VBanking: An Object-oriented, Behavioural Framework for Financial Analysis

Stathis Polyzos
Department of Business Administration
Business School
University of the Aegean
8 Michalon Str, Chios, 82100, Greece
spolyzos@aegean.gr

Abstract
The prediction and consequences of banking crises continue to be at the epicentre of academic and political discussions. Researchers attempt to describe the link between these crises and the real economy. In this paper, we present an object oriented model that attempts to establish the relation of the real economy to banking crises and contagion and examines the welfare effects of regulatory policies. We describe Virtual Banking, a model which can be used to carry out simulations on the banking system of a hypothetical economy and propose the link between the banking system and the real economy, incorporating fiscal and welfare issues. We show how this model can be of use to researchers that want to perform parameterised financial simulations on a hypothetical economy and examine the effect of financial crises on the real economy and on public welfare.

Keywords: VBanking, contagion, banking crises, economic simulations, public welfare

JEL Classification: G01 E02 H2 H3

Introduction

The banking sector has been the centre of public attention in the past few years. Its importance in the workings of the economy is evident by the attention given to it governments and by the significant amounts of money spent on keeping it healthy, even when foul play had been suspected or confirmed. Academic researchers attempt to propose estimation models for the effects of financial 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, propose an object-oriented model for economic simulations that allows for behavioural modelling of economic agents. We show how this type of model is better suited for the purposes of financial simulations. Additionally, we demonstrate that the behavioural features included in the framework allow us to simulate the welfare effects of financial and real crises. The model employs features from the relevant literature and permits us to perform simulations on a virtual economy and gather statistics on key figures and indicators. 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. Our work has resulted in a new software application, VBanking, which incorporates all these features and allows its user to execute parameterised simulations and collect statistics.

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 behavioural 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 parameterised simulations, collecting statistics on the key financial indices of the economy. The software has already been used in research papers dealing with banking crises and the proposed regulatory framework changes of Basel III (Samitas and Polyzos, 2015, Polyzos and Samitas, 2015).

The concept of the VBanking model and its object oriented nature can be attributed to the work of Tsomocos (2003a, 2003b). His work proposes a mathematical model, which incorporates object oriented characteristics, and can be used to predict the behaviour of economic agents based on a series of randomised 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 bank. 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. Goodhart and Tsomocos (2007) also suggest that dealing with default and bankruptcy should be a key issue in financial analyses.

In terms of banking-crisis prediction, Wong, Wong and Leung (2007, 2011) propose a probit model which includes variables that may be used to identify banks which are experiencing financial troubles. Their approach on banking crises, as well as that of Demirgüc-Kunt and Detragiache (1998), is used on VBanking to characterise a time period as a crisis period. For the same purpose, VBanking also employs signalling, as proposed by Kaminsky and Reinhart (1999). Another approach is proposed 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 VBanking.

In a more theoretical context, Chang (2011) suggests some macroeconomic variables that were taken into consideration during the development of VBanking and also provides implications in terms of the regulatory framework imposed. Gorton (2009, 2010) 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 VBanking environment. Boissay et al also consider issues of moral hazard of financial institutions, during interbank financial asset trading. 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 VBanking.

The model also incorporates a goods market which clears in every time period and causes for costs to be incurred to the firms. The market setup is based on Greenwald and Stiglitz (1993) and Goodhart et al. (2013) and the results of previous simulations agree with the findings of other researchers with respect to the effects of banking regulation (Angkinand, 2009) and banking crises (Hoggarth et al, 2002) on the real economy. Investment financing in the production sector follows Sengupta (2014). There is also a taxation scheme implemented, in order to collect the funds necessary to rescue banks in distress, which functions similar to the findings of Hasman and Lopez (2011) and García-Palacios et al (2014), who examine the effects of using taxpayers' money to save the banking system.

Our work contributes to three 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. Lastly, it proposes the extension of this new behavioural modelling framework to include the important welfare aspects of the economic system, which were not implemented in the past.

VBanking

The model driving VBanking was designed to describe the behaviour 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 structure 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 behavioural 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, firms 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 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.

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

VBanking employs a model that performs 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 manipulated at each simulation. All types of agents share some common characteristics and functions (this is implemented through inheritance, one of the traits of object oriented programming). Banks perform transactions with each other and with their customers (firms and households) 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 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. The software is also quite efficient in the simulation process: the entire model logic is run simply by pressing a button.

The basic model setup is shown in Figure . The 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 Banks, while Banks can also trade with each other. 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. 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. The amount Households spend on each time period is directly related to the wages paid on the previous time period. 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.

The Firms' income endowments in each time period (that is the economy's output) are not random but rather they are 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 in turn affected by their expenditure. Production costs are paid for either by the sale of goods or by financing. Firms need to pay wages to households and these wages are in effect 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 banks as to the firms' ability to handle their incurred debt. Production at time t has been produced at time t-1 and the production costs must be paid at time t.

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 and is also affected by shift in their precautionary balances. Excess balances are deposited in banks for both Firms and Households, 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 related to their Weighted Average Cost of Capital

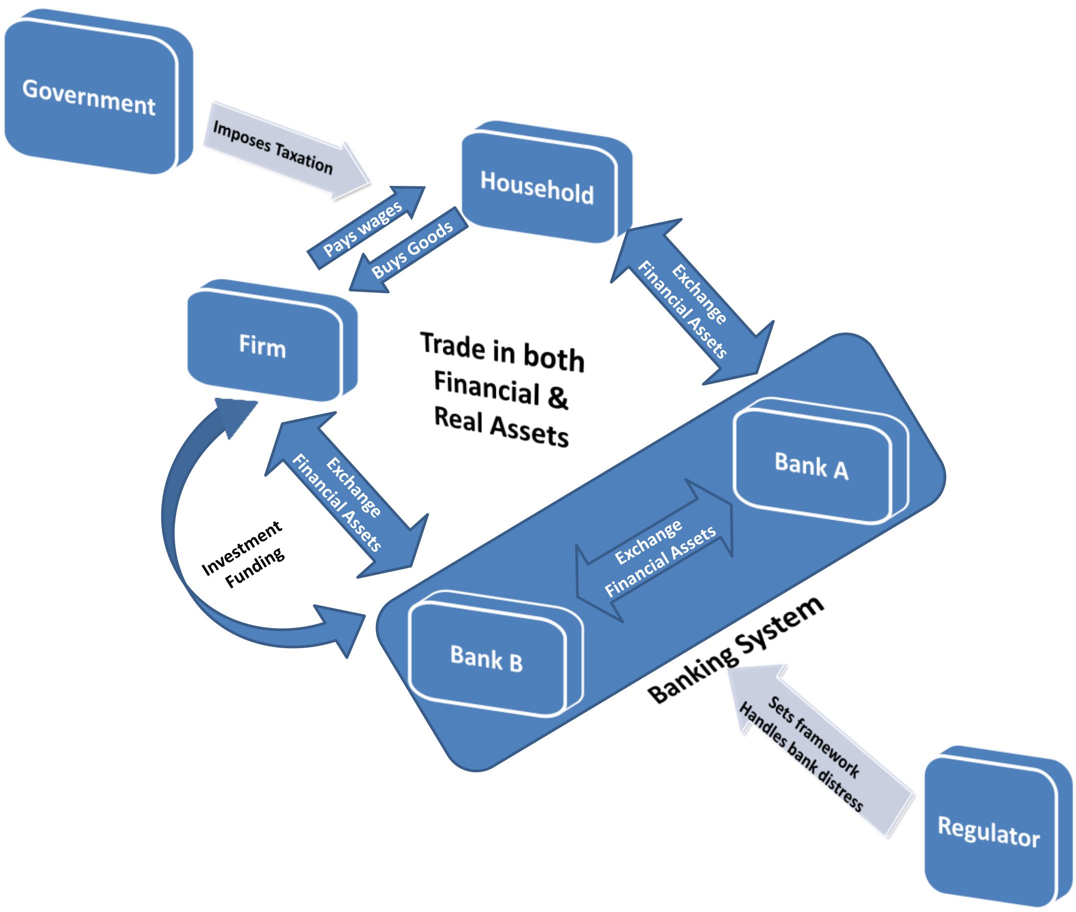

Figure 1: General Model Setup for VBanking

(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 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 cash raised through taxation is higher.

Additionally, banks will choose which firms to finance, given a variable probability of default. Similarly to the setup proposed by Sengupta (2014), 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. 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 will be reduced in case of failure. There is a bankruptcy condition for the firms imposed here, which is dependent on the firm's nominal equity position (Greenwald & Stiglitz, 1993, Tobin, 1969). The probability of success 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. 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 result in limited bank profitability, which, if matched by an increase in non-performing loans, can ultimately yield the same result.

A loan results to payment obligations from the part of the borrower. Failure to meet these obligations results in bankruptcy (for Households and Firms) 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. Note that the central Government is thought of as being 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.

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 government tries[2] to use cash raised through taxation in order to cover any outstanding obligations. Finally, 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, is a newly proposed solution in the European Union, which was enforced (in part) in the bank rescue of the Cypriot financial institutions. In VBanking, this solution may be enforced by the regulator to rescue a bank in distress. 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. 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.

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 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.

This model setup permits us to incorporate into our simulations the relationship of the banking system with the real economy. We can thus examine the income and the welfare effects associated with bank distress and rescue. Furthermore, the banks' cost of capital is a driving force both for bank profitability (and survival) and for new investments. New investment projects will in turn influence general production and output, causing a positive inflow of cash to the economy.

Formal Model Description

The notation that will be used in this paper to formally describe the system is given below:

N1. $t \in T = \{1, \ldots, T\}$
Time periods in the model

N2. $h \in H = \{1, \ldots, H\}$
Set of Households

N3. $b \in B = \{1, \ldots, B\}$
Set of Banks

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[2] The cash raised in the previous time periods may not suffice to cover the outstanding obligation of banks in distress. The amount raised through taxation (relative to the cash needs of the distraught bank) is a key factor in selecting the solution.

N4. $f \in F = \{1, \ldots, F\}$
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. $fa \in FA = \{1, \ldots, FA\}$
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. $g \in G_t = \{1, \ldots, G_t\}$
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. $\forall\, e \in E : a \in A_e \subseteq FA$
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 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. $\forall g \in G_t\!: \exists!\, h \in H\!: g \in Exp_e$ *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 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[3] and the Countercyclical Capital Buffer[4]) 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% 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 institution makes available to other agents in the system. The rule vector is the following:

N12. $r_{b\in B,t\in T} = \{CapReqVector_t, LiqC_{b,t}\} = \left\{\{t1, CapB, CntCapB_t\}, LiqC_{b,t}\right\}$

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 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 below).

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

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

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:

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

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 initialised using the algorithm described below:

0. System Initialization:

[3] 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.

[4] 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.

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

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. 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 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.

N15. $\forall\, b \in B, t \in T: AvB_{b,t} = CB_{b,t} - \left[\sum_{\forall i \in CapReqVector_t}(CapReqVector_{i,t} \times wa_{b,t})\right] - LiqC_{b,t}$
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 N12 above) with the sum of the weighted assets of the bank, as calculated in N14. 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[5] 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. Add interest 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 loan, Amt is the amount remaining in the loan and ir is the assumed interest rate.

1.4. Increase Household Incomes and subtract expenditure

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

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

1.5. Banks make Security Payments

$\forall\, b \in B: \forall\, i \in I \subseteq A_{i,t}: Amt_{i,t} = Amt_{i,t-1} + \left(Amt_{i,t-1} \times ir_I\right)$ (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 N15)

1.6. Banks, Firms and Households pay their loan obligations

$$\forall\, \lambda \in \Lambda \subseteq FA: Amt_{i,t} = Amt_{i,t-1} - Pmt_{\lambda} = Amt_{i,t-1} - InitialAmount \times \left(ir + \frac{ir}{(1+ir)^n - 1}\right)$$

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

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

is not covered, the next bank in order is chosen. Banks will finance the form 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, she will propose one to the banking system. Investment project carry 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 which 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 her productive capacity. If the firm is unable to find funding for the investment project, she gradually loses her 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)[6].

1.14. Statistics are collected

1.15. The system progresses to the next time period

Conclusions – Implications

In this paper, we presented VBanking, an object-oriented, behavioural framework that can perform simulations on a hypothetical economy. The model includes agents (Banks, Firms and Households) who trade in financial and real goods. The inclusion of Households as a separate

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[6] 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.

entity, with a different behaviour and, presumably, a different utility functions than other agents, permits the model to produce and collect information on the welfare of these agents. As long as a particular utility function is selected for the Households, VBanking can supply a virtually endless amount of data on how financial crises affect the welfare of households either directly or through the real sector.

Additionally, the Monte Carlo type functionality that VBanking encompasses permits us to examine the welfare implications of regulatory policy in the banking sector. More specifically, simulations in our model can run under the framework of Basel II, Basel III or neither, according to the user's selection. Moreover, the user can choose whether banks in distress will be saved, either by a direct bailout (using cash raised through taxation) or by a bail-in, using depositors' funds. This ability for parameterisation of the simulations allows for comparisons between the different policy selections and can let researchers approach the optimal policy mix for regulatory authorities, whilst taking welfare implication under consideration

Finally, VBanking is an extensible framework which can be expanded into various different areas of the economic system. In this manner, we can model more aspects of the economy and monitor variables in different parts of the many economic sectors, including the financial and the production sectors. The ability to extend the existing model is one of the key factors that can make it a useful tool for researchers who wish to perform simulations on the financial and the production sector of a virtual economy.

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