“Banking crises and contagion: why worry about taxation, output and the cost of capital?”

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Banking crises and contagion: why worry about taxation, output and the cost of capital?

Abstract

The prediction and consequences of banking crises continue to be a fab in academic and political discussions. Researchers attempt to describe the link between these crises and the real economy. In this paper an object oriented model is presented that attempts to establish the relation of the real economy to banking crises and contagion. The authors describe a set of extensions to Virtual Banking, an object oriented model which can be used to carry out simulations on the banking system of a hypothetical economy. The existing work is expanded by proposing a link between the banking system and the real economy, incorporating fiscal issues. The empirical results of the model are presented and the authors discuss policy implications. The findings confirm existing literature which places criticism on the ability of the regulatory measures of Basel III to prevent or handle banking crises. However, the proposed measures seem to be effective in protecting the real economy from financial crises.

Keywords: contagion, banking crises, VBanking, economic simulations.
JEL Classification: G01, E02, H2, H3.

Introduction

One of the trending topics in current economic and financial literature is the prediction of the banking crises and the way each crisis finds its way through the financial institutions, through contagion. Additionally, researchers attempt to propose estimation models for the effects of these crises not only on the banking system but also on the economy and its constituents. Current research deals with different aspects of these issues, proposing models that describe a subset of the economic agents and their transactions.

In this paper, we propose a new modelling approach to banking crisis prediction, which encompasses the real economy. We present the new features of Virtual Banking (VBanking), an object oriented model for economic simulations. This model has been designed to incorporate many aspects of the economic system and employs features from the relevant literature which allow us to perform simulations on a virtual economy. The simulations yield statistical data that can be used to locate financial crises and measure their consequences on the banking sector and on the economy as a whole. VBanking incorporates the regulatory frameworks of Basel II and Basel III and tests for their adequacy with respect to the prevention and the absorption of banking crises. Additionally, the use of an object oriented setup allows for behavioral modelling of economic agents. This model has been integrated in a new software application, which includes all these features and allows its user to execute parameterized simulations, collecting statistics on the key financial indices of the economy. We describe the new areas on which VBanking has expanded and show how the relevant literature supports the implementation of the new features.

The structure of this paper begins as follows. In Section 1, we discuss relevant literature. Section 2 presents existing work on VBanking and briefly discusses the original model. Section 3 introduces the new areas that VBanking has expanded on, namely bank lending policies, taxation (and thus government spending) and production, and presents the formal description of the model. In this section, we will also show how the relevant literature supports the way the new features have been implemented in VBanking. In Section 4, we discuss the outcome of the new simulation results and the final section includes our concluding remarks.

1. Literature review

Banking crisis prediction and contagion have recently been at the center of 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) examine an extensive series of banking crises since 1970 and develop a set of early warning indicators. They find a close relation between debt and banking crises and suggest that they often lead to currency crises. 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 can provide indications as to the aspects VBanking needs to expand on. Lee (2008) seeks the causes of financial stability in bank ownership figures and determines that higher inside ownership of banks favors financial stability. Karas et al. (2013) examine data from bank runs in Russia and establish a relationship between the behavior of depositors and deposit insurance, in the case of a banking crisis. Their findings suggest that deposit insurance often distorts the rational behavior of (risk

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averse) households, minimizing the negative effects of a crisis. In contrast, Diamond and Dybvig (1983) suggest that a bank run may be the result of rational behavior of depositors seeking increased liquidity.

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 ours in VBanking. Majerbi and Rachdi (2014) discuss banking crises in relation to the regulatory framework imposed and seem to favor deregulation for advanced economic systems. These findings are in accordance with our findings in the earlier versions of VBanking (Samitas and Polyzos, 2015).

The concept of the VBanking model and its object oriented nature can be partially attributed to the work of Tsomocos (2003a, 2003b). His work proposes a mathematical model with object oriented characteristics, which can be used to predict the behavior of economic agents based on a series of randomized initial endowments. In effect, VBanking 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. Tsomocos also introduces the role of the Economic Agents and the Regulator, which is similar to the role implemented in VBanking, as well as the risk of the securities issued by banks. However, in the mathematical model of Tsomocos, the risk is treated as exogenous and random, while VBanking links that risk to the credibility of the issuing bank. VBanking expands this work, since it measures the consequences of a bank default and calculates statistics on contagion. Goodhart and Tsomocos (2007) suggest that dealing with default and bankruptcy should be a key issue in financial analyses.

Our model records data on banking crises according to Wong, Wong and Leung (2007, 2011), who propose variables that may be used to identify banks with financial troubles. Their approach on banking crises, as well as that of Demirgüc-Kunt and Detragiache (1998), is used on VBanking to characterize a time period as a crisis period. For the same purpose, VBanking also employs signaling, as proposed by Kaminsky and Reinhart (1999). Memmel and Sachs (2013) examine contagion in the interbank market and analyze 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 VBanking. Porath (2006) and Falcetti and Tudela (2008) suggest non-performing loans and interbank loans as signals for a banking crises, a suggestion included in the model behind VBanking.

Our work contributes to four aspects of the existing literature. Firstly, it proposes a new model that can be used to predict financial crises and their consequences, incorporating the effects of the real economy. Secondly, it supports the use of object-oriented modelling as a means to describe economic systems, a technique that has seen limited support in the past, but is undeniably suitable for such a task. Thirdly, it proposes the extension of this new behavioral modelling framework to include some important aspects of the economic system, which were not implemented in the past. Lastly, it confirms 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.

2. VBanking

VBanking provides a thorough and robust framework to test for the adequacy and effectiveness of policy measures when dealing with the prevention of banking crises and their consequences. The VBanking model replicates a part of the economic system on a smaller scale and hence there are many features that can be added to increase the applicability of the framework to a more generalized version of the economy. The initial model (Samitas and Polyzos, 2015) was designed to describe the behavior of those economic agents that relate to the banking system. It uses the principles of object-oriented modelling, which makes the final model more than just a set of mathematical equations. Instead, it ensures that the data included in the data structures (the economic agents) is accurate and that other structures use this data in the appropriate manner. Upper (2011) argues on the limitations of mathematical models in terms of simulating banking systems and predicting contagion and policy implications. He suggests that behavioral features need to be incorporated into existing models; this is exactly what our aim is when designing this model.

The model that we have built has been integrated in a new simulation application named Virtual Banking, or, in short, VBanking. The application executes the simulation procedure according to the user's parameters, namely the number of economic agents (banks and households), the number of time periods and the regulatory framework implemented. The statistical data produced can be saved to disk using the popular XML[1] format, which is easily imported to Microsoft Excel as well as to most econometric software packages. The user may also

[1] Extensible Markup Language (XML) is a document formatting language where documents are encoded using a standardized set of rules so that the data included in the file is both human-readable and machine-readable.

choose to perform multiple repetitions of simulations that use a given parameter set, in which case the software also produces a summary statistics file, again in the XML format.

VBanking employs a model that performs multi-period simulations of the banking environment. The previous model included three types of economic agents: the Banks, the Households and the Regulator. Only one regulator can exist in the model, while the number of banks and households can be manipulated at each simulation. Banks and households share some common characteristics and functions (this is implemented through inheritance, one of the traits of object oriented programming). Banks and households perform transactions with each other, using another object class, the Financial Asset. This general structure in the transaction system is supported by Tsomocos (2003b), Goodhart et al. (2005), and Aspachs et al. (2007).

The innovation in the use and implementation of VBanking is that, contrary to the mathematical models proposed by the aforementioned authors, our model continues to run for any given number of time periods, as long as there are still active agents (i.e. not bankrupt) in the system. This makes our model much more capable of simulating the workings of a real economic system since the information about the agents is passed on between time periods. In the models proposed above, the authors attempt a description of the agents using a long series of mathematical equations that cannot be calculated for more than one period. Using computer programming, the computer performs all the necessary calculations and allows us to run the model for any given number of time periods. Additionally, the software incorporates a "Monte Carlo" type functionality that repeats the simulation with a specific parameter set for any given number of repetitions, producing summary statistics for the entire process[1].

The basic model setup includes economic agents (Banks and Households), that trade in financial assets, under the regulatory framework set by the Regulator. Households can trade only with Banks, while Banks can also trade with each other. The flow of funds between agents is stimulated from differences in income and spending for Households and is also affected by shifts in their precautionary balances. Excess balances are deposited in banks, where they are used as credit material, while negative balances result in loan demand from Agents. A loan results to payment obligations from the part of the borrower. Failure to meet these obligations results in bankruptcy (for Households) and bank distress (for Banks). The latter is handled by the Regulator, who decides on the solution according to model's setup choice which is passed as a parameter to the simulation[2].

If a household defaults, its loans are removed from the asset list of the lending bank and any deposits it may have are removed. Note that any liabilities the defaulting household may have are not offset by its assets. However, the defaulting household is removed from the active agents list and does not participate in any further transactions. On the other hand, if a bank defaults, the consequences for the entire system are quite significant. As we mentioned earlier, any failure from the part of a bank to fulfil its obligations will lead the bank to the regulator, who in turn decides on the institution's fate. The choices implemented are three, namely an immediate default, a bailout or a bail-in. In the first case, 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, the bailout solution, the money supply is increased to match the financing needs of the bank in distress and any outstanding obligations are covered. Finally, the Regulator can use the bail-in solution[3], a newly proposed solution in the European Union, which was enforced (in part) in the bank rescue of the Cypriot financial institutions. In that case, the bank firstly seeks to cover its needs through the use of the funds in investment products, since these would normally not be part of any deposit guarantee system. If the funds are not enough, then the bank will look for money in the deposit accounts[4].

When any bank is in distress and forces the regulator to intervene, there are important repercussions in the banking system as a whole. Naturally, the repercussions are different in each case, but it is important to note that whenever a bank is in distress (even if it is rescued), this has consequences. It is important to note at this point that the VBanking system experiences economic cycles, with random duration and a random direction. The case for an economic recession or an expansion has equal probability and the duration is calculated randomly, taking into consideration the remaining time periods until the end of the simulation.

The simulation is managed by a managing entity (the Simulation Manager) which carries out the steps presented in the algorithm above. The

[1] Note that the software is also quite efficient in the simulation process: the entire model logic is run simply by pressing a button.

[2] For a more detailed description of the initial VBanking model, see Samitas and Polyzos (2015).

[3] A bail-in requires the use of the funds the bank carries in deposit accounts or in investment products so that the bank is rescued from default.

[4] Note that even in this case, a rescue is not certain, since the total funds in the bank's deposit accounts or investment products may not be enough to cover its financing needs.

Simulation Manager also collects the necessary statistics so that conclusions can be deduced as to the adequacy of the rules implemented as well as the solutions enforced in case a bank is in distress.

3. New modelling approaches

The ultimate goal for VBanking is to supply its users with a thorough framework for economic simulations. These simulations will be based on the financial markets but will need to include other aspects of the economic environment. The implementation of these aspects is supported by the relevant literature, which we will present in this section. It must be made clear at this point that these interactions can take place in a multitude of ways, which cannot be introduced to the model at once. In this section we will present the methodology that will be implemented in VBanking as well as evidence that supports our work.

The first areas that we have expanded on are aggregate output (the real economy), the banks' lending practices and lastly taxation and government spending. The reason why these three areas were chosen is that they exhibit strong mutual links both with the banking system and amongst each other. This means that it would be difficult, if not an oversimplification, to include one of these three and not the others. The issues in adverse selection in the banks' choice of borrowers strongly affect the latters' productive capacity, while one cannot model the effects of taxation without examining its source, which is national income. The effects of these three aspects on each other and on the real economy are demonstrated below.

The new model setup now includes two new kinds of agents, the Firm and the central Government. The latter is thought of as independent from the Regulator, even though often the Regulator imposes government selected policies. The Government can use fiscal tools to gather money that will be used to bailout banks, if that is the selected policy by the regulator. Additionally, firms and households interact. Households receive money from firms in terms of wages and firms receive money from households when the latters purchase goods and services (Figure 1). The ability of firms to generate income for households is dependent on the Banks' willingness to finance investment projects and on the interest rate offered, which in turn is affected by the general economic environment as well as by the status of the borrower.

Note: This figure demonstrates the circular flow of funds between firms and households. Firms generate income for households, which use this income to purchase goods, thus returning the funds back to firms.

Fig. 1. The mutual relationship between the incomes of households and firms

The new features permit us to incorporate into our simulations the relationship of the banking system with the real economy, which was a feature missing from the previous version of VBanking. Additionally, we can examine more closely the income effects (and, in later versions, the welfare effects) of the fiscal costs of a direct bailout, which our previous work suggested was a costly solution. Furthermore, the cost of capital is now taken under consideration and is bound to be a driving force both for bank profitability (and survival) and for new investments. New investment projects will then influence general production and output, causing a positive inflow of cash to the economy. The model setup under the framework implemented in VBanking is depicted in Fig. 2, where we can see the interactions between the economic agents as well as the diverse roles of the Government and the Regulator. Trade can now occur in both financial and real assets (goods and services) and the amount spent on each time period is directly related to the wages paid on the previous time period.

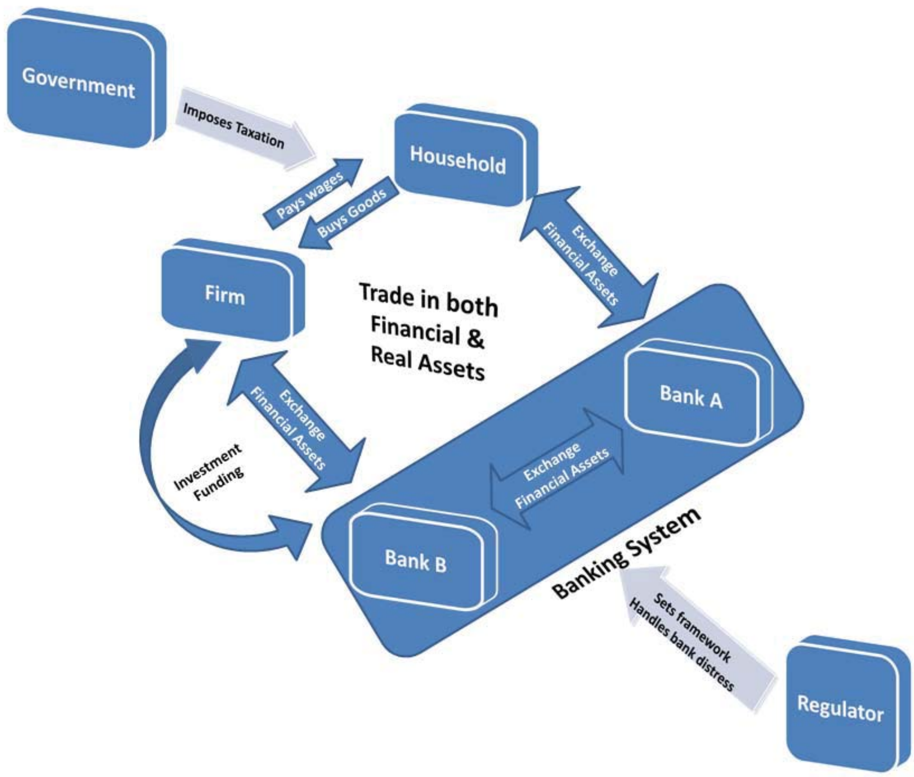


Fig. 2. Setup of the VBanking economy under the new framework

3.1. Aggregate output. VBanking's previous implementation treated production as an exogenous random variable. Income was added to households randomly on each time period and some of it (again, a random amount) was spent as expenditure. These random variables were further manipulated by introducing multipliers for the economy's business cycles. In this manner, the financial system's interactions with production and output were not handled. The first order of business in the expansion of VBanking is to include these interactions in the model, implementing them in a way that is supported by other researchers.

The issue of the interaction of the real economy with the financial markets has been at the center of the relevant literature for a long time. Tobin (1969) proposed a monetary framework that showed the way monetary events can influence demand. The model also accepts exogenous variables and can be used to provide a general model setup from the extension of VBanking. Greenwald and Stiglitz (1993) propose a simple yet thorough dynamic model that describes the firms' behavior 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 closely in the expansion of VBanking on these areas, since it incorporates nearly all implications of production on other aspects of the economy. Additionally, the authors propose a series of further features, like unemployment, output shocks and expectations that may need to be included in our model in the future. Finally, Greenwald and Stiglitz suggest that there is a contagion effect among firms in real economy shocks, which we have not dealt with yet.

More recent 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).

In the proposed extension of the VBanking 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 spiraling 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 implement the modeling of the real economy, we have expanded the set of agents in the system to include firms. Their behavior is similar to that of households as far as 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 behavior 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[1].

The model now 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. This relationship was demonstrated earlier in Figure 1. Firms, similarly to other economic agents, can go bankrupt, in which case all of its assets will be liquidated in favor of its creditors. There will be imperfect information from the part of banks as to the firms' ability to handle their incurred debt, as we will see below. Production at time t has been produced at time t-1 and the production costs must be paid at time t.

3.2. Bank lending policies. In the current version of VBanking, banks will always finance each other and will also generally accept loan applications from most households, as long as their cash balances and the effective regulatory measures permit so. However, this is not always the case since banks impose screening procedures to select potential loan candidates. Additionally, banks require collateral to agree on a loan, in an effort to screen out uncreditworthy customers.

Rajan (1994) attempts to describe the reasons that drive changes in credit policies of financial institutions. His findings on moral hazard and the agency problem could be used to expand VBanking. 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 VBanking. 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.

In the previous version of VBanking, the loan selection procedure followed a pattern of serial random selection: an agent seeking funds will randomly select a bank to cover its financial needs until the necessary capital has been raised by one or more lenders. If the necessary capital cannot be raised, the agent does not proceed with the financing since it does not make her better off[2]. All banks offer loans at the same interest rate and hence the borrower is indifferent between them.

The extension of the model introduces features that differentiate banks from each other, with the interest rate being the most important differentiating characteristic. In our previous work, banks offered a uniform interest rate and hence the borrower was indifferent between the lenders. Now, banks offer varying interest rates based on their cost of capital which is related to their Weighted Average Cost of Capital (WACC). The WACC 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

[1] Note that the generalization of firms and households as bank customers is consistent with the object oriented nature of the model, where entities that exhibit similar behavior 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 behavior.

[2] This last observation could be considered some form of information on the part of the lender, but in reality it only serves the interests of the agent.

interbank market. This latter rate is now 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 cash raised through taxation is higher. Since we will not introduce a deposit guarantee system yet, we do not need to examine any moral hazard issues in the bank's lending behavior.

Additionally, banks will choose which firms to finance, given a variable probability of default. Similarly to the setup proposed by Sengupta, a firm seeks financing in order to fund a new project with a given expected return (above the interest rate) and a given (random) probability of success, which is inherent to the firm. The bank requests collateral, only a fraction of which can be recovered if the project fails. We assume that collateral is drawn from the firm's assets, which is reduced in case of failure, reducing its productive capacity. There is a bankruptcy condition for the firms imposed here, which is dependent on the firm's nominal equity position (Greenwald and Stiglitz, 1993). The probability of success is not known to the lender. 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 expected return of the project, which in essence signifies the scheduled increase in productive capacity.

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, 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.

3.3. Taxation and government spending. In the last feature included in the first expansion of VBanking, we choose to include the money account of the central government. This account receives cash from taxation and is used to salvage banks in distress[1]. In the previous model, the government had endless cash and, when a bailout was required and was selected as the rescuing option, could finance any bank in distress regardless of its cash deficit. This is naturally not the case in a real economy and we have handled this in our first expansion of the model.

The fiscal implications of a banking crisis is 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[2]. On the other hand, Demirgüç-Kunt et al. (2006) suggest that these safety nets protect the banking system from loss in deposits since they minimize potential 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 favor recapitalization 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[3] or a tax on early withdrawals[4]) as a plausible solution with more social fairness. These studies also introduce the social welfare factor, which will not be added to VBanking at this point but will definitely be handled in the future. 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.

The inclusion of this aspect of the economic system would not be possible without modeling the real economy, which we have described above. The government raises cash from taxing household incomes. In the proposed setup, banks and firms will

[1] Admittedly, this is not the only use of government funds, but other uses, like public spending on services, will be introduced in future work, when we also introduce household happiness and the utility function of consumption.

[2] 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.

[3] The Tobin tax will be a useful addition to the model when we include foreign economies and currency.

[4] 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.

not be taxed. 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[1].

3.4. Variable interaction. In this setup, the new variables interact with each other through a series of processes. Firstly, output is closely related to both the interest rates and taxation. Imposing taxation has a direct negative effect on output, since in our model the funds collected are saved only for future use. However, these funds will be used to stabilize the financial system in case of bank distress, which means that should the need occur, the amount gathered from this source should be enough to cover the needs of the troubled bank. This solution is supported by Morrison and White (2011). If taxation is low, then it is possible that the amount required for bank bailouts may not be available when needed and this could have severe adverse effects on the economy. On the other hand, a high tax rate will hinder economic activity and will result in lower output. There is an unmistakable trade-off at this point for policymakers (Honohan and Klingebiel, 2003) and this shows the strong mutual effect of the examined variables with each other.

Additionally, economic growth is closely related to the interest rates. Increased interest rates function as a disincentive to corporate investments, since firms will require a higher project NPV. This will result in a loss of productive capacity for the economy, as supported by Hoggarth et al. (2002). The output loss signifies a loss in household incomes (Greenwald and Stiglitz, 1993) and this can have negative effects on the liquidity of the banking sector due to the increased risk of non-performing loans (Louzis et al., 2012). This in turn may bring about increasing trends to the banks' cost of capital, which will be passed on to borrowers through the interest rate. Rinaldi and Sanchis-Arellano (2006) showed that non-performing loans are closely linked to disposable income and interest rates, in a similar manner to our implementation in VBanking.

[1] 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.

3.5. Formal model description. The notation that will be used in this paper to formally describe the system is given below:

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

Time periods in the model

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

Set of households

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

Set of banks

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

Set of firms

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

The set of potential bank customers (i.e. firms and households).

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

Set of all economic agents

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

Set of active financial assets

N8. $eb \in EB \subseteq E$.

Set of bankrupt economics agents (banks or households), a subset of E – initially empty.

N9. Once an agent becomes bankrupt, she does not participate in the workings of the economy. Hence, in the simulation steps given below, when we refer to the sets E, H or B, we in fact refer to the difference of these sets from EB. Consequently, the active respective agents sets are:

$h \in H = H - EB$,

$b \in B = B - EB$,

$e \in E = E - EB = (H - EB) \cup (B - EB)$.

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

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

N11. Total production is equal to the total capacity of active firms.

$$Production_t = \sum_{\forall f \in F} Capacity_{f,t}.$$

Also, the following assumptions hold:

A1. $\forall_e \in E$: $a \in A_b \subseteq FA$.

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

A2: $\forall_e \in E$: $l \in L_b \subseteq FA$.

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: $fa \in A_b$ and

$\forall fa \in FA$: $\exists!\ e \in$ E: $fa \in L_b$.

For all financial assets, there exists only one agent that carries the item in her assets and there exists only one agent that carries the item in her liabilities. For banks, the asset vector can be split into two subgroups according to the asset's liable agent and this subgrouping can 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 or household).

A4. $\forall g \in G_t$: $\exists!\ h \in H$: $g \in Exp_b$ 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 there exists only one firm that has produced it.

We will choose to treat prices as fixed for now, but this should definitely be handled in future work. Additionally, the goods market must clear domestically since foreign trade (as well as currency crises) will not be handled for now.

The regulator enforces a set of market rules which includes the capital adequacy ratios (the basic Tier 1 ratio, the Capital Conservation Buffer[1] and the Countercyclical Capital Buffer[2]) as well as the Liquidity Coverage Ratio. The latter, when applicable, is calculated at each time period and for each bank and is set equal to a percentage equal to 100%[3] of the 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:

N12. $r_{b\in B,\, t\in T} = \{CapReqVector_t,\, LiqC_{b,t}\} =$

$$= \left\{\{t_1, CapB, CntCapB_t\},\, LiqC_{b,t}\right\}.$$

The vector for each bank at each time period contains a Tier 1 capital requirement (t_1), 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 at the given bank at the given time period (*LiqC*). This amount *LiqC* is calculated for each bank at each time step (see Step 1.2).

The rules are applied in sets. If no banking regulations are imposed then:

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

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

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

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

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

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 III.

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.

N13. $w = \{w_{b\in B}, w_{h\in H}\}$.

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

N14. Hence, the sum of weighted assets of the bank can be calculated using the following equation:

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

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 from the weight.

The system is initialized using the algorithm described below:

0. System initialization:

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.

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

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:

[1] 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.
[2] 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.
[3] The schedule for the implementation of the Liquidity Coverage Ratio is to introduce it on 1 January 2015 and gradually increase it on an annual basis.

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

0.3. Households receive a random amount of initial cash and are characterized by a random precautionary demand for money, which is the money they will keep outside the deposit accounts. 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). Additionally, some households behave in a risk-loving manner, opting for higher interests rates for their deposits even if the bank offering them is in distress.

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

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

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

$$Money\ Supply_t = \sum_{\forall b \in E} CB_{b,t}.$$

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.

N15. $\forall b \in B, t \in T: AvB_{b,t} = CB_{b,t} -$

$-\left[\Sigma_{\forall i \in CapReqVector_t} (CapReqVector_{i,t} \times wa_{b,t})\right] -$

$-LiqC_{b,t}$.

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 N12) with the sum of the weighted assets of the bank, as calculated in 0. This amount is subtracted from the bank's cash balance, since it cannot be used to purchase assets.

N16. $\forall h \in H, t \in T: AvB_{h,t} = CB_{h,t} - PB_{h,t}$.

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

N17. The growth multiplier (GM) is used as a coefficient when calculating income and expenditure for households. 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[1] rule is given by the equation:

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

1.3. Add interest to loans:

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

where Λ is the subset of financial assets that represents loan, Amt is the amount remaining in the loan and ir is the assumed interest rate.

1.4. Increase household incomes and subtract expenditure:

$\forall h \in H: CB_{h,t} = CB_{h,t-1} +$

$+Wage(\overset{def}{=} f(Production_{t-1}, |H|)) -$

$-Expenditure(\overset{def}{=} g(Wage))$.

Household wages are a function of last period's total production (by firms) and the number of households.

1.5. Banks make security payments:

$\forall b \in B: \forall i \in I \subseteq A_{i,t}: Amt_{i,t} = Amt_{i,t-1} + (Amt_{i,t-1} \times ir_I)$

(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 N15).

[1] Under our implementation, the liquidity coverage ratio is always set to 100%, as will be the case under the full implementation of the rule.

1.6. Banks, Firms and Households pay their loan obligations.

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

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

The payment *Pmt* is the 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.

If CB does not suffice, households will go into their savings, until either the savings are all withdrawn or no more outstanding payments remain.

1.7. Households place their excess cash balance to a deposit account. In this case, banks in need of cash will issue securities. If this is the case, the household may pick to place the money on a security (if any banks are offering the product) or a deposit, with equal probability for each case. Once the choice of product is made, a random bank will be chosen.

1.8. Bank customers seek funds. In this step, any firms or households that have liabilities with missed payments or that have 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 order is chosen. Banks will finance the firm or household if the banking system can cover their full financing needs.

1.9. Banks seek funds. In this step, any banks that have liabilities with missed payments or that have 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 is 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 is 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. 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.

1.12. Firms propose investment projects. If a firm does not currently have an investment project underway, it will propose one to the banking system. The investment project carries a random return (can be considered as 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 that will offer financing at a cost lower than the project's return. Each firm carries a random probability that the project will fail, thus hindering its productive capacity. If the firm is unable to find funding for the investment project, it gradually loses its productive capacity.

1.13. 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 expected implementation of the policy (Drehmman et al., 2010)[1].

1.14. Statistics are collected.

1.15. The system progresses to the next time period.

4. Empirical results

VBanking's initial purpose was to test for the adequacy of Basel III as opposed to Basel II. In the initial versions, where production was 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).

However, the new model setup has 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 in Table 2, 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 virtual economy consisted of 10 banks, 25 firms and 250 households and the

[1] 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.

simulations lasted 100 periods each. The simulations produce 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. Note that, similar to our earlier work, we verified the model's robustness, by running the simulation model with the same parameter values in two sets of 10,000 simulations; the results produced were similar for each one of the simulation sets.

Table 1 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 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).

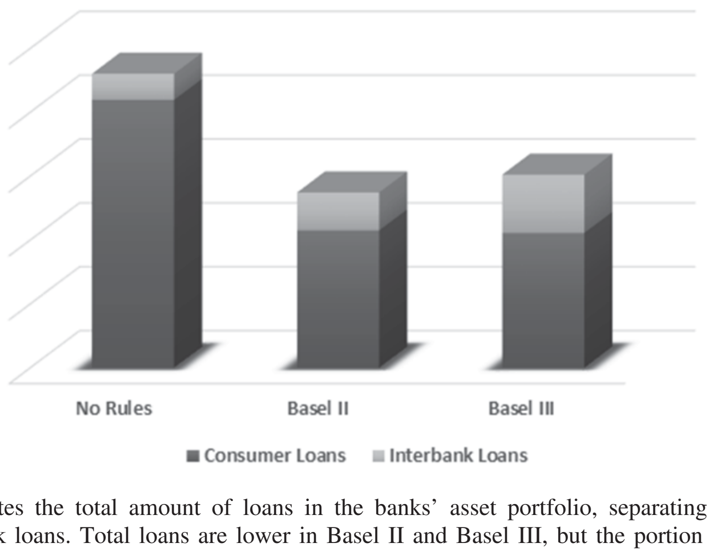
Table 1. Average values for the monitored variables of the banking sector for each set of rules

	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 + 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

The results confirm our previous 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.

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 3, 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 note 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.



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.

Fig. 3. Asset portfolio mix for banks under each regime

Table 2 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 only approximately doubles with respect to the initial average capacity of firms[1]. The negative effects on total production are naturally 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.

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

Table 2. 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 3. 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%

Table 3, 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 VBanking 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. 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 Fig. 4.

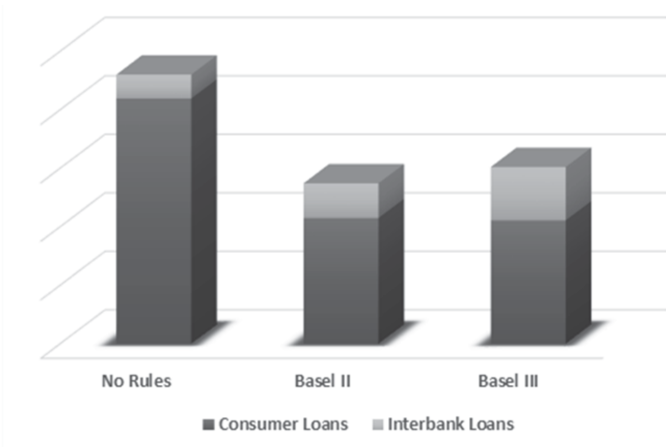


Fig. 4. The real contagion effect under each regulatory regime

[1] 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.

Conclusions

The analysis of our findings from the simulations leads to a series of useful policy implications. 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 the real economy, with 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. 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 protect the European banks from banking crises. Moreover, the pressures applied to financial institutions seem to lead them to distress quite more often and force the intervention of the regulator. 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 protection to the real economy as opposed to a bank default.

On the other hand, we must point out the effectiveness of the strict regime of Basel III with respect to real contagion, that is 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, using taxpayers' money, this regime appears to offer the best defense to the real economy when dealing with banking crises.

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 have some negative effects on the banking sector. The positive effect 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.

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