraints.

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Appendix: Simulation Results for Welfare

Public Goods Preference			
	Without Tobin Tax		
	Bail-in	**Bailout**	**Default**
Subjective Well Being	34,879.24	41,213.39	28,398.99
Subjective Well Being (Vulnerable)	4,941.09	5,883.70	3,915.22
Subjective Well Being (Non-Vulnerable)	29,938.15	35,329.69	24,483.77
Public Goods Spending	36,964.00	55,318.58	45,447.15
Rescuing Costs	0.00	487,541.52	0.00
Periods to Recover (Banking Crisis)	2.24	1.89	2.44
Periods to Recover (Welfare Crisis)	2.26	1.58	2.70
Average Wage	69.71	235.46	86.58
Tax Rate	8.39%	8.44%	8.38%
Unemployment Rate	5.98%	5.68%	6.15%
Unemployment Rate (Vulnerable)	7.55%	7.21%	7.89%
Unemployment Rate (Non-Vulnerable)	5.70%	5.41%	5.84%
Real Contagion	57.37%	47.57%	82.23%
Welfare Contagion	26.67%	28.87%	23.45%
Subjective Well Being Standard Deviation	16,200.67	20,082.32	13,442.88
Welfare Spending Standard Deviation	21,939.27	30,425.40	26,934.30
Unemployment Rate Standard Deviation	2.88%	1.85%	3.30%

Public Goods Preference			
	With Tobin Tax		
	Bail-in	Bailout	Default
Subjective Well Being	36,819.75	37,105.28	30,053.08
Subjective Well Being (Vulnerable)	5,190.08	5,277.03	4,274.45
Subjective Well Being (Non-Vulnerable)	31,629.67	31,828.25	25,778.63
Public Goods Spending	34,682.15	35,240.59	38,633.61
Rescuing Costs	0.00	872,081.06	0.00
Periods to Recover (Banking Crisis)	2.02	1.94	2.07
Periods to Recover (Welfare Crisis)	2.15	1.78	2.35
Average Wage	66.40	170.56	72.44
Tax Rate	8.41%	8.47%	8.39%
Unemployment Rate	5.92%	5.78%	6.09%
Unemployment Rate (Vulnerable)	7.61%	7.48%	7.71%
Unemployment Rate (Non-Vulnerable)	5.62%	5.48%	5.80%
Real Contagion	60.18%	52.41%	94.61%
Welfare Contagion	25.13%	26.60%	25.40%
Subjective Well Being Standard Deviation	17,755.16	20,149.94	12,610.34
Welfare Spending Standard Deviation	11,082.18	7,709.86	18,136.94
Unemployment Rate Standard Deviation	2.72%	2.07%	3.12%

Equal Preferences			
	Without Tobin Tax		
	Bail-in	Bailout	Default
Periods Executed	38.38	39.40	37.38
Subjective Well Being	24,207.74	30,801.69	24,900.67
Subjective Well Being (Vulnerable)	3,306.18	4,344.75	3,491.76
Subjective Well Being (Non-Vulnerable)	20,901.55	26,456.94	21,408.91
Public Goods Spending	28,108.50	32,822.75	61,617.44
Rescuing Costs	0.00	883,922.53	0.00
Periods to Recover (Banking Crisis)	2.26	2.03	2.03
Periods to Recover (Welfare Crisis)	2.42	1.91	2.77
Average Wage	54.81	200.28	116.00
Tax Rate	8.40%	8.47%	8.33%
Unemployment Rate	5.89%	5.64%	5.95%
Unemployment Rate (Vulnerable)	7.49%	7.26%	7.52%
Unemployment Rate (Non-Vulnerable)	5.60%	5.36%	5.68%
Real Contagion	52.24%	47.03%	86.38%
Welfare Contagion	22.40%	28.63%	23.68%
Subjective Well Being Standard Deviation	9,760.73	17,254.68	12,751.10
Welfare Spending Standard Deviation	10,283.89	14,897.53	17,884.18

Unemployment Rate Standard Deviation	2.54%	1.93%	2.91%

Equal Preferences

		With Tobin Tax	
	Bail-in	**Bailout**	**Default**
Periods Executed	38.33	39.24	37.43
Subjective Well Being	25,240.24	30,881.90	20,315.44
Subjective Well Being (Vulnerable)	3,482.77	4,326.10	2,772.44
Subjective Well Being (Non-Vulnerable)	21,757.47	26,555.79	17,542.99
Public Goods Spending	26,933.89	27,999.47	28,454.65
Rescuing Costs	0.00	1,465,459.67	0.00
Periods to Recover (Banking Crisis)	2.23	1.95	2.06
Periods to Recover (Welfare Crisis)	2.40	1.86	2.63
Average Wage	51.03	158.62	55.71
Tax Rate	8.41%	8.44%	8.33%
Unemployment Rate	5.97%	5.61%	6.04%
Unemployment Rate (Vulnerable)	7.63%	7.14%	7.77%
Unemployment Rate (Non-Vulnerable)	5.67%	5.34%	5.73%
Real Contagion	52.12%	43.99%	87.80%
Welfare Contagion	22.18%	22.37%	22.71%
Subjective Well Being Standard Deviation	10,415.40	12,928.66	9,023.78
Welfare Spending Standard Deviation	11,470.15	10,387.75	9,261.66
Unemployment Rate Standard Deviation	2.98%	1.94%	3.16%

Financial Stability Preference

		Without Tobin Tax	
	Bail-in	**Bailout**	**Default**
Periods Executed	38.17	38.54	37.84
Subjective Well Being	12,558.20	14,817.90	15,489.28
Subjective Well Being (Vulnerable)	1,573.61	1,926.43	2,063.52
Subjective Well Being (Non-Vulnerable)	10,984.58	12,891.47	13,425.75
Public Goods Spending	41,972.04	28,835.27	24,663.83
Rescuing Costs	0.00	853,915.42	0.00
Periods to Recover (Banking Crisis)	2.48	2.09	2.10
Periods to Recover (Welfare Crisis)	2.41	2.28	2.50
Average Wage	79.65	158.41	49.03
Tax Rate	8.38%	8.44%	8.37%
Unemployment Rate	6.05%	5.74%	6.03%
Unemployment Rate (Vulnerable)	7.81%	7.34%	7.75%
Unemployment Rate (Non-Vulnerable)	5.74%	5.45%	5.72%
Real Contagion	62.87%	46.71%	108.69%
Welfare Contagion	19.08%	16.48%	23.01%
Subjective Well Being Standard Deviation	7,295.32	6,026.75	7,862.81

Welfare Spending Standard Deviation	15,157.10	8,645.34	8,847.14
Unemployment Rate Standard Deviation	3.36%	2.12%	3.20%

Financial Stability Preference

		With Tobin Tax	
	Bail-in	**Bailout**	**Default**
Periods Executed	37.30	39.15	37.52
Subjective Well Being	14,592.75	17,108.69	13,170.94
Subjective Well Being (Vulnerable)	1,941.48	2,272.75	1,701.13
Subjective Well Being (Non-Vulnerable)	12,651.28	14,835.94	11,469.81
Public Goods Spending	97,178.15	45,730.95	51,752.77
Rescuing Costs	0.00	457,285.24	0.00
Periods to Recover (Banking Crisis)	2.03	1.63	2.28
Periods to Recover (Welfare Crisis)	2.27	2.11	2.30
Average Wage	176.02	183.24	97.55
Tax Rate	8.31%	8.46%	8.34%
Unemployment Rate	5.88%	5.72%	6.03%
Unemployment Rate (Vulnerable)	7.43%	7.27%	7.64%
Unemployment Rate (Non-Vulnerable)	5.60%	5.45%	5.74%
Real Contagion	67.68%	55.72%	91.10%
Welfare Contagion	16.89%	15.17%	23.30%
Subjective Well Being Standard Deviation	7,940.23	7,014.31	5,721.89
Welfare Spending Standard Deviation	53,842.96	11,442.51	13,291.44
Unemployment Rate Standard Deviation	2.81%	2.00%	3.29%