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

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Abstract

Our paper contributes to the literature on the causes of the 2007-2008 crisis. Following Stiglitz (2012) and Fitoussi and Saraceno (2010), we argue that the combination of growing inequality and lax monetary policy may have jeopardised the stability of the economic system, thus paving the way for the financial crisis. In particular, we build an Agent-Based Model in order to identify the effect of inequality on the likelihood of a crisis and the stability of the economic system under different policy responses. Our economy is populated by heterogeneous agents who interact with each other based on adaptive and imitative behaviours. The model includes a behavioural rule for consumption based on expenditure cascades and habit persistence, 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 faster than their income via home equity-based borrowing as described by Mian and Sufi (2009). Rising total debt service ratios lead to a higher number of bankrupt households and, consequently, to the emergence of a crisis as an endogenous dynamic.

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

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"The American economy became leveraged, in such a way that its performance as a whole came to depend on the possibility of a very small number of people becoming very rich in very limited lines of work. [...] In the 2000s, where growth was driven first by war and then for a few brief years by abusive mortgage lending, the saving grace is harder to see. The deeper issue with inequality of this type is surely instability. That which rises like a rocket above the plain also eventually falls back to earth. And the problem with the trick of generating prosperity through inequality is simply that it cannot be continually repeated" (Galbraith, 2012).

1 Introduction - Inequality and the Borrowing Binge

As pointed out by Kumhof and Rancière (2010), the income share of the top 5% increased from 22% in 1983 to 34% in 2007. 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). The CJEC (2010) reports even larger numbers: household debt as a share of household income skyrocketed from approximately 1 in 1975 to slightly more than 2 in 2007. Also Kumhof and Rancière (2010) stress that, between 1983 and 2007, the ratio of household debt to income jumped from roughly 80% to 139%. Based on these data, we can reasonably argue that 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; and the other one is about the mechanisms that allowed households to borrow with virtually no constraints.

The first point can be traced back to the dramatic rise in income inequality and it is discussed in section 2 of this paper. The second aspect, instead, is explained by house price dynamics which allowed households to

borrow against their equity (FCIC, 2011). This latter issue is analysed in section 3. In section 4 we introduce our agent-based model, whose main goal is to assess the impact of income inequality on debt dynamics and financial stability. Finally, in section 5, we discuss the results of different simulations. Section 6 concludes.

2 The Stiglitz-Fitoussi Hypothesis

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.

In our view, the problem of inequality has been ignored for so long because of the belief that people can make an efficient use of credit markets to insure against temporary fluctuations of income. For example, in 1996 the former Chairman of the Federal Reserve, Alan Greenspan, hold a speech in which he stressed that variations in asset holdings and debt buffer changes in income: in his view, this explains why the well-being of the lower-income segments of society had not worsened that much by looking at consumption from the late 1960s, even in the face of growing income disparities (1996).[1] The optimistic point of view of Greenspan suggests that credit markets worked efficiently by compensating for rising income inequality. Also Krueger and Perri (2006) claim consumers made stronger use of credit markets "exactly when they needed to (starting in the mid-1970s), in order to insulate consumption from bigger income fluctuations".

By looking at the recent financial disaster one may reasonably wonder whether this confident position is well grounded. Indeed, there is a growing consensus in the literature that financial and economic stability was jeopardised not only by the development of bizarre financial instruments, but also by a more structural real factor, namely income inequality which

[1] Greenspan's interpretation of the data stems from Friedman's Permanent Income Hypothesis (1957): consumption choices are largely determined by a change in permanent income rather than in temporary income and "even with a higher variability in the transitory component of income, consumption can be smoothed through lending and borrowing in the presence of efficient credit markets" (Van Treeck, 2012).

could, and in fact did, play a role in boosting the risk of a crisis. Stiglitz (2012) and Fitoussi (2013) put forward a theory linking inequality, aggregate demand, monetary policy and financial bubbles. They stress two main points: (1) rising inequality is the main source of the 2007-2008 financial crisis; and (2) rising inequality goes together with structural weaknesses of aggregate demand. The mechanism is straightforward: starting from an equilibrium position, with supply equal to demand, a transfer of income from low/middle-income households to rich ones, who have a lower propensity to consume, results in higher savings and therefore a lower aggregate demand, thus pushing the economy into a recession. This is where monetary authorities step in: they implement an expansionary policy (often accompanied by lax regulation) in order to stimulate the economy and sustain consumption for a while.[2] By lowering the interest rate, the central bank facilitates household access to credit markets thereby increasing the level of private debt.[3]

The above explanation fits the description of the events that took place in the United States before and during the 2007-2008 financial crisis. The expansionary monetary policy implemented by the Federal Reserve in the 2000s successfully pushed low and middle-income households to increase their private consumption faster than their disposable income by borrowing (Fitoussi and Saraceno, 2010). However, the other side of the story is that the incredibly small part of the American society who benefited from higher inequality needed to find a way to profitably use their newly accumulated savings: "a huge pool of available financial capital - the product of increased inequality - went in search of profitable opportunities in which to invest" (Milanovic, 2010). This 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

[2] One might wonder why the usual response to reduced aggregate demand is a monetary expansion and not a fiscal one. Stiglitz (2012) suggests that political reasons matter in this case:

> High inequality is often accompanied by a demand for a smaller government and more fiscal restraint. (...) Policies are often affected by lobbying, campaign contributions, and revolving doors, so that the wealthy have disproportionate influence. Thus, as inequality grows, at least in many countries, so too do constraints on the governments fiscal space.

[3] Following the same line, Rajan (2010) emphasises in particular the role of government failure by claiming that "the political response to rising inequality - whether carefully planned or an unpremeditated reaction to constituent demands - was to expand lending to households, especially low-income ones", so as to end up with rising household debt

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).

Hence, even though the crisis emerged in the financial sector, "its roots are much deeper and lie in a structural change in income distribution that had been going on for twenty-five years" (Fitoussi and Saraceno, 2010).

3 Household Debt and Equity Extraction

In this section we focus on the main mechanisms that allowed american households to increase their debt up to sky-rocketing levels. To this purpose, we trace the link between rising income inequality, easier access to credit markets and house price dynamics that allow for equity extraction processes.

First of all, the empirical literature on consumption behaviour has found evidence supporting upward-looking comparisons (Bertrand and Morse, 2013; Frank et al., 2014; Perugini et al., 2013): households tend to compare their level of consumption (a proxy for living standards) with richer households "in the same neighbourhood". In addition, households also compare their level of consumption with their behaviour in the past. For example, Drechsel-Grau and Schmid (2013) find that consumption decisions of U.S. households are also driven by consumption habits.

Given this social phenomena, increasing inequality puts stronger pressure on low and middle income households as their income does not rise as much as that of richer households or as much as needed to keep consumption expenditure in line with the past. As a result, low and middle income households are forced to cut their savings and, eventually, to find external financial resources: they access the credit market to borrow. This is made easier because, following the Stiglitz-Fitoussi hypothesis, monetary authorities lower interest rates in order to avoid the negative impact that an increasingly unequal distribution of income would have on aggregate demand. However, lower interest rates in a deregulated environment, combined with a "greedy research" for high-return investment by richer households, leads to the emergence of market bubbles. In particular, this is created via 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, supply mortgages not only to trustworthy new home buyers but also

to risky ones, namely subprime borrowers. This results in growing demand for houses and therefore higher house prices. Indeed, 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), because higher house prices imply a greater value of home equity. Mian and Sufi (2009) refer to this as home equity-based borrowing (HEBB). HEBB allowed U.S. homeowners to increase their debt.[4] As a matter of fact, since "credit standards and the cost of external finance are determined by considering the value of households collateral, which is influenced by housing prices" (Arestis and Gonzalez, 2013), as these rise, homeowners with greater equity feel more financially secure and, partly as a result, save less and less. Many others go one step further, borrowing against their equity. The effect is unprecedented debt (FCIC, 2011).

4 The Model

For the purpose of our work, we build an agent-based model where the economy is modelled as a complex evolving system: it is 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 the likelihood of a crisis and the stability of the economic system as a whole. In particular, we introduce some key features that allow the model to capture the dynamics described by the Stiglitz-Fitoussi Hypothesis and the home equity-based borrowing mechanism. Such key features are:

- The introduction of a consumption behaviour based on both expenditure cascades and internal habit formation, that captures the economic and social pressure of inequality on low and middle income households;

[4] 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.

- 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 implicit mechanisms for a representative firm, a government and a central bank that are not explicitly modelled. 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.
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[5] (TDS). Since houses serve as collateral, the amount of credit households can get depends

[5]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.

on the value of their equity. In addition 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 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 based on the average market price in the previous period, 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.

4.1 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 income dispersion by higher precautionary savings, like in Germany, but by borrowing more (Van Treeck, 2012). In fact, inertia in consumption habits as well as the need to "keep up with the Joneses" might provide a suitable explanation for the drop in the savings of American households. For this reason, households in the model set desired consumption ($C^d_{t,h}$) based on a combination of habit persistence and upward looking comparison. The former follows the literature on internal habit formation and their impact on macroeconomic dynamics (see Boldrin et al., 1999 and Carroll et al., 200, among others); the latter is in line with the "expenditure cascades" hypothesis introduced by Frank et al. (2010), which is "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".[6] According to Frank et al. (2010), the expenditure cascades hypothesis is essential in explaining why the "pervasive pattern of growing income inequality in the United States has led to the observed decline in savings rates".

Hence, each household h sets her desired consumption following this algorithm:

$$\textit{if} \quad C_{t-1,j} \geq C_{t-1,h} \quad \textit{then} \quad C^d_{t,h} = a_1 * C_{t-1,j} \quad \textit{else} \quad C^d_{t,h} = a_2 * C_{t-1,h} \quad (1)$$

That is, if j (i.e. the household who ranks just above h in the income scale, so that $j = h + 1$) consumed more than h at time $t - 1$, than h tries to mimic j's consumption based on the sensitivity parameter $a_1 > 0$. Otherwise, h replicates her own consumption in the previous period multiplied by a different sensitivity parameter $a_2 > 0$.

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 $Y_{t,h}$, a portion

[6] Our approach differs from the work by Frank et al. (2010) in that (1) we do not include permanent income in the equation for desired consumption and (2) we refer to household ranking in terms of temporary income rather than permanent one.

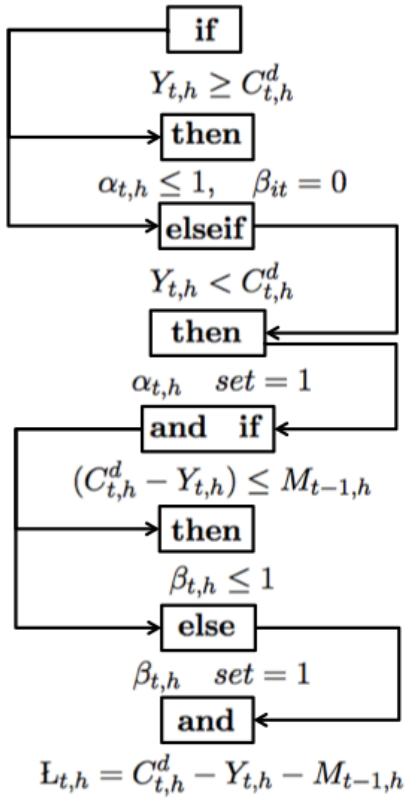

Figure 1: Hierarchical structure of household finance.

$0 \leq \beta_{t,h} \leq 1$ of liquid wealth $M_{t,h-1}$ and, eventually, consumption loans $(L_{t,h})$:

$$\alpha_{t,h} Y_{t,h} + \beta_{t,h} M_{t-1,h} + L_{t,h} \tag{2}$$

More specifically, h adjusts her propensity to consume out of income so that $\alpha_{t,h} = C^d_{t,h}/Y_{t,h}$. 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[7]. If $(C^d_{t,h} - Y_{t,h}) \leq M_{t,h}$, $\beta_{t,h} \leq 1$ 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. Notice that loans are collateralised by houses, so that only homeowners can enter the credit market.

4.2 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:

$$L^d_{t,h} = C^d_{t,h} - (Y_{t,h} + M_{t-1,h}) \tag{3}$$

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 $E_{t,b}$, that is:

$$LS_{t,b} = \frac{E_{t,b}}{v} \tag{4}$$

Notice that v can be interpreted as a capital requirement coefficient.

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).

We assume 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, $RW_{t,h}$[8], the balance owed on the existing mortgage, $ZR_{t,h}$, and the interest rate on consumption loans, $r^L_{t,b,h}$:

$$LSH_{t,b,h} = \frac{\gamma RW_{t,h} - ZR_{t,h}}{1 + r^L_{t,b,h}} \tag{5}$$

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

[8]Real wealth is defined formally in section 4.3.

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:

$$r^L_{t,b,h} = \overline{r} + \widehat{r_{b,t}} + r_{t,h} \tag{6}$$

$\overline{r}$ is an exogenous component representing the policy rate decided by the central bank: we use it in order to simulate monetary policy shocks. $\widehat{r_{t,b}}$ 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.

Each household searches for the bank applying the lowest interest rate.[9] Once found, if $LSH_{t,b,h} \geq L^d_{t,h}$, household h accepts the offer, enters the credit network of bank b and gets $LOAN_{t,h} = L^d_{t,h}$. 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. Households who do not accept the offer, get no loans at all.

Notice that 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.

4.3 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 $t = 1$.[10] 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.

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

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

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.

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.[11] 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 assess whether this is experiencing excess supply or excess demand using the number of unsold houses as a proxy. As shown in conditions 7 and 8, all sellers set their price, $PS_{t,h}$, based on the average market price in the previous period, $\overline{P^H_{t-1}}$, plus a markdown, $-\xi_{t,h}$, if there are unsold houses, or a markup, $+\xi_{t,h}$, if all houses were sold in the previous period.[12]

$$PS_{t,h} = \begin{cases} \overline{P^H_{t-1}}(1 - \xi_{t,h}) & \text{if } unsold > 0 \quad (7) \\ \overline{P^H_{t-1}}(1 + \xi_{t,h}) & \text{if } unsold = 0 \quad (8) \end{cases}$$

In every period, all households who do not own a house enter the housing market placing themselves on the demand side.[13] All buyers set a desired price, $PB_{t,h}$, as a multiple $\theta > 0$ of their liquid wealth (condition 9). If they have no liquid wealth, they will apply a mark-up to the average market price in the previous period (condition 10).

$$PB_{t,h} = \begin{cases} \theta M_{t-1,h} & \text{if } M_{t-1,h} > 0 \quad (9) \\ \overline{P^H_{t-1}}(1 + \xi_{t,h}) & \text{if } M_{t-1,h} = 0 \quad (10) \end{cases}$$

[11] 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.

[12] Again, this is similar to Erlingsson et al. (2013): in their model, sellers set their price "based on the last market round average transaction price" plus a random draw from a uniform distribution.

[13] 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:

$$Z^d_{t,h} = PS_{t,h} - M_{t-1,h} \tag{11}$$

Notice that 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.

$$ZSH_{t,b,h} = \frac{\gamma RW_{t,h}}{1 + r^z_{t,b,h}} \tag{12}$$

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

$$r^z_{t,b,h} = \overline{r} + \widehat{r_{b,t}} + r_{t,h} \tag{13}$$

Each household searches for the banks whose individual supply is higher than her demand. Then, as shown in condition 14, h selects the bank offering the lowest interest rate.[14]

$$\forall\, b \quad s.t. \quad ZSH_{t,b,h} \geq Z^d_{t,h}\,, \quad find \quad min(r^z_{t,b,h}) \tag{14}$$

If h finds a bank b satisfying condition 14, 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 repayment schedule, $RS^Z_{t,h}$, with a constant fraction of principal and an amount of interest payment calculated on the residual amount of principal to be paid.

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.

After all transactions take place, a new average market price is calculated as the mean of all selling prices. Existing homeowners who did not enter the housing market at its opening, update the value of their equity based on the new average market price. This updating mechanism allows to capture the impact that housing price dynamics have on existing homeowners' and their home equity based borrowing behaviour.

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 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:

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

$$Debt_{t,h} = Debt_{t-1,h} + LOAN_{t,h} + Z_{t,h} \tag{15}$$

$$TDS_{t,h} = \frac{RS^Z_{t,h} + RS^L_{t-1,h}}{Y_{t,h}} \tag{16}$$

4.4 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 $RS^Z_{t,h} + RS^L_{t-1,h} \leq Y_{t,h} + M_{t-1,h}$. If this condition is satisfied, household h pays $RS^Z_{t,h}$ 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.

Each bank b earns profits equal to the sum of the interest payment of all the household in its credit network, CN, that is:

$$INT_{t,b} = \sum_{h \in CN} (r^L_{t,b,h} LOAN_{t-1,h} + r^Z_{t,b,h} ZR_{t,h}) \tag{17}$$

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 $\sum_{ii=t^*}^{T_z} RS^Z_{ii,h} + RS^L_{t^*,h} \leq Liq_{t,h}$, their debt goes down to zero and they are not labelled as bankrupt anymore.[15] In addition, they will keep the excess liquidity thus increasing their liquid wealth. On the contrary, if $\sum_{ii=t^*}^{T_z} RS^Z_{ii,h} + RS^L_{t^*,h} > Liq_{t,h}$, households give priority to the payment of the residual principal (i.e. $LOAN_{t^*,h} + ZR_{t^*,h}$) and use the residual liquidity for a part of the due interest payment. Also in this case their debt falls to zero, but the bank will record lower profits than expected.

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

Finally, in the extreme case in which h's liquidity is lower than the principal to be paid back, h pays a lower amount than due. In this case, banks earn zero profit as they get no interest payment. Moreover, if h belongs to the credit network of two banks at the same time[16], she splits the liquidity in two parts depending on the composition of h's debt: 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. In addition, the non-performing loan results in bad debt on the banks balance sheets:

$$bd_{t,h,b} = \begin{cases} LOAN_{t^*,h} - \delta^L_{t,h} Liq_{t,h} \quad where \quad \delta^L_{t,h} = \dfrac{LOAN_{t^*,h}}{LOAN_{t^*,h} + ZR_{t^*,h}} & (18) \\ ZR_{t^*,h} - \delta^Z_{t,h} Liq_{t,h} \quad where \quad \delta^Z_{t,h} R = \dfrac{Z_{t^*,h}}{LOAN_{t^*,h} + ZR_{t^*,h}} & (19) \end{cases}$$

The overall amount of bad debt, $BD_{t,b}$, for each bank b is calculated as follows:

$$BD_{t,b} = \sum_{h \in HB} bd_{t,h,b} \tag{20}$$

Where $HB \subset CN$ 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:

$$E_{t,b} = E_{t-1,b} + INT_{t,b} - BD_{t,b} \tag{21}$$

4.5 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

[16]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.

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:

$$M_{t,h} = M_{t-1,h} + D_{t,h} + Liq_{t,h} \tag{22}$$

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

$$A_{t,h} = M_{t,h} + RW_{t,h} - ZR_{t,h} \tag{23}$$

5 Scenarios and Policy Simulations

In order to run simulations we calibrate model parameters as shown in table 1. Strictly economic parameters are based on the literature and empirical evidence, whereas sensitivity and behavioural parameters are based on the need to rule out explosive dynamics and unrealistic patterns.

Parameter		Value
T	Number of periods	500
H	Number of households	200
B	Number of banks	10
HO	Number of homeowners	130
a_1	Sensitivity parameter to j's past consumption	0.9
a_2	Sensitivity parameter to h's own past consumption	1.05
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
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

The choice of assigning a house to 130 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. Finally, 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).

Notice that in all cases we drop the first 100 periods in order to get rid of transients.[17]

For the purpose of simulations, we build three different scenarios with the same unequal income shares for the top 10% and bottom 90%, with values respectively equal to 38.11% and 61.9%. These are retrieved from the World Top Income Database (Facundo et al., 2014) with reference to the United States.

More specifically, the scenarios are as follows:

1. Baseline (BA) scenario: the model starts with constantly unequal income shares and keeps running until the end in period 400.

2. Rising inequality (RI) scenario: after 200 periods of stable income inequality, we shock income shares three times, every 40 periods. The central bank does not react to widening income disparities thus leaving the interest rate to its initial level of 3%.

3. Stiglitz-Fitoussi (SF) scenario: the simulation follows the RI scenario. However, monetary authorities step in as soon as income inequality starts rising thereby lowering the interest rate from 3% to 2% from period 200 to period 220.

The values of the income shares for the RI and SF scenarios are reported in Table 2.

5.1 Simulation Results

As shown in Figure 2 GDP oscillates along an increasing trend in both BA and CI. However, after period 200, differences show up in the dynamics of GDP in the two scenarios. In fact, as soon as inequality rises in RI, GDP

[17]The description of simulation scenarios and results refers to period 100 as time zero.

Period	Income share of the top 10%	Income share of the bottom 90%
$t = 300$	38.84%	61.16%
$t = 340$	43.11%	56.89%
$t = 380$	46.35%	53.65%

Table 2: Income shares

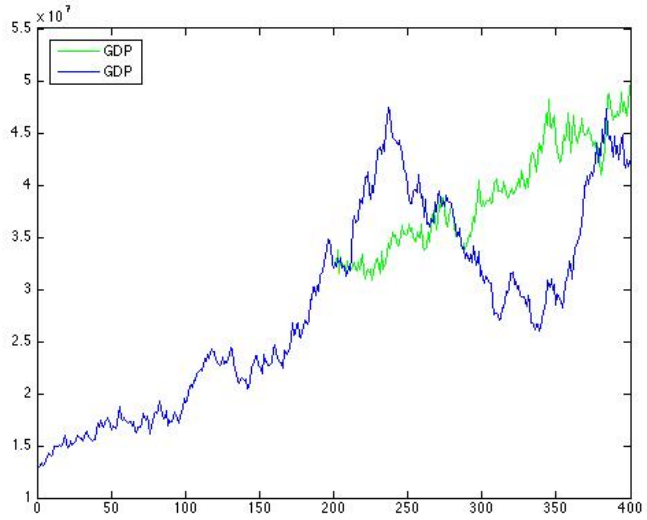

Figure 2: GDP in scenarios BA (green) and RI (blue).

jumps upwards in the short run, thereby falling due to the continuous rise in income disparities (Figure 3). By looking at the evolution of household debt and, therefore, at the average price of houses, we can have better insights.

The rise of income inequality should imply a reduction in aggregate demand and, therefore, GDP. Yet, in BA, the transfer of income to the top 10% results in higher house prices in the short run (Figure 4). Indeed, right after period 200, $\overline{P_t^H}$ skyrockets, rising from approximately $2 * 10^5$ to almost $4 * 10^5$. As such, low and middle income households can borrow more using the increased value of their home equity. In other words, debt-financed consumption pushes GDP upwards as household debt goes from roughly $1 * 10^7$ to almost $2.5 * 10^7$ (Figure 5). However, the institutional setting does not change since the central bank does not react to higher inequality. With constant policy interest rates, credit conditions are not relaxed so

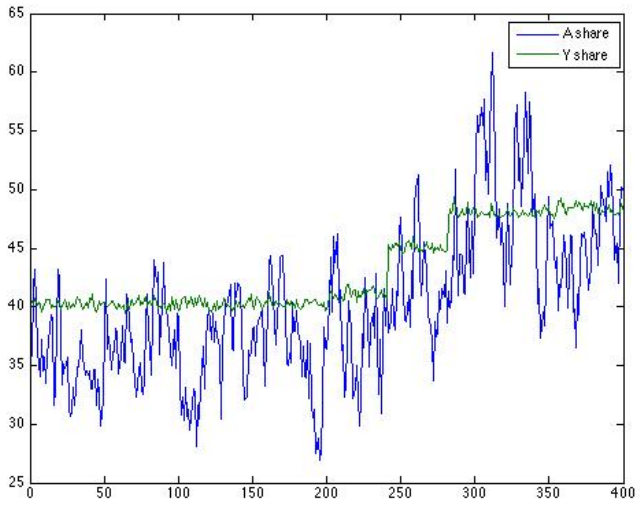

Figure 3: Income (green) and Wealth (blue) shares in scenarios RI.

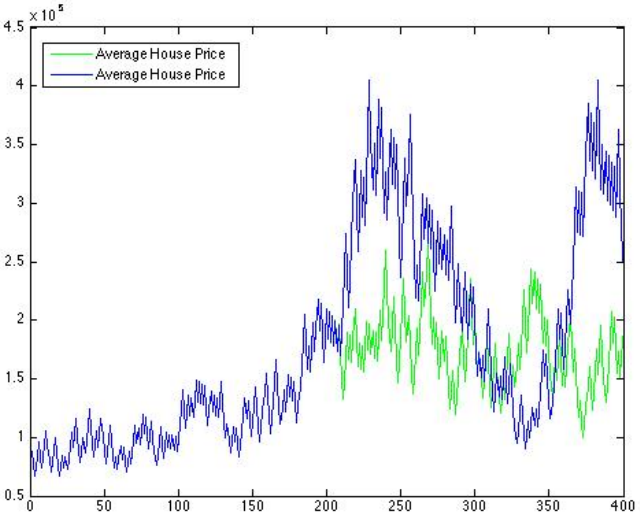

Figure 4: Average house price in scenarios BA (green) and RI (blue).

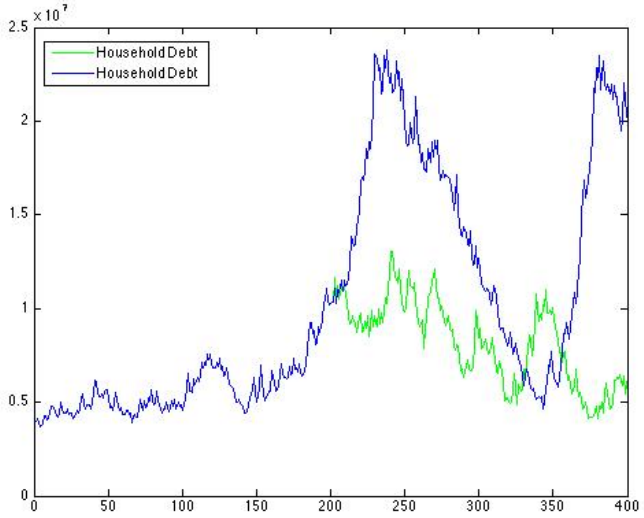

Figure 5: Household debt in scenarios BA (green) and RI (blue).

that a number of households leave the credit market without getting any consumption loans. As the income share of the top 1% reaches its peak of 46.35%, low and middle income homeowenrs lack the internal resources to finance desired consumption and the decline of aggregate demand prevails thus reversing the trend in GDP: the economy enters a recession. Notice also that the economy gets back on a growing path only after inequality stabilises. That is to say that changes in income disparities seem to matter more than the level of inequality itself for the overall dynamics of our artificial economy.

Let us analyse the results of the SF scenario.

As shown in the RI simulation, rising inequality eventually leads to a recession as a result of lower expenditure from the bottom 90% of the population. In order to avoid such outcome, monetary authorities step in as soon as income inequality starts growing. Compared to the RI scenario, indeed, we simulate a shock in the interest rate which falls from 3% to 2% for a limited number of period and we interpret this as a policy measure by the central bank. The effect of a lower interest rate is to increase the amount of credit that banks are willing to supply to each individual household. Therefore, the number of households who find a bank that satisfies their credit needs rises. In other words, as a result of higher inequality and relaxed financial constraints a credit boom takes place.

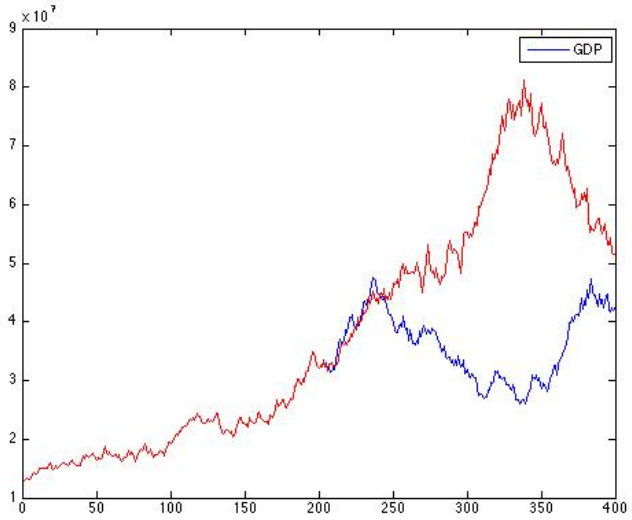

Figure 6: GDP in scenarios SF (red) and RI (blue).

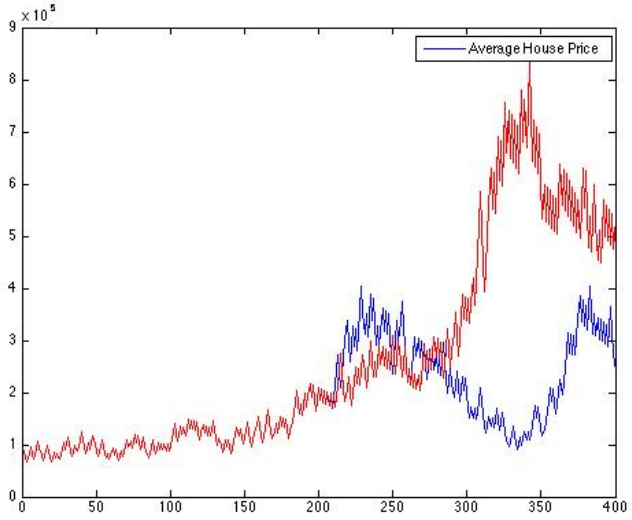

Figure 7: Average house price in scenarios SF (red) and RI (blue).

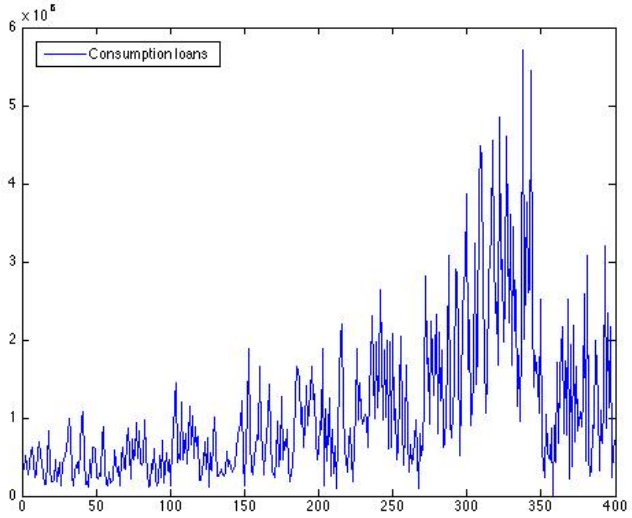

Figure 8: Consumption loans in SF scenario.

Figure 6 shows the dramatic rise in GDP following the reduction in the policy interest rate starting from period 200. As the interest goes down, house prices grow (Figure 7) mostly due to the higher availability of mortgage credit. This has a feedback effect on existing home-owners who enter the credit market to get consumption loans exploiting the higher value of their home equity. Indeed, as shown in Figure 8, the amount of consumption credit records a sharp increase right after credit constraints are relaxed. However, after a number of periods, the increasing amount of household debt (Figure 9) and the wider income disparities result in a higher peak of the average total debt service ratio. This has two major consequences for the stability of the system: (1) a higher number of households now lack the internal resources to pay back their debt and (2) banks increase the interest rate on both mortgages and consumption loans. As an implication, part of the population starts defaulting on debt obligations (Figure 10) and house prices collapse as lower mortgage credit lead to a higher number of unsold houses. The endogenous dynamics stemming from agents' interactions move the economy from a credit-financed expansion to a recession.

Notice that the policy intervention is limited in time because we assume the central bank is concerned with the stability of the system and as soon as household debt rises above a certain threshold, it decides to reverse its

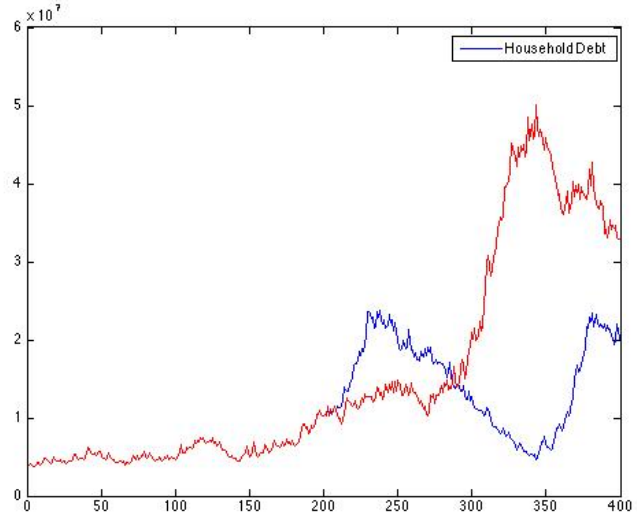

Figure 9: Household debt in scenarios SF (red) and RI (blue).

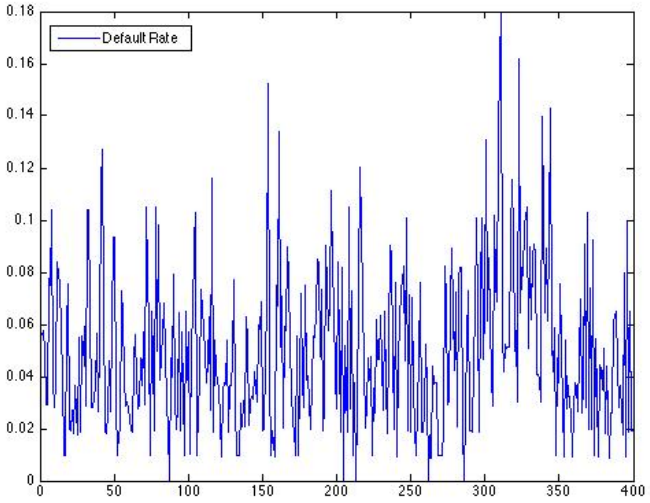

Figure 10: Household default rate in SF scenario.

policy in order to limit credit expansion. However, results show that the credit boom and GDP growth persist well after the interest rate gets back to its initial level. This is due to house price dynamics and income disparities. In fact, the interest rate gets back to 3% in period 221, whereas income inequality rises until period 280 when the top income share stabilises at 46,35%. Such transfer of income from the bottom to the top results in higher house prices as richer households use their newly accumulated amount of resources to buy houses. This pushes house prices, as well as existing (low and middle income) home-owners' equity, upward. Such dynamics suggests that income inequality works also as a propagation mechanism until the debt burden is too high and households in financial distress start defaulting.

6 Concluding Remarks

Our work is an attempt to contribute to the growing literature on inequality and financial instability. By means of an agent-based model we create an artificial economy with heterogenous agents whose mutual interactions result in 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 market, 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 need. This captures the pressure of inequality on the lower segments of society. On the other hand, lower interest rates and higher house prices allow for relaxed collateral constraints and, therefore, higher credit availability.

The combination of these 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, the higher values of TDS and interest rates lead to a growing number of households defaulting on their debt obligations. Hence, the credit bubble explodes and the structural vulnerability of the economy emerges.

Put it simply, the story our model captures is that "the problem with the trick of generating prosperity through inequality is simply that it cannot be continually repeated" (Galbraith, 2012).

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