Inequality, Household Debt and Financial Instability: An Agent-Based Perspective

Alberto Cardaci, Ph.D. Student*
Lombardy Advanced School of Economic Research, Milan

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Abstract

Our paper contributes to the literature on the causes of the 2007-2008 financial crisis in the U.S.. By means of an Agent-Based Model, we argue that growing inequality and the resulting debt-financed consumption boom jeopardised the stability of the economic system, thus paving the way for the financial crisis as suggested by Cynamon and Fazzari (2013); Fitoussi and Saraceno (2010); Stiglitz (2012). Our model includes a behavioural rule for consumption based on expenditure cascades, a hierarchical structure of household finance, an articulated credit market with collateralised consumption loans and mortgages and a simple housing market. Results show that the model is able to capture the economic and social pressure of inequality on low and middle income households that pushes them to increase their consumption via home equity-based borrowing as described by Mian and Sufi (2009). Rising non-performing loans lead to higher bad debt on banks' balance sheets and, consequently, to the emergence of a crisis as an endogenous dynamic.

Keywords: Agent-Based Models, Equity Extraction, Household Debt, Inequality

JEL Classification: C63, D31, E21, G01

*alberto.cardaci@unimi.it - Supervisor: Prof. Domenico Delli Gatti (*Università Cattolica del Sacro Cuore, Milan*). I'm particularly grateful to Jakob Grazzini (*Università Cattolica del Sacro Cuore, Milan*) and Francesco Saraceno (*OFCE-SciencesPo, Paris*) for their support and advice.

1 Introduction

There is a growing consensus in the literature that financial and economic stability in the U.S. was jeopardised not only by the development of bizarre financial instruments, but also by a more structural real factor, namely income inequality which could, and in fact did, play a role in boosting the risk of a crisis (Cynamon and Fazzari, 2013; Fitoussi, 2013; Fitoussi and Saraceno, 2011; Stiglitz, 2012, 2013).

In the period between 1983 and 2007, the income share of the top 5% increased from 22% to 34% (Kumhof and Rancière, 2010b). Moreover, the top 1% of the population in the U.S. doubled its share in national income from around 8% in the mid-1970s to almost 16% in the early 2000s (Milanovic, 2010). This transfer of income from the bottom of the distribution to the top reproduced the same situation that existed prior to the 1929 crisis, when the share of the top 1% reached its previous high-water mark. One would expect the transfer of income from the bottom to the top to reduce overall consumer demand thus leading to unemployment and stagnation in general since the richest part of the population is assumed to have a lower propensity to consume. Still, in the years before the crisis, the U.S. economy performed well as American households, in the aggregate, increased their spending relative to income: using an adjusted measure of demand relative to adjusted disposable income of the household sector, Fazzari and Cynamon (2013) show that rising inequality, starting roughly in the early 1980s, corresponds unequivocally with a historic increase in American household demand relative to income from roughly 81% to almost 95%. The authors refer to this as a paradox and they wonder how consumption spending could rise so quickly in the face of stagnant income growth over much of the income distribution. The answer is that "American households, outside of those in the top of the income distribution, went on an extended borrowing binge" (Fazzari and Cynamon, 2013): household debt increased from 48% of GDP in the early 1980s to 100% of GDP before the crisis (Milanovic, 2010). Hence, the observed drop in the propensity to save can be explained by the higher debt to income ratio and percentage of consumption financed by borrowing, as pointed out also by Zezza (2008).

Starting from these key facts, two major issues are worth analysing: one is about the reasons that pushed household debt to increase to such unsustainable levels; the other one is about the mechanisms that actually allowed households to borrow with virtually no constraints. The former can be traced back to the dramatic rise in income inequality, while the latter is explained by house price dynamics which made equity extraction a viable option for households (FCIC, 2011).

In the period before (and during) the recent U.S. financial crisis, only a very few number of studies focused on the link between rising income inequality and the increase in household debt. Most of the studies, in particular, ignored the role these facts may have played in increasing the risk of financial instability. Galbraith (2012) argues that before the crisis the relationship between inequality and financial instability was not even thought of, as there was no study of the link between the two. Also Atkinson and Morelli (2011) stress that there have been few economic models showing how inequality can generate a greater risk of crisis. Our work is an attempt to fill the gap in the literature. The few existing major contributions are built in a dynamic stochastic general equilibrium (DSGE) setting (e.g. Kumhof and Rancière, 2010a) whose representative agent framework does not allow to capture heterogeneity among agents or the existence of emerging credit networks. For this reason, similar to Russo et al. (2013), we explore the issue of inequality and financial instability by means of an agent-based model (ABM) that allows us to assess the impact of income inequality on debt dynamics and financial stability by representing the economy as a complex evolving system with heterogenous interacting agents. However, compared to Russo et al. (2013) we include additional features, such as the existence of a housing market and collateralised loans, as well as a different setting for household desired consumption based on imitative behaviour.

The paper is organised as follows. After this introduction, Section 2 introduces the theory linking inequality to higher household debt and hose price dynamics. Section 3 includes the description of our ABM. Section 4 reports simulation results. Finally, Section 5 concludes.

2 Inequality, equity extraction and the borrowing binge

In the years before the crisis, as a result of increasing inequality, income growth outside the top quintile was stagnant (Cynamon and Fazzari, 2013; Fazzari and Cynamon, 2013). Yet, demand remained strong and contributed to the good performance of the American economy. This counterintuitive fact may be explained by looking at micro and macro aspects of economic theory, ranging from household imitative behaviour to house price dynamics.

Let us start from micro-foundations. As Cynamon and Fazzari (2013) point out, the literature on social psychology provides useful insights: "households learn consumption patterns from their social reference group". As such, they tend to compare their living standard, proxied by their level of consumption, with that of their neighbours or richer households. Hence, growing income disparities lead to the observed decline in the savings rates of American households through *expenditure cascades* (Frank et al., 2014): "a process whereby increased expenditure by some people leads others just below them on the income scale to spend more as well, in turn leading others just below the second group to spend more, and so on". In fact, following the rise in income inequality households at the bottom of the distribution looked for external resources to finance their growing desired consumption: they accessed credit markets to borrow.

Turning to macro dynamics, higher inequality contributed to booming household debt via the real estate market and equity extraction processes.

On the one hand, "a huge pool of available financial capital - the product of increased inequality - went in search of profitable opportunities in which to invest" (Milanovic, 2010). On the other hand, the expansionary policy implemented by the Federal Reserve in the 2000s successfully allowed low and middle-income households to increase their private consumption faster than their disposable income by borrowing (Fitoussi and Saraceno, 2010). Lower interest rates in a deregulated environment contributed to strong house price appreciation, "fueled by the availability of mortgage credit to a riskier set of new home buyers" (Mian and Sufi, 2009). Banks and financial intermediaries, seeking profitable opportunities in the housing market, supplied mortgages not only to trustworthy new home buyers but also to risky ones, namely subprime borrowers. This resulted in growing demand for houses and therefore higher house prices. Also the Financial Crisis Inquiry Commission (2011) stresses that house prices grew markedly due to lower interest rates for mortgage borrowers and greater access to mortgage credit for households who had traditionally been left out (including subprime borrowers).

House price dynamics have "an important feedback effect on household leverage through existing homeowners" (Mian and Sufi, 2009), as higher house prices imply a greater value of home equity that can be extracted for consumption purposes. Mian and Sufi (2009) refer to this as home equity-based borrowing (HEBB), claiming that it allowed U.S. homeowners to increase their debt.[1] Since "credit standards and the cost of external finance are determined by considering the value of households collateral, which is

[1] Notice that 65% of U.S. households already owned a house before house prices started to rise so fast in the late 1990s (Mian and Sufi, 2009). This stresses the importance of the HEBB channel.

influenced by housing prices" (Arestis and Gonzalez, 2013), as these rose, homeowners with greater equity felt more financially secure and, partly as a result, saved less and less. Many others went one step further, borrowing against their equity. The effect was unprecedented debt (FCIC, 2011).

Higher house prices led to the emergence of a bubble, thus giving the false impression that high levels of debt were sustainable (Fitoussi and Saraceno, 2010). Eventually the bubble exploded and net wealth returned to normal levels. The crisis revealed itself because the terms of credit were built upon the intrinsic instabilities involved in lending to those who cannot pay: "like any Ponzi scheme, or any bubble, it is a matter of timing: those who are in and out early do well and those who are not nimble always go bust" (Galbraith, 2012).

3 The Model

For the purpose of our work, we build an agent-based model where the economy is modelled as an ecology populated by heterogeneous agents whose interactions continuously change the structure of the system (Fagiolo and Roventini, 2012). At the micro level, agents repeatedly interact with each other based on adaptive and imitative behaviours thus giving rise to stable and predictable aggregate configurations at the macro level (Delli Gatti et al., 2011; Tesfatsion, 2006).

The main goal of our model is to identify the effect of inequality on household debt and the stability of the economic system as a whole. To do so, we focus mostly on the household sector and its relationship with banks. Our economy is demand-driven, that is we assume the existence of a representative firm that always satisfies demand by households thus supplying the required amount of goods. In other words, no rationing takes place in the goods market.

The structure of our model has some key features that allow to capture the dynamics described in the previous section of this paper. Such key features are:

- The introduction of a consumption behaviour based on an imitative behaviour as described by the Expenditure Cascades Hypothesis (Frank et al., 2014), so as to capture the economic and social pressure of inequality on low and middle income households;
- A hierarchical structure of household finance that leads households to demand credit only in the extreme case in which internal resources are

not enough to finance desired consumption;

- An articulated credit market with collateralised consumption loans and mortgages;
- A simple housing market with price dynamics that allow for equity extraction behaviour by households.

Our model features two main categories of agents, namely households ($h = 1, ..., H$) and banks ($b = 1, ..., B$). It also includes an extremely simplified government and a central bank. Agents are heterogeneous, they have bounded rationality and follow behavioural rules based on adaptive expectations.

The sequence of events in each period t is as follows:

1. GDP at time $t-1$ is distributed to households at the beginning of period t, based on exogenously set income shares. The government provides a subsidy to all households in the bottom 90% of the distribution, whose income is lower than a given threshold. The central bank endogenously sets the policy interest rate, targeting the change in GDP at time $t-1$ with respect to the mean of the previous three periods.
2. The pay back phase begins. Each household assesses whether she is able to pay back her debt by using her income and liquid wealth. Households that are not able to do so will have to sell their house and use the resulting liquidity to pay back their outstanding debt. For convenience, such households are labelled as "bankrupt". Banks use earned interests to increase the value of their net worth.
3. All households set their desired consumption based on adaptive and imitative behaviour and adjust their propensity to consume out of income and wealth accordingly. Households whose desired consumption is higher than the available internal resources have a positive consumption gap: they can apply for a consumption loan, provided that they own a house and have previously paid back their debt.
4. Credit market for consumption loans opens. Banks set their total available credit supply as a multiple of their equity and rank households based on their Total Debt Service Ratio[2] (TDS). Since houses

[2]Total Debt Service Ratio (TDS) is defined as the ratio between household repayment schedule (the sum of consumption loan and mortgage principal plus interests) and household income.

serve as collateral, the amount of credit households can get depends on house prices. Households in the credit market for consumption loans can apply to one bank only in each period. After the market closes, households who get a lower amount of credit than asked, will not fill their consumption gap: credit rationing takes place.

5. Housing market opens. All households update their price; those who do not own a house are potential buyers. Supply of houses comes from all the households who are forced to sell their house to pay back their debt plus a random set of homeowners selected in each period. Sellers set their desired price equal to the value of their house, whereas buyers generally set their prices as a multiple of their liquid wealth. Buyers are sorted randomly, whereas sellers are sorted in ascending order based on their selling price, so that each buyer tries to buy from the seller asking for the lowest price. Households who have enough liquid wealth can buy a house directly. Those who have a deal with a seller but lack the internal resources to pay for the entire amount, enter the credit market for mortgages.

6. Credit market for mortgages opens. Individual demand for mortgages depends on the difference between the selling price and the liquid wealth of the buyer. Individual mortgage supply is based on the value of the house to be provided as collateral. Again, banks rank households based on their TDS. After the mortgage market closes, households who get the needed amount of credit get back to the seller to close the deal and buy the house. Credit-rationed households, instead, will drop the deal and search for another house in the following period. The housing market closes and existing homeowners update the value of their real wealth based on the average market price.

7. If bankrupt households have managed to sell their house, they use the resulting liquidity to pay back their outstanding debt. Due to changes in house prices, each household's liquidity may be lower than the value of her outstanding debt: the bank will record a non performing loan and the resulting bad debt will slow down the accumulation of its net worth.

We now provide a detailed description of all the algorithms and rules of behaviour introduced in each section of the model.

3.1 Habit Persistence, Expenditure Cascades and Desired Consumption

Our model features a key mechanism in order to explain the reason why American households did not react to falling incomes and increased inequality by higher precautionary savings, like in Germany, but by borrowing more (Van Treeck, 2012). In particular, the specification of desired consumption in our model follows the expenditure cascades hypothesis introduced by Frank et al. (2014), with the only difference that we also include liquid wealth (equation 1)[3].

$$C^d_{t,h} = k * (1 - a) * (Y_{t,h} + M_{t-1,h}) + a * C_{t-1,j} \tag{1}$$

Hence, h's desired consumption is a function of her income ($Y_{t,h}$) and liquid wealth ($M_{t-1,h}$) as well as j's actual consumption in the previous period, where j is the household who ranks just above h in the income scale, so that $j = h + 1$. Put it simply, h tries to replicate j's consumption in the past based on k, which is "a parameter unrelated to permanent income level or rank" (Frank et al., 2014) and a sensitivity parameter a, such that $0 \leq a \leq 1$: when $a = 1$, h fully mimics j's consumption; whereas when $a = 0$, h does not consider j's consumption.

Given the target level for consumption, each household has to assess whether her internal financial resources are enough to meet it. Such process is based on a hierarchical structure of household financing behaviour as shown in Figure 1. Indeed, in general households finance their desired consumption by using a portion $0 < \alpha_{t,h} \leq 1$ of their income, a portion $0 \leq \beta_{t,h} \leq 1$ of liquid wealth and, eventually, consumption loans ($L_{t,h}$).

More specifically, h adjusts her propensity to consume out of income so that $\alpha_{t,h} = C^d_{t,h}/Y_{t,h}$.[4] If $C^d_{t,h} \leq Y_{t,h}$, then $\alpha_{t,h} \leq 1$ and h is able to finance her desired consumption by using her income only: no wealth wears away (i.e. $\beta_{t,h} = 0$ and $L_{t,h} = 0$). On the contrary, if $C^d_{t,h} > Y_{t,h}$, then $\alpha_{t,h} > 1$ thus violating its domain. In this case, household income is not enough to finance desired consumption. Hence, we impose $\alpha_{t,h} = 1$, so that h consumes her income entirely. Still, h needs to use her liquid wealth as well: $\beta_{t,h}$ becomes positive and equal to $(C^d_{t,h} - Y_{t,h})/M_{t,h}$, provided that h has a positive amount of liquid wealth[5]. If $(C^d_{t,h} - Y_{t,h}) \leq M_{t,h}$, $\beta_{t,h} \leq 1$

[3] The inclusion of liquid wealth in the equation for desired consumption follows Russo et al. (2013)

[4] We assume the government provides a subsidy to h whenever Y˙t,h = 0.

[5] It may be the case that h has no liquid wealth: if she is a homeowner, then she can

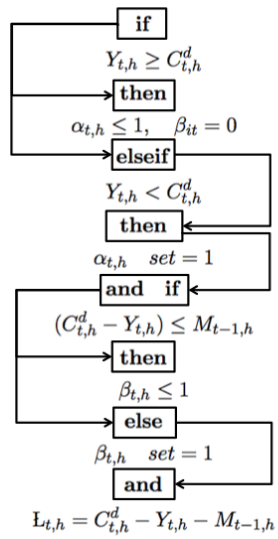

Figure 1: Hierarchical structure of household finance.

and h has enough internal resources to pay for her desired consumption. If $(C^d_{t,h} - Y_{t,h}) > M_{t,h}$, $\beta_{t,h}$ is greater than one, thereby violating its domain. In this case we impose $\beta_{t,h} = 1$: h also consumes her liquid wealth entirely but has to apply for a consumption loan in order to close the gap between her desired consumption and the resources needed to finance it. Note that loans are collateralised by houses so that only homeowners can enter the credit market.

3.2 Credit Market for Consumption Loans

Demand for consumption loans, $L^d_{t,h}$, is defined as the difference between desired consumption and the sum of income and liquid wealth:

$$L^d_{t,h} = C^d_{t,h} - (Y_{t,h} + M_{t-1,h}) \tag{2}$$

Following Delli Gatti et al. (2011), the maximum allowable credit supply by bank b is defined as a fraction $\frac{1}{v}$ of its equity $E_{t,b}$, where v can be interpreted as a capital requirement coefficient. That is:

enter the credit market directly to ask for a consumption loan. If h does not own a house, she will be forced to consume less than her desired consumption.

$$LS_{t,b} = \frac{E_{t,b}}{v} \tag{3}$$

Each bank ranks households in ascending order based on their TDS, and supplies credit until $LS_{t,b} = 0$. Therefore, applicants with zero TDS are given priority and they are selected in random order. The formulation of credit supply follows the literature on collateral constraints spawned by Kiyotaki and Moore (1997) and recalled by more recent works in the DSGE literature (e.g. Justiniano et al., 2013).

Bank b offers individual single-period debt contracts, $LSH_{t,b,h}$, whose amount is based on the loan to value ratio, γ, the market value of h's real wealth, $RW_{t,h}$[6], the balance owed on the existing mortgage, $ZR_{t,h}$, and the interest rate on consumption loans, $r^L_{t,b,h}$:

$$LSH_{t,b,h} = \frac{\gamma RW_{t,h} - ZR_{t,h}}{1 + r^L_{t,b,h}} \tag{4}$$

We assume the loan to value ratio to be the same for all banks. Following Russo et al. (2013), the interest rate on consumption loans is based on three elements:

$$r^L_{t,b,h} = \overline{r} + \widehat{r_{b,t}} + r_{t,h} \tag{5}$$

$\overline{r}$ is the policy rate set by the central bank at the beginning of each period (see subsection 3.6) $\widehat{r_{t,b}}$ is a bank specific component that reflects the sensitivity (measured by ρ) of each bank to its own leverage, $LB_{t,b}$. Hence, $\widehat{r_{t,b}} = \rho LB_{t,b}$, where bank leverage is the ratio between the total amount of loans and mortgages supplied by bank b and its equity. Finally, $r_{t,h}$ is a household specific component equal to $\mu TDS_{t,h}$, where μ is banks' sensitivity to household total debt service ratio. We also assume ρ and μ to be the same for all banks.

Note that our setting of the credit market for consumption loans implies banks have an information set that includes the amount of outstanding debt of each borrower. Hence, by looking at each borrower's TDS, the bank is able to apply an interest rate that takes into account the financial soundness of each borrower.

[6] Real wealth is defined formally in section 3.3.

Each household searches for the bank applying the lowest interest rate.[7] Once found, household h accepts the offer, enters the credit network of bank b and gets $LOAN_{t,h} = L^d_{t,h}$ if $LSH_{t,b,h} \geq L^d_{t,h}$ or $LOAN_{t,h} = LSH_{t,b,h}$ otherwise. The debt contract corresponds to a repayment schedule defined as $RS^L_{t,h} = LOAN_{t,h}(1 + r^L_{t,b,h})$, to be paid back entirely in the following period.

The design of the credit market for consumption loans allows the model to capture the home-equity based borrowing mechanism as described by Mian and Sufi (2009). Indeed, when house prices increase, both existing and new homeowners can exploit the higher value of their real wealth to access credit market and borrow against their equity. The newly accumulated debt is then used to finance consumption expenditure.

3.3 Housing and Mortgage Market

The housing market features a fixed stock, $\overline{H}$, of identical houses, which is distributed to a constant number of households randomly selected at the beginning of period $t = 1$.[8] Each homeowner owns one house only and does not want to increase her stock. In other words, existing homeowners can enter the housing market on the supply side only: they never demand additional houses. As a result, the number (but not the identity) of homeowners, is fixed over time.

In period $t = 1$, each homeowner is also assigned a house price, $P^H_{t,h}$ drawn from a uniform distribution. Therefore, household real wealth, $RW_{t,h}$, is defined as $RW_{t,h} = P^H_{t,h} H_{t,h}$, where $H_{t,h}$ is h's housing unit and it is equal to 1 for all households.

In every period, each homeowner updates the value of her house, by assessing whether the market is experiencing excess supply or excess demand using the number of unsold houses as a proxy. In particular, as shown in conditions 6 and 7, homeowners set the new value of their house at time t based on their price in the previous period ($P^H_{t-1,h}$) and a markdown ($-\xi_t$), if the number of unsold houses at the beginning of t is higher than at the beginning of $t-1$, or a markup ($+\xi_t$) otherwise. The price remains the same if the number of unsold houses does not change.

[7] If two or more banks set the same interest rate, households select one randomly.

[8] We do not include construction firms as we are not interested in quantity dynamics, but exclusively on housing price dynamics.

$$P^H_{t,h} = \begin{cases} P^H_{t-1,h}(1-\xi_t) & \text{if } unsold_t - unsold_{t-1} > 0 \quad (6) \\ P^H_{t-1,h}(1+\xi_t) & \text{if } unsold_t - unsold_{t-1} < 0 \quad (7) \\ P^H_{t-1,h} & \text{if } unsold_t - unsold_{t-1} = 0 \quad (8) \end{cases}$$

The magnitude of the change in the number of unsold houses reflects into the mark-up/down (9), so that the higher the difference between $unsold_t$ and $unsold_{t-1}$, the higher ξ_t.

$$\xi_t = \xi_{min} + \frac{(\xi_{max} - \xi_{min})}{1 + \frac{1}{|X_t|}} \quad \text{where} \quad X_t = \frac{unsold_t - unsold_{t-1}}{unsold_{t-1}} \tag{9}$$

ξ_{max} and ξ_{min} in equation 9 are parameters set in the initialisation phase, which are meant to limit the range of oscillation of the mark-up/down.

In every period, a number of randomly selected homeowners enters the housing market on the supply side. Similar to Erlingsson et al. (2013), we include random sellers in order to "address the trading activities driven not by speculative reasons but by different reasons, like family needs, migration", and so on.[9] In addition, all bankrupt households have to join the supply side of the market: since they have failed to meet their obligations with banks, they have to sell their house in order to get the liquidity to pay back their outstanding debt.

When entering the market, sellers set their selling price equal to their updated price at the beginning of each period, that is $PS_{t,h} = P^H_{t,h}$.

All households who do not own a house enter the housing market placing themselves on the demand side.[10] All buyers set a desired price, $PB_{t,h}$, as a multiple $\theta > 0$ of their liquid wealth (condition 10). If they have no liquid wealth, they will apply a mark-up to the average market price in the previous period (condition 11).

$$PB_{t,h} = \begin{cases} \theta M_{t-1,h} & \text{if } M_{t-1,h} > 0 \quad (10) \\ \overline{P^H_{t-1}}(1+\xi_{t,h}) & \text{if } M_{t-1,h} = 0 \quad (11) \end{cases}$$

[9]This random set in each period t cannot include homeowners who use their house as a collateral for consumption loan in the same period. In addition, we also rule out the possibility of selecting homeowners who have bought the house in the previous "$rest_s$" periods, where "$rest_s$" is a parameter set in the initialisation phase of the model.

[10]The set of buyers does not include all households who have sold a house in the previous "$rest_b$" periods, where "$rest_b$" is a parameter set in the initialisation phase of the model.

Transactions among households in the housing market are based on a search and matching mechanism: the main rule for buyers is to look for a seller such that $PS_{t,h} \leq PB_{t,h}$. All sellers are sorted in ascending order based on the selling price, whereas buyers are sorted randomly. The first buyer to enter the search and matching process assesses whether her price is higher than that of the first seller. If so, they set a deal; otherwise the buyer leaves the market and tries to buy a house in the following period. The second buyer steps in and searches for an available seller (i.e. a seller who does not have a deal with a buyer). The process keeps running until all buyers have had the chance to search for a seller.

When a deal is set up, the agreed price of the transaction is the price set by the seller. Buyers who have enough liquid wealth are allowed to buy the house directly: the seller transfers her real wealth to the buyer, who is now a new homeowner. In exchange, the seller gets an amount of liquidity equal to the selling price, so that $Liq_{t,h} = PS_{t,h}$. This will increase her liquid wealth.

Buyers who do not have enough liquid wealth to buy a house, enter the mortgage market. Demand for mortgages, $Z^d_{t,h}$, is equal to the selling price net of the downpayment, that is the whole amount of available (if any) liquid wealth:

$$Z^d_{t,h} = PS_{t,h} - M_{t-1,h} \tag{12}$$

By design, also households with no liquid wealth can apply for a mortgage. In other words, a downpayment is not necessary. Even though this might sound as an extreme assumption, in the years before the recent financial crisis “buyers could be given loans exceeding 80% of home price; or they could be given two loans, one for 80% of purchase price - making the loan potentially sellable to FNMA - and another (the down payment) for the other 20%” (Dimsky, 2010).

Bank behaviour in the credit market for mortgages follows the same rules as in the credit market for consumption loans: they rank households in ascending order based on their TDS and supply mortgages until $LS_{t,b} = 0$. Again, applicants with zero TDS are given priority. We assume all banks issue standard “plain-vanilla” mortgage contracts, $ZSH_{t,b,h}$, with fixed interest rates, the duration being T_z.

$$ZSH_{t,b,h} = \frac{\gamma RW_{t,h}}{1 + r^z_{t,b,h}} \tag{13}$$

Also in the mortgage market, the definition of the interest rate, $r^z_{t,b,h}$, is as follows:

$$r^z_{t,b,h} = \overline{r} + \widehat{r_{b,t}} + r_{t,h} \tag{14}$$

Each household searches for the banks whose individual supply is higher than her demand. Then, within the subset of selected banks, h selects the bank offering the lowest interest rate as shown in condition 15.[11]

$$\forall\, b \quad s.t. \quad ZSH_{t,b,h} \geq Z^d_{t,h}\,, \quad find \quad min(r^z_{t,b,h}) \tag{15}$$

If h finds a bank b satisfying condition 15, she accepts the offer of that bank, joins its credit network and gets a mortgage equal to $Z_{t,h} = ZSH_{t,b,h}$: from the following period until $t{+}T_z$, h will have a constant periodic payment which is based on the standardised calculations in the U.S. (as defined by Kohn, 1990):

$$ZP_{t,h} = Z_{t,h} * \frac{r^z_{t,b,h} * (1 + r^z_{t,b,h})^{T_z}}{(1 + r^z_{t,b,h}) - 1} \tag{16}$$

All households who do not find any bank willing to supply more than what they demand, leave the market without getting any mortgage. They drop the deal with the corresponding seller and search for a house and, eventually, a mortgage in the following period.

On the contrary, all the households who successfully found a mortgage get back to the corresponding seller to proceed with the transfer of real wealth. The buyer becomes the owner of the house, whereas the seller gets the corresponding liquidity equal to the selling price, thus increasing her liquid wealth.

Notice that the mechanisms included in the housing market allow to capture the impact that housing price dynamics have on existing homeowners and their home equity based borrowing behaviour. This is because the value of their equity reflects the changes in the number of unsold houses via house prices.

After mortgage and housing market close, each bank has a credit network made of all the households to which it has supplied consumption loans and

[11] Also in the mortgage market, if two or more banks set the same interest rate, each household selects one randomly.

mortgages. All banks update the value of their assets, $AB_{t,b}$, and their leverage ratio, that is $LB_{t,b} = AB_{t,b}/E_{t,b}$.

All borrowers update their debt and total debt service ratio as follows:

$$Debt_{t,h} = Debt_{t-1,h} + LOAN_{t,h} + Z_{t,h} \tag{17}$$

$$TDS_{t,h} = \frac{ZP_{t,h} + RS^{L}_{t-1,h}}{Y_{t,h}} \tag{18}$$

3.4 Pay Back Phase

As already pointed out, the pay back phase (PBP) starts at the beginning of each period t. In the PBP, some borrowers have to pay the repayment schedule of the consumption loan obtained in the previous period; others have to fulfill the recurring mortgage payment. Finally, a number of households has to do both. Each household is able to meet her obligations entirely if and only if $ZP_{t,h} + RS^{L}_{t-1,h} \leq Y_{t,h} + M_{t-1,h}$. If this condition is satisfied, household h pays $ZP_{t,h}$ and $RS^{L}_{t-1,h}$ in sequence, thus experiencing a reduction of her debt and the balance owed on the existing mortgage. Consequently, also her total debt service ratio decreases. In addition, each bank b earns profits equal to the sum of the interest payment of all the household in its credit network, CN, that is:

$$INT_{t,b} = \sum_{h \in CN} (r^{L}_{t,b,h} LOAN_{t-1,h} + int^{Z}_{t,h}) \tag{19}$$

Households who fail to meet their obligations, instead, try to pay back their outstanding debt only after selling their house. If they do not manage to sell it in period t, they will try to do so in any other following period. When bankrupt households sell their house, they assess whether the resulting liquidity, $Liq_{t,h}$, is higher than the entire repayment schedule: if $\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^{L}_{t^*,h} \leq Liq_{t,h}$, their debt goes down to zero and they are not labelled as bankrupt anymore as they pay back both the entire principal and interests.[12] Moreover, they will keep the excess liquidity thus increasing their liquid wealth. On the contrary, if $\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^{L}_{t^*,h} > Liq_{t,h}$,

[12]Notice that t^* identifies the default period, namely the period at which household h failed to meet her obligation

household h pays a lower amount than due. In this case, the non-performing loan results in bad debt on banks' balance sheets. The computation of bad debt is based on the composition of household debt. Indeed, if h belongs to the credit network of two banks at the same time[13], she splits the liquidity in two parts (equations 20 and 21): a part of it, $\delta^L_{t,h}$, will go to the bank that supplied the consumption loan, the remaining part, $\delta^Z_{t,h}$, being paid to the bank that issued the mortgage.

$$\delta^L_{t,h} = \frac{RS^L_{t^*,h}}{\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^L_{t^*,h}} \tag{20}$$

$$\delta^Z_{t,h} = \frac{ZP_{t^*,h}}{\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^L_{t^*,h}} \tag{21}$$

Hence, the amount of bad debt due to h's default is as follows:

$$bd_{t,h,b} = \begin{cases} RS^L_{t^*,h} - \delta^L_{t,h} Liq_{t,h} & (22) \\ \sum_{ii=t^*}^{T_z} ZP_{ii,h} - \delta^Z_{t,h} Liq_{t,h} & (23) \end{cases}$$

As shown in equation 9, the overall amount of bad debt, $BD_{t,b}$, for each bank b is calculated as the sum of the entire bad debt coming from the bankrupt households who belong to its credit network.

$$BD_{t,b} = \sum_{h \in HB} bd_{t,h,b} \tag{24}$$

$HB \subset CN$ identifies the subset of all the bankrupt households in the credit network of bank b.

After the pay back phase, each bank updates her equity based on the following accumulation process:

$$E_{t,b} = E_{t-1,b} + INT_{t,b} - BD_{t,b} \tag{25}$$

[13] Households can join two credit networks when they get a consumption loan from a bank and a mortgage from another one. Notice that since households cannot apply for more than one consumption loan and one mortgage, they cannot belong to more than two credit networks.

Notice that, similar to Delli Gatti et al. (2010), the bankruptcy of a household creates a negative externality since the bad debt recorded on the bank's balance sheet results in a reduction of banks' equity and, therefore, a higher bank leverage which implies a higher interest rate and a reduction in the overall credit supply.

In addition, it may be the case that bad debt is high enough that $E_{t,b}$ is lower than zero, the bank has negative net worth and goes bankrupt. In this case, following Delli Gatti et al. (2011), we assume that whenever a bank records negative equity, "the government bails the bank out, replacing it with a random copy of surviving banks".

3.5 Goods Market, Consumption and Saving

After the housing and mortgage markets close, the goods market opens. We assume the representative firm always supplies the required amount of goods, so that no rationing takes place in the goods market.

All households make their consumption and saving decisions based on the level of desired consumption. Households who have enough internal resources, as well as those who managed to access the credit market and get a consumption loan, can close the gap between desired consumption and actual consumption expenditure, so that $C_{t,h} = C^d_{t,h}$, where $C_{t,h} \equiv \alpha_{t,h} Y_{t,h} + \beta_{t,h} M_{t-1,h} + L_{t,h}$.

All households save a portion $1 - \alpha_{t,h}$ of income that is converted into a zero interest rate deposit, $D_{t,h} = (1 - \alpha_{t,h}) Y_{t,h}$.

Household liquid wealth therefore becomes:

$$M_{t,h} = M_{t-1,h} + D_{t,h} + Liq_{t,h} \tag{26}$$

Finally, each household has an overall amount of wealth equal to:

$$A_{t,h} = M_{t,h} + RW_{t,h} - ZR_{t,h} \tag{27}$$

3.6 Policy Authorities

In our model the government serves the only purpose of smoothing income disparities by redistributing income from the top to the bottom.

To do so, we assume the government does deficit spending: it collects taxes on income based on the same tax rate for all households and spends a constant exceeding percentage of its earnings from taxes.

Government spending is entirely distributed to households at the bottom 90% of the distribution in the form government subsidies that increase their individual income. Subsidies are the same for all households. However, since the amount of taxes collected in each period t depends on income in the previous period (i.e. GDP_{t-1}), the amount of each subsidy depends on the performance of the economy.

On the other hand, the central bank has a countercyclical policy: at the beginning of each period it increases the policy rate if GDP at time $t-1$ is lower than the mean of GDP in previous three periods ($\overline{GDP_{t-2,t-4}}$). However, it also looks at the one-to-one change in GDP between $t-1$ and $t-2$. That is:

$$\bar{r}_t = \begin{cases} \bar{r}_{t-1} * (1-\tau_t) & \text{if } GDP_{t-1} \leq \overline{GDP_{t-2,t-4}}\, and\, GDP_{t-1} \leq GDP_{t-2} \quad (28) \\ \bar{r}_{t-1} * (1+\tau_t) & \text{if } GDP_{t-1} > \overline{GDP_{t-2,t-4}}\, and\, GDP_{t-1} \geq GDP_{t-2} \quad (29) \end{cases}$$

Similar to house prices, τ_t is a mark-up/down that depends on the magnitude of the change in the key variable, that is GDP in this case (Equation 30).

$$\tau_t = \eta_{min} + \frac{(\eta_{max} - \eta_{min})}{1 + \frac{1}{|Q_t|}} \quad \text{where} \quad Q_t = \frac{GDP_{t-1} - \overline{GDP_{t-2,t-4}}}{\overline{GDP_{t-2,t-4}}} \tag{30}$$

η_{min} and η_{max} are set in the initialisation phase and are meant to limit the degree of oscillation of τ_t.

4 Model Results

We use our model to simulate two scenarios: a baseline scenario (BA) in which income shares at the beginning of each period t remain constant over time and a rising inequality scenario (RI) in which we shock income shares after a number of periods in order to simulate rising inequality. Model results are obtained by means of Monte Carlo (MC) analysis: given a parameter vector, we run 30 simulations for each of the two scenarios, selecting a different random seed at each run, similar to Delli Gatti et al. (2011) and Russo et al. (2013). Our parameter vector is set up mostly based on the literature as well as the need to rule out explosive dynamics and unrealistic patterns, similar to Delli Gatti et al. (2011), so that "no attempt has been made at this stage to calibrate the model for instance, by means of genetic algorithms in order to force the output of simulation to replicate some pre-selected empirical regularities". In addition, we also perform univariate sensitivity analysis by changing the values of some key parameters so as to asses the change in the outcome of simulations.

Parameter		Value
T	Number of periods	2000
H	Number of households	400
B	Number of banks	20
HO	Number of homeowners	260
a	Sensitivity parameter to j's past consumption	0.5
k	Consumption parameter independent of income or rank	0.8
v	Capital requirement coefficient	0.08
μ	Bank sensitivity to TDS	0.005
ρ	Bank sensitivity to own leverage	0.005
γ	Loan to value ratio	0.8
θ	Multiple of liquid wealth	100
ξ_{min}	Minimum mark-up/down for house prices	0.01
ξ_{max}	Maximum mark-up/down for house prices	0.1
η_{min}	Minimum mark-up/down for the policy interest rate	0.01
η_{max}	Maximum mark-up/down for the policy interest rate	0.05
T_z	Duration of mortgages	120
$rest_s$	Number of "freezing" periods for sellers	16
$rest_b$	Number of "freezing" periods for buyers	4

Table 1: Model calibration

In order to run simulations we calibrate model parameters as shown in Table 1.

The choice of assigning a house to 260 randomly selected households follows Mian and Sufi (2009) who point out that "65% of U.S. households already owned their primary residence before the acceleration in house prices beginning in the late 1990s". The initial loan-to-value ratio for all banks is equal to 0.8 and it is in line with the data for 1990 reported in Duca et al. (2011) and retrieved from the American Housing Survey. Mortgage duration is equal to 120 periods, which we interpret as a standard 30-years time period. v, which, as already pointed out, can be interpreted as a capital requirement coefficient is set to 0.08, following the standard value in the literature (see, for example, Benes et al., 2014). Finally, the values of a and k are taken from the original work on expenditure cascades by *Franket al.* (2014).

4.1 Monte Carlo Analysis: Baseline Scenario vs. Rising Inequality

Starting from our parameter vector, we perform our MC simulations: for each scenario, we compute the cross-simulation mean of the key variables. For example, we calculate GDP at each time t as the average of GDP across the 30 MC simulations for each of the two scenarios.

In all simulations we drop the first 1100 periods in order to get rid of transients: graphs only show the last 900 periods for the purpose of simplicity.[14] In addition, we represent all data generated by our model as simple moving averages in order to smooth out the cyclical fluctuations of the key time series.[15]

In each scenario, the key time series show the same pattern across all MC simulations: cross-section time series in particular (e.g. total wealth share, consumption share, default rate, successful mortgage applicants) are all stationary at least in the last 500 periods in BA.

In both BA and RI, the model starts with unequal income shares for the top 10% and bottom 90%, with values respectively equal to 31.51% and 68.49%. These are retrieved from the World Top Income Database (Facundo et al., 2014) with reference to the United States for the year 1975. In RI we simulate a shock in the income shares that become equal 62.57% for the bottom 90%, 37.43% for the top 10% from period 100 until the end.[16]

Model results suggest our ABM fits the stylised facts described in section 2 of this paper. GDP, household debt and house prices follow the same pattern and are strictly correlated as shown in Figure 2, which collects the combined plots of such key time series in the two scenarios, together with their correlation values.

Endogenous business cycles emerge in BA as a result of the agents' interactions that lead to small oscillations of house prices and household debt. However, when income shares change and inequality rises, GDP increases

[14] Hence, the description of the two scenarios refers to the last 900 periods and thus takes period 1101 as period 1.

[15] We choose a window size for our moving averages equal to 20.

[16] Such values are equal to the mean of the income shares for the groups in the period between 1971 and 2006.

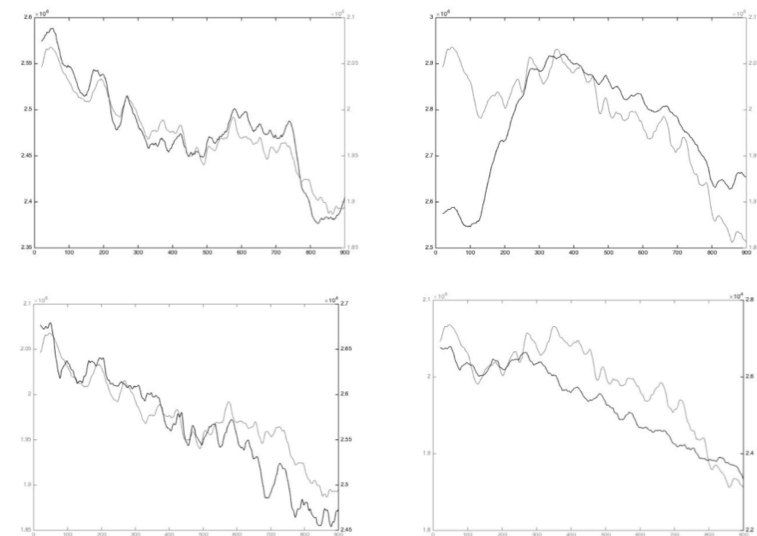

Figure 2: Left column, top: GDP (black) and household debt (gray) in BA (correlation: 0.99, significant at 5% level); bottom: household debt (gray) and average house prices (black) in BA (correlation: 0.85, significant at 5% level). Right column, top: GDP (black) and household debt (gray) in RI (correlation: 0.89, significant at 5% level); bottom: household debt (gray) and average house prices (black) in RI (correlation: 0.82, significant at 5% level).

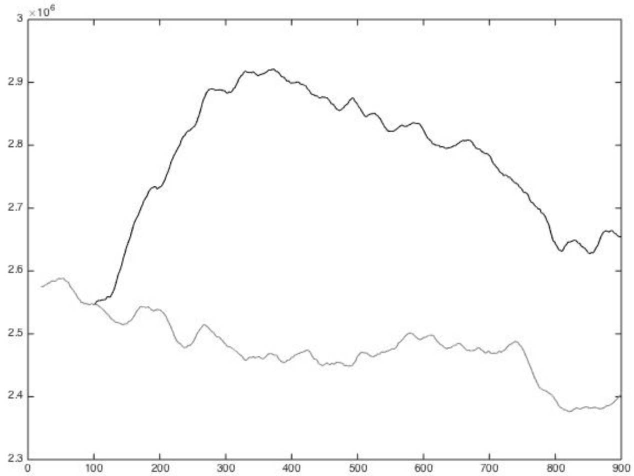

Figure 3: GDP in BA (gray) and RI (black).

substantially, as shown in Figure 3. The inequality shock has various consequences.

First, Figure 10 compares the amount of consumption loans households actually get in each period in the two scenarios. Clearly, with higher inequality, households' demand for consumption loans increases as income at the bottom of the distribution is stagnating and households need external resources to finance their desired consumption. However, also note that house prices do not change significantly for a number of periods as shown in Figure 5. Hence how can households increase their debt?

The answer to this question comes by looking at the behaviour of households at the top of the distribution: they exploit the newly accumulated amount of income to buy more houses whereas households in the bottom 90% lower the number of houses being bought. Indeed, as shown in Figure 4, the real wealth of the top 10% rises right after the shock.

This results in a greater number of direct buys and, consequently, in a reduction of mortgages (Figure 6).

The impact on the banking sector is relevant: lower mortgages imply lower bad debt and therefore higher net worth. Hence, banks increase the maximum allowable credit supply: a greater number of households is now able to get the desired amount of consumption loans (Figure 7). This is the reason why, right after the shock, the overall amount of consumption

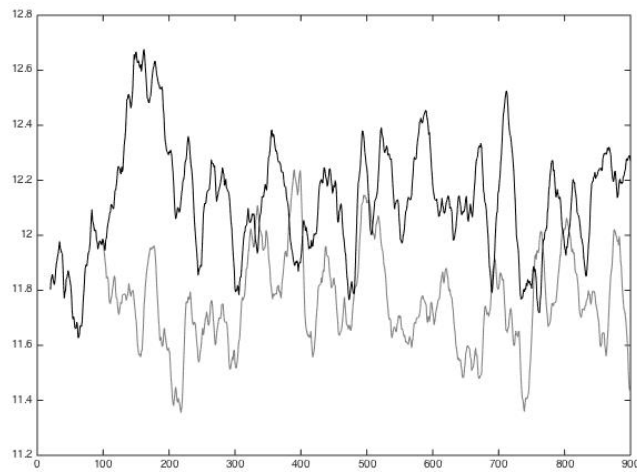

Figure 4: Share of real wealth held by the top 10% in BA (gray) and RI (black).

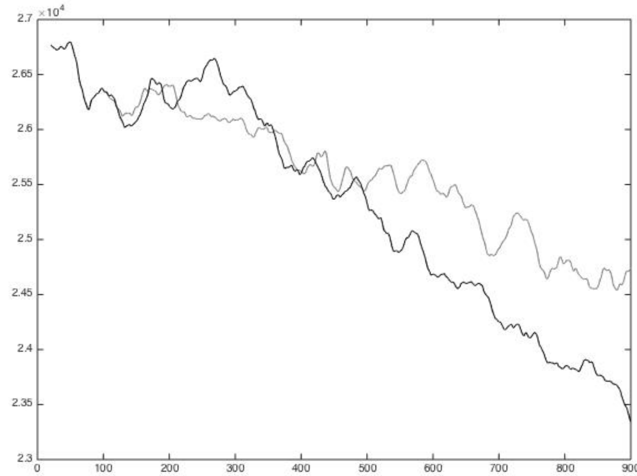

Figure 5: Average house price in BA (gray) and RI (black).

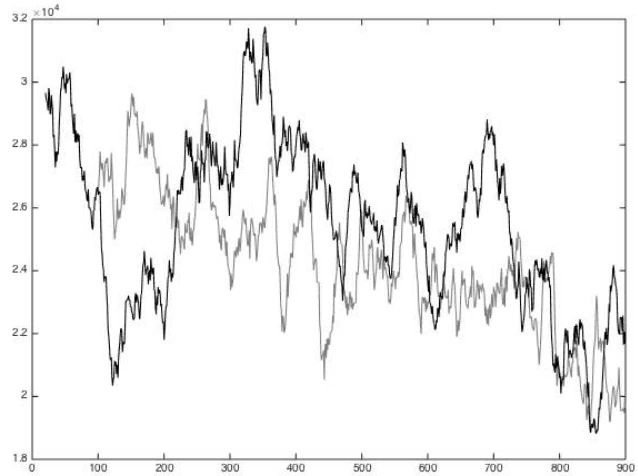

Figure 6: Amount of mortgages in BA (gray) and RI (black).

loans (Figure 10) increases even though house prices remain roughly stable for a while. We could call this a "supply effect": more households can borrow because of greater availability of credit, not because of changes in house prices. The increased amount of debt for consumption loans results immediately in higher household spending thus pushing GDP upwards, as seen in Figure 3.

After a number of periods, house prices increase smoothly. Indeed, as these rise, the value of mortgages being issued increase as well: people at the bottom of the distribution borrow to buy a house as well. Higher house prices also result in greater consumption loans. The overall consequence is boosting household debt (Figure 8). This sustains consumption and GDP for a while, thereby giving the false impression that the economy is performing well.

Nonetheless, when households start defaulting on their obligations, a dramatically large amount of bad debt is accumulated by the banking system that reacts by cutting credit supply and increasing interest rates. Given the existence of interconnected credit networks among households and banks, the consequence of a growing number of non-performing loans is a credit crunch that affects future borrowers and their ability to finance desired consumption. Therefore, the crisis emerges as a balance sheet recession: households fail to meet their debt obligations and banks record a substantial value

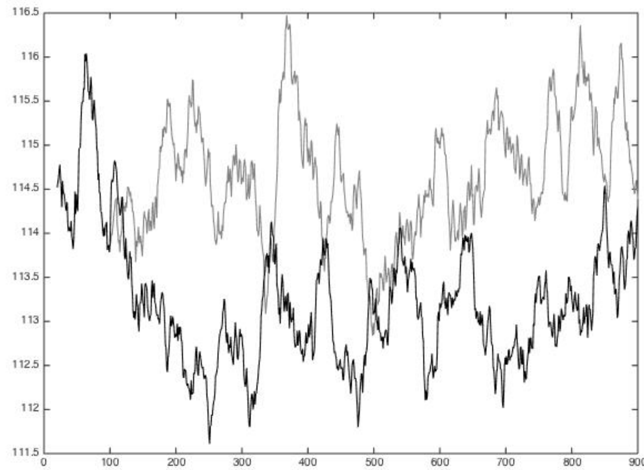

Figure 7: Number of households who demand consumption loans but fail to get one in BA (gray) and RI (black).

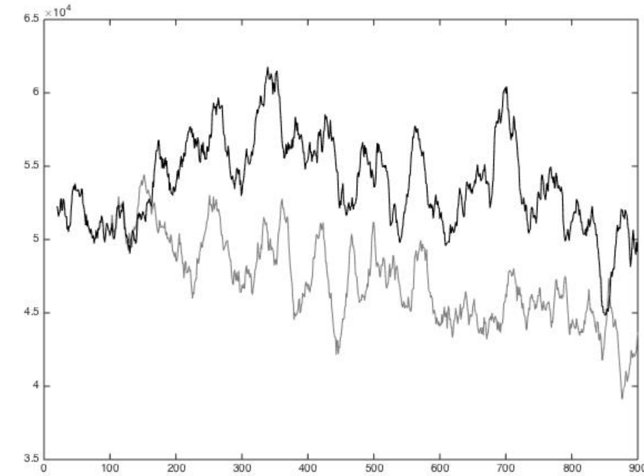

Figure 8: Household debt in BA (gray) and RI (black).

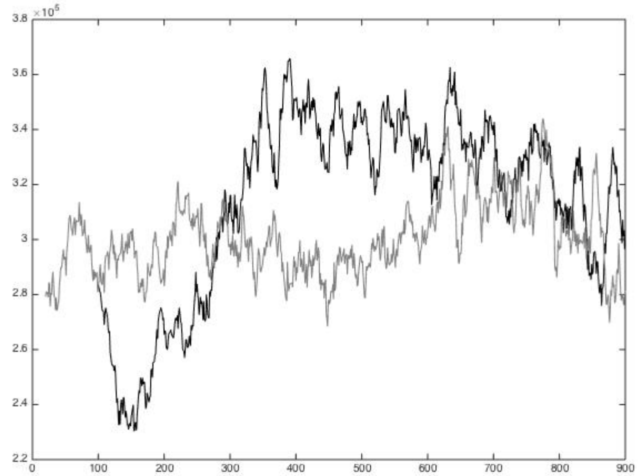

Figure 9: Bad debt for the banking sector in AB (gray) and RI (black).

of bad debt. Figure 9 shows this is the case in RI: as households take on more debt, both in the form of consumption loans and mortgages, they lack the internal resources to pay it back due to rising income inequality and bad debt rises. Note that the correlation between GDP and bad debt of the banking sector is 0.89, which are statistically significant at 5% level: this suggests that the expansion of the economy goes together with the amount of non-performing loans.

Due to the emerging credit crunch, households are forced to consume less than desired, thus leading to falling actual consumption and GDP. After entering a recession, household debt and bad debt decline as well: this is mostly due to lower mortgages. In fact, the amount of consumption loans remains roughly stable even though this is not enough to keep consumption up to its previous levels. The reason is that the number of households who is able to get the desired amount of consumption loans drops: in other words, less people are getting more loans but a wider number of households is forced to cut their consumption as a consequence of bankruptcy.

Finally, as already pointed out,

4.2 Sensitivity analysis

We now show the results of our sensitivity analysis with the aim of showing how model output changes when we explore the parameter space. In

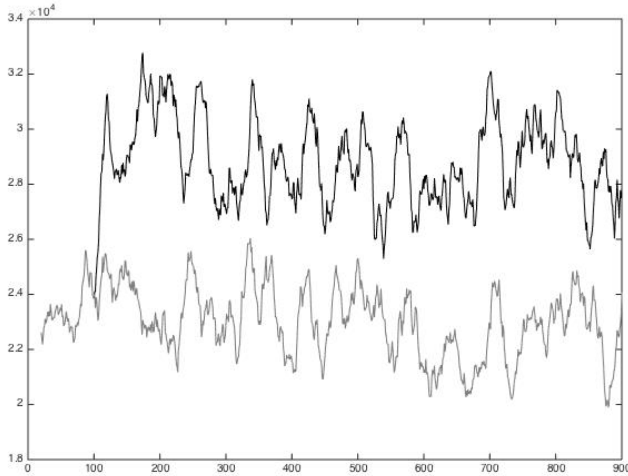

Figure 10: Amount of consumption loans supplied to households in each period t in BA (gray) and RI (black).

particular, following Delli Gatti et al. (2011), we perform univariate sensitivity analysis for the baseline scenario, "according to which the model outcomes are analyzed with respect to the variation of one parameter at a time, whereas all the other parameters of the system remain constant". We act on five different parameters, namely a, k, μ, ρ and θ which are the sensitivity parameters of our model. We find that for three of these parameters, that is a, k and ρ, model results change in line with our intuitions. On the contrary, changes in μ and θ do not seem to affect the dynamics of our artificial economy in any relevant manner.

Let us summarise our main findings.

Sensitivity parameter to j's past consumption: a. We run 30 MC simulations for the baseline scenario, for 4 different values of a: 0.2, 0.4, 0.6 and 0.8. Results show that the lower the value of a, the higher the (stationary) trend along which GDP oscillates. In particular, lower levels of a imply a less imitative behaviour by households: since desired consumption is set mostly based on internal resources, a larger number of households is able to finance it without accessing credit markets for consumption loans. Indeed, the lower a, the lower the amount of consumption loans. This also results in smaller debt-to-GDP ratios and total debt service by households. Consequently, less households default on their obligations and banks record a fewer number of non-performing loans.

Consumption parameter: k**.** We run 30 MC simulations for the baseline scenario, for 3 different values of k: 0.2, 0.4, 0.6. Remember that in all these experiments, a is equal to its original value of 0.5. Changing the value of k does not imply a different sensitivity to j's consumption for household h. Rather, it means each household is targeting a different amount of internal resources to set her desired consumption. Results suggest that lower values of k go along together with business cycles along lower trends: GDP and consumption loans have smaller values. With less GDP to be distributed, households have lower internal resources to pay back their debt: non-performing loans and bad debt have higher values, thus resulting in higher debt-to-GDP ratios.

Bank sensitivity to TDS: μ**.** In this experiment we run 30 MC simulations for the baseline scenario, for 3 different values of μ: 0.001, 0.01, 0.05. In this case we find that modifications in banks' sensitivity to households' total debt service ratios do not imply any significant change in the model results and the overall dynamics of the economy. Results are in line with those reported for the baseline scenario using the parameter vector described above.

Bank sensitivity to own leverage: ρ**.** In this experiment we run 30 MC simulations for the baseline scenario, for 3 different values of ρ: 0.001, 0.01, 0.05. When banks are more sensitive to their own leverage, interest rates are higher. This results in higher total debt service ratio and a rise in the number of defaults and the value of bad debt. On the other hand, households are less willing to take on more debt so that household debt falls as well as debt-to-GDP ratios.

Multiple of liquid wealth: θ**.** In this experiment we run 30 MC simulations for the baseline scenario, for 4 different values of θ: 50, 80, 120, 150. We find that modifications in the value of θ do not result in significant changes in model outcome: all the key time series follow the same pattern as in our baseline, thus suggesting that θ is not a key parameter in affecting output and model dynamics.

5 Concluding Remarks

By means of an agent-based model we create an artificial economy with heterogenous agents whose interactions result in mutual feedbacks and emerging macroeconomic dynamics resembling the ones that took place before and during the recent financial crisis in the United States. By including some key elements regarding household consumption behaviour and the functioning of credit and housing markets, the data generating process built in our model captures the impact of increasing inequality on household debt and the overall stability of the economy.

On the one hand, growing income disparities force low and middle income households to enter credit markets so as to find the external resources that are needed to satisfy consumption needs. This captures the pressure of inequality on the lower segments of society. On the other hand, higher house prices, fueled by mortgage credit and the accumulation of wealth at the top of the distribution, allow for relaxed collateral constraints thus impacting households' ability to borrow.

The combination of these elements gives rise to an extended borrowing binge, as described by Fazzari and Cynamon (2013). This undermines the stability of the system: when household debt skyrockets, a growing number of households default on their obligations. Non-performing loans affect banks' balance sheets and their willingness to lend. Hence, the credit bubble created by higher inequality and household debt collapses and the structural vulnerability of the economy emerges. Therefore, as highlighted by Galbraith (2012), the link between radical inequality and financial crisis runs precisely through private debt. However, "the problem with the trick of generating prosperity through inequality is simply that it cannot be continually repeated" (Galbraith, 2012).

From a policy perspective, our results seem to go in the direction of a redistributive policy in favour of the poorer segments of society, as a less unequal society seems to benefit from smoother and more stable oscillations of GDP, whereas a more unequal society suffers from dramatic booms and busts for the reasons explained above. In other words, our findings support the work carried out at the International Monetary Fund by Ostry et al. (2014) who find that lower inequality has a positive impact of growth both in terms of speed and stability.

Even though the current setting of our model proves useful in studying the dynamics described above, further improvements could be made in order to assess a broader set of issues. For example, similar to Delli Gatti et al. (2011, 2010), we could include heterogenous firms that can hire and fire workers, or access credit markets, based on their financial conditions. This would allow us to include bargain processes in wage setting mechanisms and to study unemployment dynamics in periods of expansion and recession.

Another possible extension is the inclusion of construction firms in the housing market so as to drop the assumption of a fixed stock of houses and number of homeowners. This might change house price dynamics and investment mechanisms by richer households.

Finally, another interesting aspect deals with the international dimension of the crisis. Indeed, by extending our model to a multi-country setting we could capture the dynamics of business cycles and external imbalances in the presence of rising income disparities. As a matter of fact, the higher inequality results in different economic patterns across countries: on the one hand, households in debt-led economies increase consumption by borrowing, thus leading to a borrowing binge or capital inflows; on the other hand, households in export-led countries lower their consumption thereby leading to excessive savings and depressed growth.

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