Journal of Economic Behavior and Organization 000 (2018) 1–25

Contents lists available at ScienceDirect

Journal of Economic Behavior and Organization

journal homepage: www.elsevier.com/locate/jebo

Inequality, household debt and financial instability: An agent-based perspective

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ARTICLE INFO

Article history:
Received 22 January 2016
Revised 19 September 2017
Accepted 14 January 2018
Available online xxx

JEL classification:
C63
D31
E21
G01

Keywords:
Agent-based models
Inequality
Equity extraction
Household debt
Financial crises

ABSTRACT

Our paper contributes to the literature on the causes of the 2007–2008 financial crisis in the United States. By means of an agent-based model, we replicate an artificial credit-network economy in order to assess the impact of growing income inequality in the presence of peer effects and home equity borrowing. We show that the resulting debt-financed consumption boom jeopardises the stability of the economic system, thus paving the way for a financial crisis. 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 extraction. Rising non-performing loans lead to higher bad debt on the banks' balance sheets and, consequently, to the emergence of a crisis as an endogenous dynamic.

1. Introduction

In the period between 1983 and 2007, the income share of the top 5% in the U.S. increased from 22% to 34% (Kumhof and Rancière, 2010). Moreover, the top 1% of the population 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 (Cardaci and Saraceno, 2016). One would expect the transfer of income from the bottom to the top to reduce overall consumer demand - thus leading to unemployment and stagnation - since the richest part of the population is assumed to have a lower propensity to consume (Kaldor, 1956). 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: 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 disposable 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 growth over much of the income distribution. The answer is that American households at the bottom 95% of the distribution went on an extended borrowing binge, which allowed their spending share to rise (Fazzari and Cynamon, 2013). Indeed, household

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https://doi.org/10.1016/j.jebo.2018.01.010

debt increased from 48% of GDP in the early 1980s to 100% of GDP before the crisis (Milanovic, 2010). In particular, debt to income has increased more sharply in lower income groups: “the debt-to-income ratio for the bottom 50% increased from 61% (1989) to 137% (2007); for the next 40 percentiles it increased from 81% to 148%; whilst the debt-to-income ratios also increased for the top 10% of the income distribution, the dynamic was much weaker” (Stockhammer, 2015, p. 14).

In the light of these empirical facts, we follow the 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, 2012; Fitoussi, 2013; Fitoussi and Saraceno, 2011; Stiglitz, 2012; 2013; Stockhammer, 2015; van Treeck, 2014). In particular, we propose a narrative that traces the emergence of the recent financial crisis back to the dramatic rise in income disparities in a context of peer effects in consumption and home equity extraction driven by house price appreciation, thereby combining two aspects that have traditionally been analysed separately. Indeed, our view is that increasing inequality - which, for the purpose of our analysis, is taken as exogenous[1] - caused higher desired for consumption spending by poorer households who tried to keep up with the norms set by those who benefit from rising inequality (Cynamon and Fazzari, 2014). Such behaviour triggered a process of expenditure cascades that resulted in a massive accumulation of household debt via home equity borrowing. This indeed sustained consumption and the performance of the American economy only for a limited period of time, leading to the observed drop in the propensity to save (Zezza, 2008). In fact, rising inequality and household debt increased the fragility of the economy, thereby paving the way for the financial collapse.

In order to validate our narrative, we study the interaction of inequality, peer effects and home equity extraction, by building a macroeconomic agent-based model (ABM) with imitation in consumption, collateralised loans and mortgages and, therefore, a simple housing market. The model describes a credit-network economy with heterogeneous households and banks whose mutual interactions lead to the emergence of complex relationships similar to those that characterise a modern economic system. The goal of our macro ABM it to show that a shock to the distribution of income that increases inequality in the presence of house price appreciation and peer effects among households, accentuates the upward-looking pressure on consumption norms thus triggering a debt-financed consumption boom. Eventually, a financial crisis occurs as a consequence of households' default and the resulting accumulation of non-performing loans on the balance sheets of the banks. Hence, we analyse the evolution of the credit network, focusing on the changes in the degree centrality of the bank nodes in order to assess their exposure to the default risk of borrowers. The network analysis identifies the central role of households in financial distress in driving model dynamics towards the crisis via a sequence of default cascades. Finally, we perform a sensitivity analysis in order to shed some light on the key parameters affecting model dynamics. This allows to draw some policy implications about the role of banks' lending behaviour, macroprudential and monetary policies.

The paper is organised as follows: the rest of this first section provides the main theoretical roots of the narrative that we propose; eventually we also identify some recent macroeconomic models investigating the consequences of rising inequality and financialisation, in order to highlight the main similarities and differences with our macro ABM. In Section 2 we introduce our model, while Section 3 reports simulation results. Finally, Section 4 concludes.

1.1. Inequality, peer effects and house price appreciation

Our narrative combines findings from behavioural economics, finance and macroeconomics – which have typically been analysed separately – in order to provide an interpretation of the events preceding the 2007–2008 financial crisis in the United States.

First of all, one should wonder why American households at the bottom of the distribution did not react to falling incomes and rising inequality by higher precautionary savings but rather by demanding more loans. In line with Cynamon and Fazzari (2012), we believe that the literature on social psychology and behavioural economics – dating back to the contributions by Veblen (1899), Duesenberry (1949) and, more recently, by Frank (1997) and Schor (1998) – may provide useful insights on this matter. In fact, households learn consumption patterns from their social reference group and, as such, they tend to compare their living standard, proxied by the level of consumption, with that of their neighbours or richer households. That is, there exist dynamic social processes that shape consumption behaviour among American households in ways that encouraged consumers to spend a greater share of income in the period before the crisis (Cynamon and Fazzari, 2012). In particular, according to Frank et al. (2014), growing income disparities led to the observed decline in the savings rates of American households through *expenditure cascades*: “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” (Frank et al., 2014, p. 57). In fact, given the presence of imitation and peer effects, the rise in income inequality triggered stronger expenditure cascades that resulted in higher desired consumption and greater demand for loans by poorer households.

The need for external finance emerged in a context of rising house prices and lax financial regulation, which allowed low and middle-income households to increase their private consumption faster than their disposable income by borrowing

[1] The introduction of endogenous inequality would certainly enrich the structure of the model. However, at this stage, we are not interested in the determinants of inequality. Rather, we focus on the consequences of changes in income distribution for household debt dynamics and consumption. The exogenous distribution serves this purpose while lowering the degree of complexity of the model.

(Fitoussi and Saraceno, 2011). Indeed, we believe that the ongoing process of financial liberalisation, as well as the expansionary policy implemented by the Federal Reserve in the 2000s, contributed to strong house price appreciation “fueled by the availability of mortgage credit to a riskier set of new home buyers” (Mian and Sufi, 2011, p. 2132). 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, who had traditionally been left out. This resulted in growing demand for houses and therefore higher house prices (Financial Crisis Inquiry Commission, 2011). House price dynamics have “an important feedback effect on household leverage through existing homeowners” (Mian and Sufi, 2011, p. 2132), as an appreciation implies a greater value of home equity that can be extracted for consumption purposes. Mian and Sufi (2011) refer to this as home equity-based borrowing (HEBB), claiming that it allowed U.S. homeowners to increase their debt.[2] 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, p. 4), 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 (Financial Crisis Inquiry Commission, 2011). As highlighted by Fitoussi and Saraceno (2010), higher house prices gave the false impression that high levels of debt were sustainable. Ultimately, 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, p. 4).

1.2. Related macroeconomic models

In the period before (and during) the recent U.S. financial crisis, there were very few studies of the link between inequality and financial instability (Atkinson and Morelli, 2011; Galbraith, 2012). Only in the aftermath of the crisis, economists have started to investigate the macroeconomic consequences of rising income disparities. Some have focused on the interaction between inequality and financialisation. For example, Onaran et al. (2011) extend the standard Kaleckian–Steindlian approach by incorporating the effects of financialisation on aggregate demand in order to estimate the effects of changes in income distribution. Their analysis suggests that greater inequality led to the reliance on debt-led consumption fuelled by the housing bubble which increased the fragility of the U.S. economy. In a three-country Stock-Flow Consistent (SFC) model, Belabed et al. (2013) find that the interplay of rising (top-end) household income inequality and institutions explain the major increase in household debt in the United States in the years preceding the recent crisis. Another contribution that goes in the same direction is the paper by Kumhof et al. (2015) who build a dynamic stochastic general equilibrium (DSGE) model showing how greater inequality results in asset price appreciation that eventually leads to the emergence of a financial bubble. Yet, the representative agent framework, a peculiarity of DSGE models, does not allow to capture either heterogeneity among agents or the existence of emerging credit networks. In addition, the model does not include a proper financial/banking sector, as all the borrowing-lending transactions occur between rich (lenders) and poor (borrowers) households. As a consequence, it is impossible to take into account the impact of household defaults on the balance sheets of the banking system and the possible resulting credit crunch.

The literature on macroeconomic ABM has dealt with the role of the credit market and financial stability (e.g. Dawid and van der Hoog, 2015; Delli Gatti et al., 2011), trying to overcome the limitations of DSGE models. In particular, recent contributions have analysed the role of inequality, private debt accumulation or house price dynamics, even though changes in income distribution, peer effects and home equity extraction – when taken into account – have been analysed separately. The work by Russo et al. (2016), for example, focuses on the role of increasing inequality with consumer credit but does not include imitation in consumption or collateralised loans. The authors find that consumer credit boosts aggregate demand for a short period of time, thus increasing the tendency of the economic system towards a crisis, due to the decline of the firmsâ profit rate. Dosi et al. (2013) study the link between income inequality and monetary/fiscal policies in an agent-based model, which features Keynesian mechanisms of demand generation, a Schumpeterian innovation-fuelled process of growth with Minskian credit dynamics. They find that societies that are more unequal suffer from more severe business cycles oscillations and higher unemployment rates, thus increasing the likelihood of economic crises. Notice, however, that peer effects, household debt accumulation, as well as house price dynamics, are not part of the analysis. Finally, Erlingsson et al. (2014) models an agent-based economy with no imitation and inequality, but with housing market bubbles and financial crises that emerge endogenously as a result of easier access to credit.

There is a clear common approach between such works and ours, in modelling the economy as a credit network in which agents, either firms or households, have access to bank loans. However, our contribution combines some elements analysed independently, or typically ignored, in the macro ABM literature. The distinctive feature of our work is the introduction of the expenditure cascades that capture the upward-looking imitation and peer effects in household consumption, in line with the narrative provided above. This is an element of novelty, which none of the contributions mentioned here has. Additionally, our model includes an articulated credit market where households interact with heterogeneous banks in order

[2] 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, 2011). This stresses the importance of the HEBB channel.

Please cite this article as: A. Cardaci, Inequality, household debt and financial instability: An agent-based perspective, Journal of Economic Behavior and Organization (2018), https://doi.org/10.1016/j.jebo.2018.01.010

to apply for both consumption loans and mortgages. As such, similar to Erlingsson et al. (2014), we introduce also a housing market that allows for the endogenous dynamics of house prices (a feature that is present neither in Dosi et al., 2013, nor in Russo et al., 2016). This is a relevant element of our work since consumption loans and mortgages are collateralised so that asset price formation is a key mechanism for the functioning of the credit market.

2. The model

In order to capture the link among inequality, household debt accumulation and financial instability, we build a macroeconomic agent-based model where the economy is represented 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 behaviour thus giving rise to stable and predictable aggregate configurations at the macro level, in line with traditional macro ABM (Delli Gatti et al., 2011; Tesfatsion, 2005).

The choice of adopting the agent-based approach allows to overcome the major drawbacks of the standard New-Keynesian DSGE models and aggregate models in general. In particular, the introduction of heterogeneous households and banks makes it possible to represent the economy as an evolving credit network. This gives us the opportunity to trace changes in macro dynamics back to modifications in the structure of the network, by studying the role of bank hubs, as well as that of borrowers in financial distress.

Our model has some key features that allow to capture the dynamics described in the previous section of this paper, such as:

- The introduction of a consumption behaviour based on peer effects 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 via upward-looking comparisons;
- 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 endogenous price dynamics and equity extraction by households.

The model features an exogenous distribution of income, based on individual income shares that are constant over time. Additionally, even though our focus is mostly on heterogeneous households ($h = 1, \dots, H$) and banks ($b = 1, \dots, B$), the model also includes an aggregate productive sector and an extremely simplified public sector with a central bank and a government. Our economy is free of supply constraints in the goods market, that is we assume that the aggregate productive sector always satisfies demand: it supplies the required amount of goods and, as such, no rationing takes place in the goods market.[3]

The model has a sequential structure so that the following events take place within each period t:

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 (PBP) begins. Each household tries to pay back her debt by using her income and liquid wealth. Some households may not able to do so: they are in financial distress and they will try to sell their house and use the resulting liquid assets to pay back their outstanding debt. Banks use earned interests to increase the value of their net worth.
3. All households set their desired consumption based on imitative behaviour. Households whose desired consumption is higher than the available own resources apply for a loan, provided that they own a house and have previously paid back their debt.
4. The credit market for consumption loans opens. Banks set their total available credit supply as a multiple of their equity and rank households in ascending order based on their Total Debt Service Ratio (TDS).[4] Since houses serve as collateral, house prices determine the amount of credit that households can actually borrow.
5. The housing market opens. The supply side features all borrowers in financial distress who are forced to sell their house in order to pay back their debt, whereas demand comes from all households who do not own a house. After setting their reservation prices, buyers select sellers based on a simple search-and-match mechanism. Buyers with enough liquid wealth can buy a house directly, whereas those who lack the internal resources to pay for the entire amount, enter the credit market for mortgages.
6. The credit market for mortgages opens. Individual demand for mortgages depends on the difference between the selling price and the liquid wealth of the buyer that serves as a down payment. Individual mortgage supply is based on the value of the house to be provided as collateral. After the mortgage market closes, households who get the needed amount of credit get back to the selected seller and buy the house. Credit-rationed households, instead, will drop the deal with the corresponding seller and search for another house in the following period.

[3] One can imagine that the productive sector is able to produce goods based on actual orders, so that the goods market is always in equilibrium. This strong assumption allows us to simplify a consistent part of the model as it does not represent the focus of our paper.

[4] TDS is defined as the ratio between household repayment schedule (the sum of consumption loan and mortgage principal plus interests) and household disposable income.

7. All banks update their financial conditions. Borrowers in financial distress who have managed to sell their house use the resulting liquid assets to pay back their outstanding debt. Due to changes in house prices, each household's liquid assets may be lower than the amount to be paid: 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.

2.1. Expenditure cascades and desired consumption

Households are divided in two income groups: the top 10% and the bottom 90%.[5] In every period t, each group is assigned a share ($share_y$) of the income generated at the end of the previous period (GDP_{t-1}), which corresponds to the revenues of the productive sector. Households within each of the two groups also have constant individual income shares ($share_h$).[6] Therefore, household income is defined as $Y_{t,h} = GDP_{t-1} \cdot share_y \cdot share_h$. Finally, disposable income is $Y^d_{t,h} = Y_{t,h} - RS^L_{t,h} - ZP_{t,b,h}$, where $RS^L_{t,h}$ and $ZP_{t,\,b,\,h}$ correspond to the debt repayment on consumption loans and mortgages respectively, which are defined in Sections 2.2 and 2.3.

Eq. (1) introduces the formulation of desired consumption in our model, which follows the expenditure cascades hypothesis introduced by Frank et al. (2014). As already pointed out, this allows to capture the presence of imitation and peer effects in consumption and the need for external finance for households at the bottom of the distribution.

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

Desired consumption ($C^d_{t,h}$) for household h is a function of her disposable income ($Y^d_{t,h}$) 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 (i.e. $j = h+1$, if we rank households in ascending order based on income).[7] Put it simply, h tries to replicate j's consumption in the past based on a sensitivity parameter a, such that $0 \le a \le 1$: when $a = 1$, h fully mimics j's consumption; whereas when $a = 0$, the imitation effect is nil. Finally, k^y and k^m identify the propensity to consume out of income and liquid wealth, respectively.

2.2. Credit market for consumption loans

Households who lack the internal resources to finance desired consumption can apply for a loan to a commercial bank. Demand for consumption loans ($L^d_{t,h}$) is defined as the difference between desired consumption and the sum of disposable income and liquid wealth, as shown in Eq. (2), so that households demand loans only in case the entire amount of their own resources is not enough to finance desired consumption.

$$L^d_{t,h} = max\{C^d_{t,h} - (Y^d_{t,h} + M_{t-1,h}), 0\} \tag{2}$$

Yet, since loans are collateralised by houses, only homeowners can enter the credit market. This allows the model to resemble existing mechanisms, such as the home equity line of credit in the United States, and, in general, to capture the equity extraction process as described by Mian and Sufi (2011). Indeed, when house prices increase, both existing and new homeowners can borrow against the higher value of their equity so as to finance consumption expenditure.

Following Delli Gatti et al. (2011), each bank b sets a maximum credit supply ($LS_{t,\,b}$) defined in Eq. (3) as a fraction $1/v$ of its equity ($E_{t,\,b}$), where v can be interpreted as a capital requirement coefficient. This setting is in line with the regulatory framework introduced by Basel III (Basel Committee on Banking Supervision, 2011), thus implying that the commercial bank has to comply with a prudential regulation.

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

The design of the credit market is based on a simple search-and-match mechanism: households send their loan applications to all banks, while these latter rank households in ascending order based on their TDS and set an individual credit supply for each applicant. Eq. (4) describes the formulation of the credit supply to each household, which 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., 2015). Indeed, bank b offers a loan ($LSH_{t,\,b,\,h}$) based on the loan to value (LTV) ratio (γ), the market value of h's house ($P^H_{t,h}$), the balance owed on the existing mortgage ($ZR_{t,\,h}$) and the interest rate ($r_{t,\,b,\,h}$).

$$LSH_{t,b,h} = \frac{\gamma P^H_{t,h} - ZR_{t,h}}{1 + r_{t,b,h}} \tag{4}$$

[5] The choice of splitting the population based on the 90/10 income ratio is motivated by easy data availability for such ratio and the fact that this is the most common quintile ratio, as noted by the World Bank (2000).

[6] The shares $share_h$ are drawn from a Uniform distribution. In particular, the individual shares for the two income classes are generated in Matlab using the *rand* command, which returns an array of random numbers uniformly distributed in the interval (0,1). Eventually, the shares are normalised so that their sum is equal to 1. Appendix B reports some key statistics about the distributions of $share_h$ for the two macro income groups.

[7] The inclusion of liquid wealth in the equation for desired consumption follows Russo et al. (2016).

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Following Russo et al. (2016), $r_{t,b,h}$ is based on three elements, as described by Eq. (5). $\bar{r}$ is the constant policy rate set by the central bank (see Section 2.6). $\widehat{r_{t,b}}$ 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.[8]

$$r_{t,b,h} = \bar{r} + \widehat{r_{b,t}} + r_{t,h} \tag{5}$$

Put it simply, the formation of the interest rate follows the general principle that lenders extend credit at more favourable terms if they are in good financial shape, and charge a risk premium to the borrower, depending on her financial soundness (Delli Gatti et al., 2010). A criticism may be that a more prudent behaviour by the banks – that is, a greater sensitivity to the borrower's TDS – might paradoxically exacerbate the risk of a crisis, through the application of the greater interest rates on loans to more indebted borrowers. Hence, one might argue that banks do not deal with the default risk of borrowers by increasing the interest rate but, rather, by cutting down lending to risky loan applicants. However, our setting tries to replicate the essential features of the prevailing business model in the lax credit market of the United States before the crisis, which often implied profiting from lending to âexcessively riskyâ borrowers, as pointed out by Dymski (2010). Indeed, rather than denying loans to households traditionally excluded from the credit market, lenders often offered loans at exploitative terms – that is, loans carrying fees and higher interest rates (Dymski, 2010).

The selection process in the market is based on the choice of the bank that applies the lowest interest rate. Once selected, household h joins the credit network of bank b and gets a loan equal to $L_{t,h} = \min(L^d_{t,h}, LSH_{t,b,h})$. That is, rationing may take place since, due to changes in house prices or interest rates, each borrower may receive an amount of credit for consumption that is lower than the desired one.

Each consumption loan is a one-period debt contract that corresponds to a repayment schedule defined as $RS^L_{t,h} = L_{t,h}(1 + r_{t,b,h})$, to be paid back entirely in the following period.

2.3. Housing and mortgage market

The housing market features a fixed stock of houses, which is distributed to a number of households randomly selected at the beginning of the first period. In order to keep the structure and the functioning of the market as simple as possible, we assume the following:

1. There are no construction firms as we are not interested in quantity dynamics but exclusively on price dynamics;
2. Each homeowner owns one house only and does not want to increase her stock, so that existing homeowners can enter the housing market on the supply side only: they never demand additional houses.

As a result of the simplifying assumptions, the number (but not the identity) of homeowners, is fixed over time.

In every period, each homeowner updates the value of her house (i.e. the price $P^H_{t,h}$) by assessing whether the market is experiencing excess supply or demand using the number of unsold houses as a proxy. In particular, as shown in Eqs. (6–8), homeowners set house prices at time t based on their prices in the previous period ($P^H_{t-1,h}$) and a markdown ($-\xi_t$), if the number of unsold houses ($unsold_t$) in t is higher than in $t-1$, or a markup ($+\xi_t$) otherwise. The price remains the same if the number of unsold houses does not change.

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

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

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

$\xi_{\max}$ and $\xi_{\min}$ in Eq. (9) are parameters set in the initialisation phase, which are meant to limit the range of oscillation of the mark-up/down; whereas X_t identifies the change in the number of unsold houses between t and $t-1$. Our setting follows the same principle behind the price formation mechanism introduced in the much more sophisticated agent-based model by Geanakoplos et al. (2012), in which each seller periodically reduces her price by a markdown in case a house does not sell.

Also transactions in the housing market are based on a simple search-and-match mechanism. Similar to Erlingsson et al. (2014), the supply side of the market features all households in financial distress, that is all households

[8] 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.

who try to sell their house in an attempt to find the liquid assets to meet their debt obligation. The demand side of the market, instead, includes all households who do not own a house.[9] All buyers set a reservation price ($PB_{t,h}$) as a multiple $\theta > 0$ of their liquid wealth, as in Eq. (10). If they have no liquid wealth, they will apply a mark-up to the average market price in the previous period, as in Eq. (11).[10]

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

All sellers are sorted in ascending order based on their price, whereas buyers are sorted randomly. Every buyer looks for a seller such that $PB_{t,h} \geq P^H_{t-1,S}$ (where S identifies the set of sellers) and the process keeps running until all buyers have had the chance to search for a seller. When a buyer and a seller are matched, they set a deal for the transfer of the house at the seller's price, $P^H_{t-1,S}$. Buyers who have enough liquid wealth pay immediately thus becoming new homeowners. On the contrary, buyers who cannot afford to pay with their own resources, enter the mortgage market. Demand for mortgages ($Z^d_{t,h}$) is equal to the selling price net of the down payment, as shown in Eq. (12).

$$Z^d_{t,h} = max\{P^H_{t-1,S} - M_{t-1,h}, 0\} \quad (12)$$

Notice that households use the whole amount of available liquid wealth as down payment. Yet, by design, also households with no liquid wealth are allowed to enter the housing market, set a reservation price and eventually apply for a mortgage. In other words, a down payment 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 âdown paymentâ) for the other 20%" (Dymski, 2010, p. 248).

The functioning of the mortgage market is the same as the credit market for consumption loans, the only difference being the formulation of individual mortgage supply described in Eq. (13): we assume all banks offer standard "plain-vanilla" mortgage contracts ($ZSH_{t,b,h}$) with fixed interest rates and duration T_z. That is, mortgage contracts have a longer duration than one-period consumption loans.

$$ZSH_{t,b,h} = \frac{\gamma P^H_{t,h}}{(1 + r_{t,b,h})^{T_z}} \quad (13)$$

When a mortgage applicant selects a bank b, she joins its credit network and gets a mortgage equal to $Z_{t,b,h} = ZSH_{t,b,h}$.[11] From the following period until the deadline of the contract, the household will issue a constant periodic payment ($ZP_{t,b,h}$), described in Eq. (14), which is based on the standardised calculations in the U.S. (as defined by Kohn, 1990).

$$ZP_{t,b,h} = Z_{t,b,h} \frac{r_{t,b,h}(1 + r_{t,b,h})^{T_z}}{(1 + r_{t,b,h})^{T_z} - 1} \quad (14)$$

Hence, all home buyers who successfully find the mortgage eventually transfer the liquid assets to the corresponding seller, thus becoming new homeowners.[12] On the contrary, households who do not find any mortgage, drop the deal with the corresponding seller and search for a new house in the following period.

After the mortgage and housing markets close, all borrowers update their debt ($Debt_{t,h}$) and total debt service ratio as described by Eqs. (15) and (16). Total debt in period t is the sum of previous period debt, the new consumption loan and the new mortgage. The updated TDS, instead, is defined as the sum of the constant periodic mortgage payment and the repayment schedule on consumption loans, divided by household disposable income.

$$Debt_{t,h} = Debt_{t-1,h} + L_{t,h} + Z_{t,h} \quad (15)$$

$$TDS_{t,h} = \frac{ZP_{t,h} + RS^L_{t-1,h}}{Y^d_{t,h}} \quad (16)$$

[9] 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.

[10] The rationale for Eq. (11) stems from some empirical findings in economic psychology. In particular, when setting a reservation price in a price negotiation, buyers faced with multiple sources of information simplify and allow only one reference point to dominate (Kristensen and Gärling, 1997; White and Neale, 1994). Such reference typically takes the form of an estimate of the market price that induces changes in the adopted reservation price. Hence, this motivates the use of the average market price in the previous period as the reference point to set heterogeneous individual reservation prices for buyers in the housing market.

[11] 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, that is $\forall\, b\ s.t.\ ZSH_{t,b,h} \geq Z^d_{t,h},\ find\ \min(r^z_{t,b,h})$. Notice that consumption loan applications and mortgage applications cannot be sent to the same bank b. Furthermore, households cannot have more than one consumption loan and one mortgage on their balance sheet. Finally, the interest rate on mortgages does not include any household specific component since mortgage applicants have not previously accumulated any debt, thus having zero TDS.

[12] New homeowners cannot sell their house in the next $rest_s$ periods, where $rest_s$ is a parameter set in the initialisation phase of the model.

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2.4. Pay back phase

In the PBP, some borrowers have to pay back the 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 her internal resources are higher than the overall amount to be paid, that is if $ZP_{t,h} + RS^L_{t-1,h} \leq Y^d_{t,h} + M_{t-1,h}$. If this condition is satisfied, household h experiences a reduction of her debt and TDS. In addition, each bank earns profits from the interest payment of all the households in its credit network ($INT_{t,b}$), thus increasing the value of its equity, as shown in Eq. (17).

$$E_{t,b} = E_{t-1,b} + INT_{t,b} - BD_{t,b} \tag{17}$$

Rising bad debt ($BD_{t,b}$) for bank b slows down its equity accumulation process due to borrowers in financial distress who default on their debt obligations.[13] This occurs whenever changes in the number of unsold houses result in falling house prices so that sellers eventually receive an amount of liquid assets that is lower than the outstanding amount of debt. Consequently, bank b records a surge of non performing loans on its balance sheet and, as a result, a lower equity.

Note that if the level of bad debt is such that the bank b has negative net worth, we assume that the government bails the bank out, thereby replacing it with a random copy of a surviving bank.

2.5. Goods market, consumption and saving

As already pointed out, our economy features no supply constraints in the goods market, so that the productive sector always satisfies demand as it supplies the required amount of goods. As a consequence, no rationing takes place in this market.

Households who have enough own resources, as well as those who managed to access the credit market and get a consumption loan, are able to fully finance their desired consumption. The remaining set of households, instead, can only consume their available resources, that is the sum of disposable income and liquid wealth.

Liquid wealth, which we assume is held in the form of a zero interest rate deposit, is defined in Eq. (18) as the sum of previous period liquid wealth and household savings. The latter corresponds to the difference between disposable income, household consumption ($C_{t,h}$) and the down payment for the mortgage (equal to the difference between $P^H_{t-1,S,h}$ and $Z_{t,b,h}$).

$$M_{t,h} = M_{t-1,h} + Y^d_{t,h} - C_{t,h} - (P^H_{t-1,S,h} - Z_{t,b,h}) \tag{18}$$

Finally, each household has an overall amount of wealth ($A_{t,h}$) equal to the sum of liquid wealth and housing wealth net of the balance owed on the existing mortgage, as described in Eq. (19).

$$A_{t,h} = M_{t,h} + P^H_{t,h} - ZR_{t,h} \tag{19}$$

2.6. Policy authorities

In our model the government serves the only purpose of smoothing income disparities by redistributing income from the top to the bottom. For simplicity, we assume the government runs a balanced budget: it collects taxes on income based on the same tax rate for all households and spends all 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}), also the amount of each subsidy depends on the performance of the economy.

The central bank is rather simplified in our framework, as its only purpose is to set the policy interest rate. For simplicity, we make the (extreme) assumption that the central bank sets the initial level of the policy rate ($\bar{r}_t$) and it commits to keep it fixed along the entire timespan of the simulations. After all, the model does not have price dynamics and, as such, the inclusion of an active central bank would not add any relevant contribution given the current setting.

3. Model results

We investigate the macro and micro features of the ABM described in this paper by means of computer simulations.[14] Our strategy is as follows.

First, we simulate two scenarios: a baseline scenario (BA) in which income shares remain constant over time, and a rising inequality scenario (RI) in which we shock income shares after a number of periods in order to replicate increasing inequality. We analyse the simulated time series, cross-correlations and other relevant statistics in order to test the ability of the model to replicate some key micro and macro empirical regularities, consistent with the narrative described in Section 1.

[13] For details about the computation of bad debt see Appendix A.

[14] The codes of the model are available on Github and upon request.

Table 1
Model calibration.

Parameter	*Description*	*Value*
T	Number of periods	1500
H	Number of households	400
B	Number of banks	30
HO	Number of homeowners	260
a	Sensitivity parameter to j's past consumption	0.5
k^y	Propensity to consume out of income	0.8
k^m	Propensity to consume out of liquid wealth	0.1
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
$\bar{r}$	Policy interest rate	0.0225
$\xi_{\min}$	Minimum mark-up/down for house prices	0.01
$\xi_{\max}$	Maximum mark-up/down for house prices	0.1
T_z	Duration of mortgages	120
$rest_s$	Number of "freezing" periods for sellers	16
$rest_b$	Number of "freezing" periods for buyers	4

In particular, we focus on the credit relationship between households and banks, thus highlighting the variables and the mechanisms that play a major role in pushing the system on the brink of a crisis.

Secondly, we perform univariate sensitivity analysis by changing the values of some key parameters so as to asses the change in the outcome of the simulations. Some policy implications emerge at this stage.

Our parameter vector is set up mostly based on the literature as well as the need to rule out explosive dynamics and unrealistic patterns (Table 1).

The choice of assigning a house to 260 randomly selected households follows Mian and Sufi (2011) 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. 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, Kumhof et al., 2015). The values of a and k^y are taken from the original work on expenditure cascades by Frank et al. (2014), while the value of k^m is in line with the literature (e.g. Brayton and Tinsley, 1996; Iacoviello, 2012). Finally, the value of the policy interest rate set by the central bank equals the interest rate set by the Federal Reserve at the end of 2004.

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 1970. In RI we simulate a shock in the income shares that become equal to 62.57% for the bottom 90%, 37.43% for the top 10% from period 200 until the end.[15]

Results are obtained by means of Monte Carlo (MC) analysis: based on our parameter vector, we run 30 simulations for each of the two scenarios, selecting a different random seed at each run. Eventually, we compute the cross-simulation mean of the key variables for each scenario. In all simulations we drop the first 250 periods in order to get rid of transients: graphs only show the last 1250 periods for the purpose of simplicity.[16] 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.[17]

3.1. The impact of rising inequality

In the two scenarios, 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, household default rate, successful mortgage applicants) are all stationary in BA, while showing an inverted-U dynamics in RI, thus suggesting the presence of a boom-and-bust cycle. The macro time series of GDP, house prices, household debt and aggregate desired consumption show rather smooth oscillations along a stationary trend in BA (Fig. 1): they are also strictly correlated. In particular, GDP and household debt have 0.79 correlation in BA and 0.73 in RI, both significant 5% level; household debt and house prices have 0.81 correlation in BA and 0.77 in RI, both significant 5% level. Table 2 features a few additional statistics for selected key variables.

When income shares change and inequality rises in RI, a boom-and-bust kind of dynamics emerges. In particular, our model replicates some key empirical facts related to increasing inequality and credit, such us the rise in the share of families with debt secured by a primary residence, which increases to 49.7% in our model in the pre-crisis period (600–800) in RI,

[15] Such values are equal to the mean of the income shares for the two groups in the period between 1971 and 2006.
[16] Hence, the description of the two scenarios refers to the last 1250 periods and thus takes period 251 as period 1.
[17] We choose a window size for our moving averages equal to 20.

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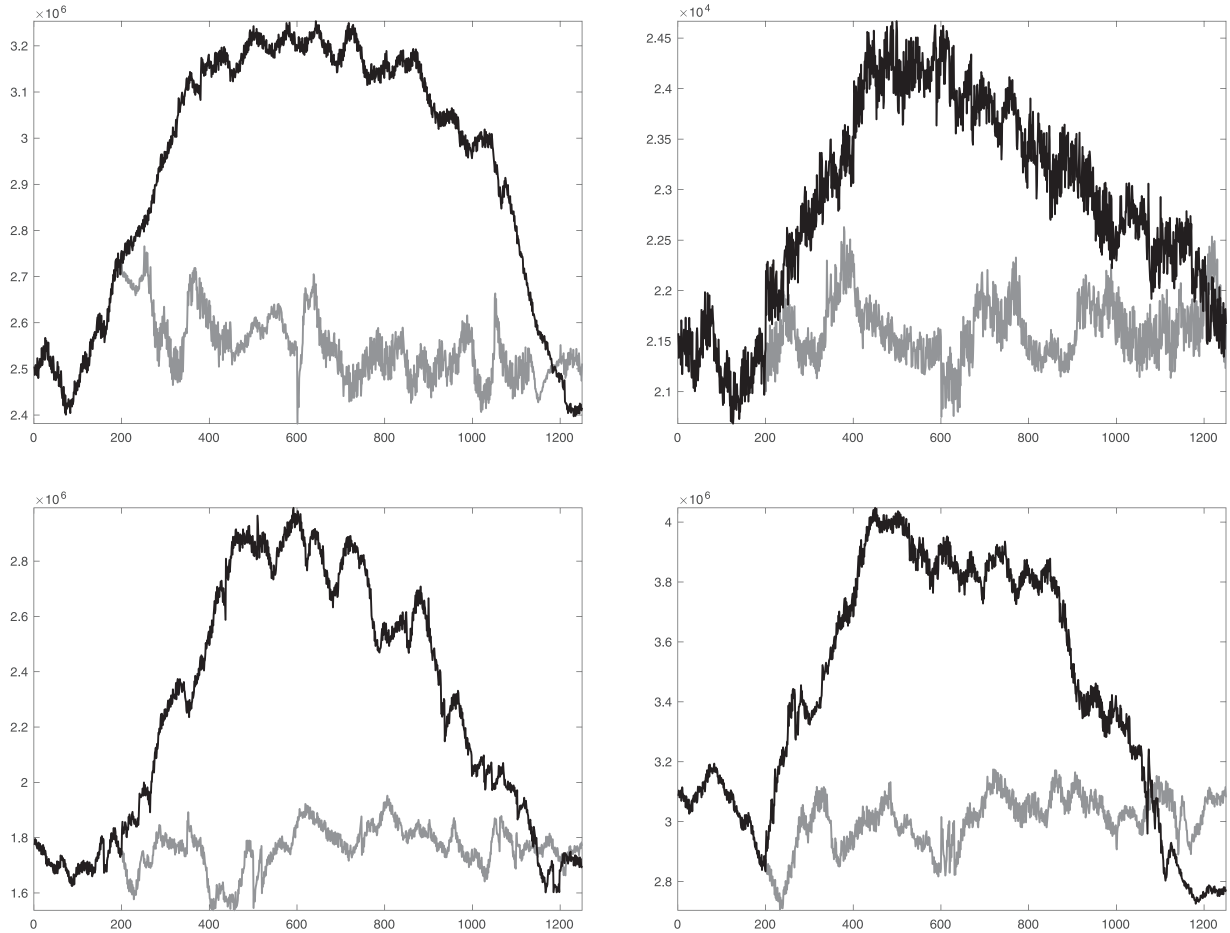

Fig. 1. Top, left: GDP in BA (grey) and RI (black); right: average house price in BA (grey) and RI (black). Bottom, left: household debt in BA (grey) and RI (black); right: aggregate desired consumption in BA (grey) and RI (black).

Table 2
Key statistics for selected variables in the two scenarios.

Scenario	*Average growth rate (%)*	*Mean*	*Variance*	*Standard Deviation*
GDP - BA	0.74	2547420.16	5278920753.54	72656.18
GDP - RI	0.11	2934702.30	75257488592.14	274330.98
Average House Price - BA	0.59	21564.05	105339.36	324.56
Average House Price - RI	0.69	23093.69	1179036.99	1085.83
Household Debt - BA	0.48	1755180.51	6067472210.94	77893.98
Household Debt - RI	1.04	2275604.57	198847901191.83	445923.64
Consumption Loans - BA	2.09	33175.63	9397548.21	3065.54
Consumption Loans - RI	3.08	41157.96	32134512.32	5668.73
Mortgages - BA	1.89	31431.86	13999703.57	3741.61
Mortgages - RI	2.35	39896.65	95127851.88	9753.35

in line with the actual average value of 48.3% in the U.S. in the period 2004–2006, as reported in the Survey of Consumer Finances (Bucks et al., 2006). The model also replicates the evidence that increased inequality is associated with an increase in bankruptcy rates of families (Frank et al., 2014): the household default rate in our model rises to an average value of 10.5% in RI compared to 5.12% in BA. Additionally, the model supports the recent empirical findings that consumption inequality tracks income inequality (Aguiar and Bils, 2015; Attanasio et al., 2014). Indeed, the distribution of consumption in our model becomes more unequal following the inequality shock, either measured as the ratio between actual consumption at the richest 20% and at the poorest 20% of the population (on average 2.63 in RI, 1.57 in BA), or as a Gini coefficient (0.38 in RI compared to 0.29 in BA).

In general, our model fits the stylised facts described in Section 1: the interplay of rising inequality in RI, peer effects in consumption and home equity borrowing, results in growing instability that drives the dynamics of our artificial economy

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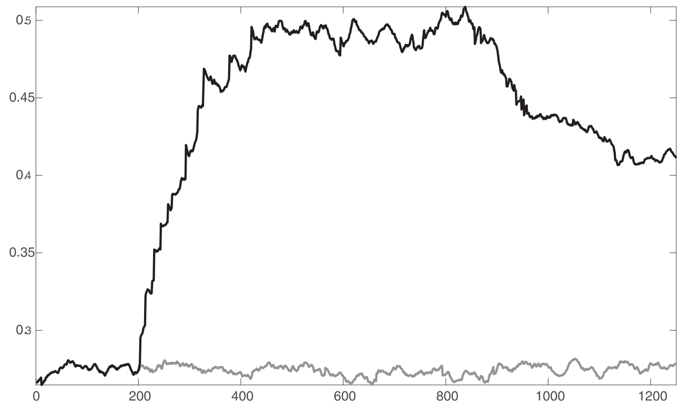

Fig. 2. Gini coefficient of desired consumption over time in both BA (grey) and RI (black).

towards a crisis. For a more comprehensive picture, let us analyse the key micro and macro facts during the economic expansion, the turning point and the recession.

Economic expansion. The income shock hits the economy in period 200 and the expansive effect on GDP lasts until period 500 approximately (Fig. 1, top left panel). In fact, due to the presence of peer effects in the household sector, wider income disparities trigger stronger expenditure cascades that result in higher desired consumption at the aggregate level (Fig. 1, bottom right panel). Hence, it is interesting to analyse whether the distribution of such variable changes following the income shock.

Fig. 2 plots the Gini coefficient of individual desired consumption, showing that, in general, desired consumption is unevenly distributed over time in the two scenarios. However, the figure also shows that the increase in desired consumption in the expanding phase in RI goes together with a more unequal distribution of the same variable. This is also confirmed by the average value of the Gini coefficient for $C^d_{t,h}$ which rises up to 0.43 in RI, compared to 0.27 in BA. In other words, expenditure cascades contribute to greater desired consumption across the entire population, even though the rise seems to be more sizeable for households at the top. However, in order to have a better understanding of the economic and social pressure that rising inequality with peer effects has on the lower segments of society, we analyse the change in the distribution of the desired consumption ratio, that is the ratio between individual desired consumption and income at the beginning of each period t. Our investigation shows that, on average, $C^d_{t,h}/Y_{t,h}$ rises for all households in RI compared to BA (from 1.17 to 1.48). Yet, households at the bottom 90% of the income distribution experience a much larger increase of the desired consumption ratio (37.2% increase on average), compared to households at the top (9.7% increase on average). This finding thus suggests that poorer households experience the pressing need for consumption loans in order to catch-up with households who rank above them in the income scale. Indeed, as income moves from the bottom to the top of the distribution, poorer households lack the internal resources to finance their greater desired expenses. Therefore, demand for consumption loans rises in RI compared to BA. In particular, Fig. 3 shows that aggregate desired consumption is positively correlated with present and future values of aggregate consumption loans (particularly at lag 1), thus suggesting that greater expenditure cascades in RI trigger higher credit demand in the future periods.

It is worth noticing that the already mentioned increase in consumption inequality is less pronounced than the increase in desired consumption inequality. This is easily explained by the greater availability of consumer credit in RI, as a consequence of growing house prices that allow a larger share of households to obtain the desired amount of loans. Hence, such result highlights the relevance of consumer credit as an alternative source of finance that compensates stagnating income growth at the bottom of the distribution. One might argue that this supports the stream of pre-crisis literature that welcomed the greater availability of credit as an efficient means to insure against fluctuations of income (e.g. Krueger and Perri, 2006). However, our results suggest that this positive effect is only limited in time, as growing inequality with home-driven credit expansion comes at the price of greater instability in the economy.

In fact, following the shock in RI, the percentage of houses held by households in the top 10% of the income distribution increases right after the shock, from 8% to, roughly, 10.5% (Fig. 4), thus suggesting that the richest part of the population contributes to house price appreciation in the aftermath of the income shock, via a reduction of the number of unsold houses. This is in line with Fitoussi and Saraceno (2010) who claim that those who benefited from the increase in inequality contributed to asset price appreciation, thus leading to the emergence of bubbles.

Since home buyers at the top of the distribution have enough liquid wealth to buy houses directly, the value of mortgages falls in the early periods after the shock (between 200 and 250). However, the house price appreciation occurring in the market results in a greater value of the collateral provided for mortgages by the bottom 90%, so that the overall value of the mortgages issued by the banking sector grows starting from approximately period 250 (Fig. 5, right panel). In turn, this implies that the number of unsold houses in the housing market falls even further so that homeowners increase house prices even more. Hence, a positive feedback between house prices and mortgages emerges in the housing market (Fig. 6).

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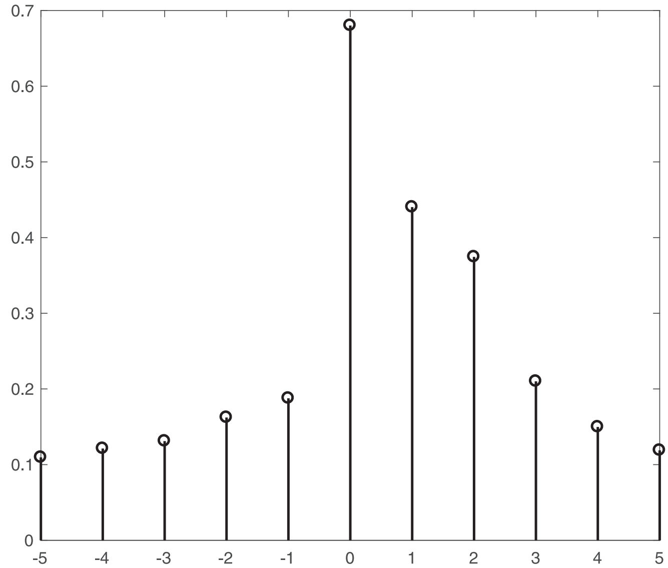

Fig. 3. Cross-correlation between aggregate desired consumption and demand for consumption loans in RI.

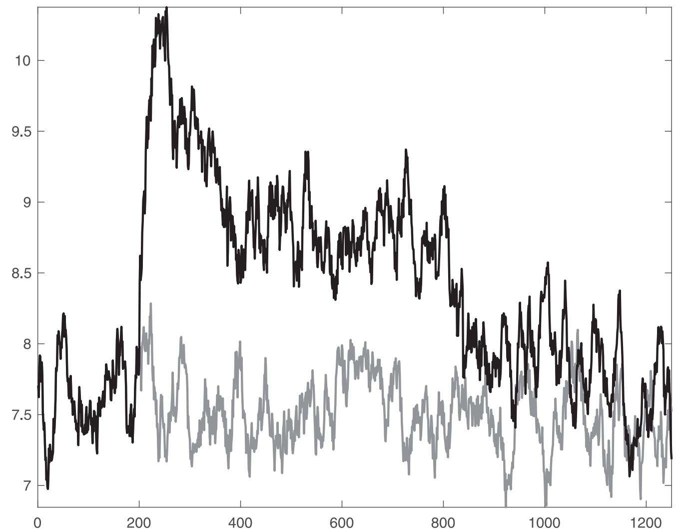

Fig. 4. Share of houses held by the top 10% of the income distribution.

Notice also, that the share of houses held by the top 10% falls down from period 250 until the end of the simulations, thus getting closer to the initial value in BA. This implies that house price dynamics from period 250 until the end of the simulations rely mostly on the mortgage availability for the bottom 90%.

As a further point, the model captures the HEBB channel identified empirically by Mian and Sufi (2011) as a key driver for the expansion of credit-led consumption in the years before the financial collapse. Indeed, existing homeowners in our model take advantage of the greater value of their equity to get new, higher, consumption loans (Fig. 5, left panel). In fact, the individual loan-to-income (LTI) ratio (i.e. the ratio between consumption loans and household income in each period t) increases, on average, for all households in RI (1.39), compared to BA (1.12). However, we find this is unevenly distributed since households at the bottom have greater LTI ratios (34.9% increase on avarege), compared to households at the top (6.4% increase on avarege). This is not surprising: the individual LTI ratio follows tightly the unequal distribution of the desired consumption ratio identified above. Our finding is in line with already mentioned empirical evidence that the debt-to-income ratio increased also for top 10% of the income distribution in the U.S., even though the dynamic was much weaker (Stockhammer, 2015).

The macroeconomic consequence of home equity based borrowing in our model is a massive increase in household debt (Fig. 1, bottom left panel), which sustains consumption and the growth of GDP for a while. In particular, we find that household debt relative to GDP rises considerably during the expanding phase of the economy in RI, from 65.1% (at $t = 200$)

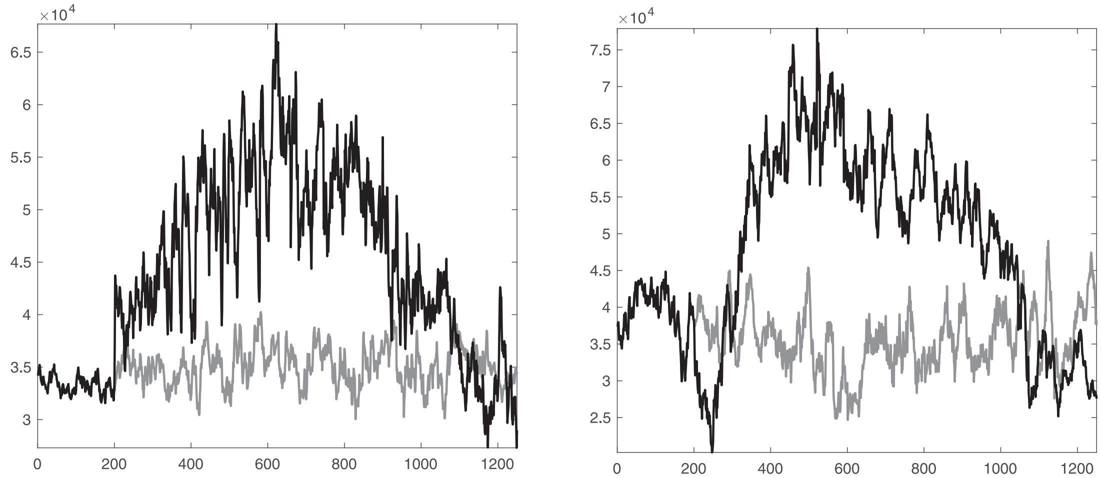

Fig. 5. Aggregate consumption loans (left) and mortgages (right) in BA (grey) and RI (black).

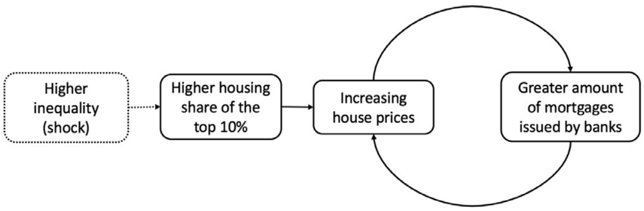

Fig. 6. Schematic representation of the positive feedback in the housing market.

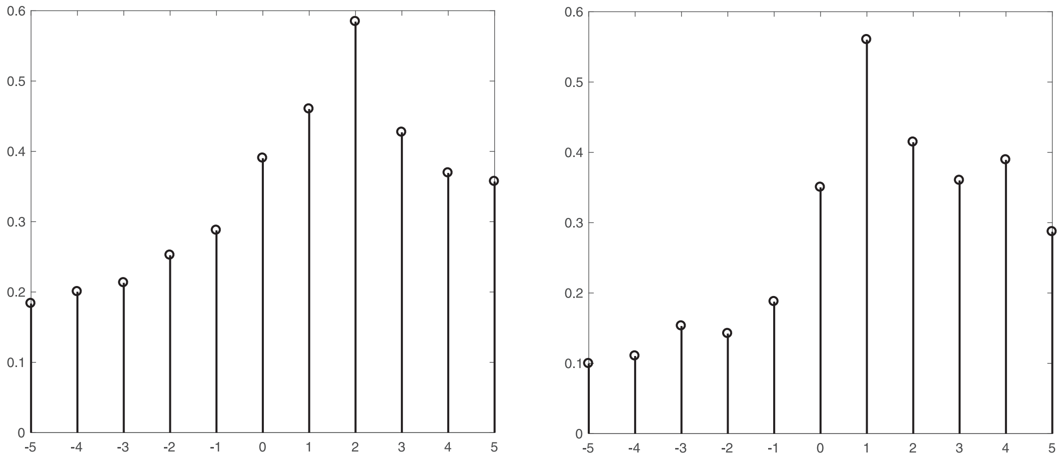

Fig. 7. Cross-correlation between household debt and (1) default rate (left) and (2) aggregate bad debt (right) in RI.

to 91.95% (at $t = 500$). It eventually stabilises at an average value of 88.54% before the recession (i.e. between $t = 501$ and $t = 800$). It is interesting to point out that such value lies within the 80–120% range which identifies the threshold above which financial development, proxied by the amount of credit to the private sector relative to GDP, starts having a negative effect on economic growth, as recently found by Arcand et al. (2015). In addition to this, we also find that aggregate household debt is positively correlated with future values of the household default rate and bad debt (Fig. 7), thus suggesting that credit expansion is an important predictor of the financial crisis, as described by Schularick et al. (2012).

Turning point and recession. The economy enters a turning point along a phase that lasts from period 500 to, approximately, 800. This represents the moment when the system reaches the brink of the cliff: GDP and aggregate desired consumption stop growing and begin oscillating around a constant trend. Also house prices stabilise for a while, at around period 500. Eventually, they start decreasing from period 600 onwards (Fig. 1, top right panel).

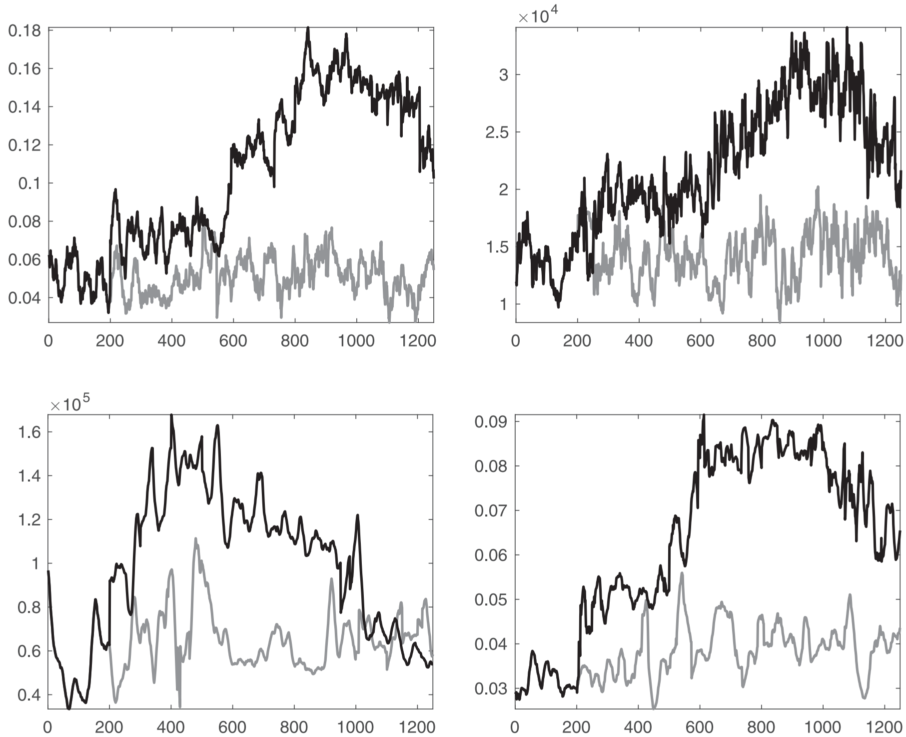

Fig. 8. Top, left: household default rate in BA (grey) and RI (black); right: aggregate bad debt in BA (grey) and RI (black). Bottom, left: aggregate credit supply in BA (grey) and RI (black); right: average interest rate in the credit market in BA (grey) and RI (black).

Different factors can explain the change in model dynamics in this phase. The macroeconomic narrative is that rising inequality and debt accumulation deteriorate the financial condition of the household sector in the expanding phase of the economy, thus resulting in the default of an increasing number of households (Fig. 8, top left panel). The banking sector thus accumulates non performing loans and growing bad debt (Fig. 8, top right panel). The consequence is that the credit supply begins to fall (Fig. 8, bottom left panel), while interest rates begin to rise (Fig. 8, bottom right panel). Hence, future borrowers have harder times obtaining new loans. This, in turn, implies that house price appreciation stops. At this stage, lower house prices result in falling home equity values thus preventing homeowners from exploiting the HEBB channel, so that consumption growth experiences a halt.

In order to validate such narrative, we analyse the microeconomic dynamics that drive the system towards the crisis. In particular, we spotlight the changes in the structure of the endogenous credit network that emerges in our economy, by focusing on the evolution of the degree centrality of each node over time.

Across all the MC simulations in BA, the network experiences the appearance of some bank hubs, identified by the bank nodes with higher degree centrality (Fig. 9, top left panel). Such banks also have the lowest coefficient of variation of degree centrality (Fig. 9, bottom left panel), thus confirming a stable number of links over time in BA. Eventually, degree centrality remains stable also during the economic expansion in RI (top right panel), while it changes dramatically in the following periods, corresponding to the turning point and the early stages of the bust in the economic cycle, thereby returning to more stable values afterwards.

Such different dynamics in BA and RI are explained by the evolution of the household default rate, which tracks the change in the degree centrality of the banks. First, since in BA household debt is lower and income inequality is constant, the household default rate remains fairly low and stable over time so that the number of bank-household links does not change significantly. On the contrary, when rising inequality and debt accumulation lead borrowers in financial distress to default on their loans in RI, the degree centrality of the bank nodes in the network changes markedly, especially for larger banks. Indeed, the coefficient of variation of the degree centrality of the bank nodes increases for all the banks in the model, with a particularly marked rise for the 5 banks with the highest degree centrality (Fig. 9, bottom right panel). Also smaller banks incur a noticeable change in their degree centrality when the household default rate begins to rise. However, Fig. 9 (top right panel) shows that their relevance within the network falls even further with respect to the previous periods, since their degree centrality drops, on average, to 14.8 (from 21.1 in BA), while the average degree centrality of the top 5 banks amounts to 36.6 (33.7 for the top 10 banks).

Notice that bank hubs seem to play a slightly more important role in triggering the crisis. As a matter of fact, larger banks are also linked to a higher percentage of households in financial distress (Fig. 10), thus being exposed to greater

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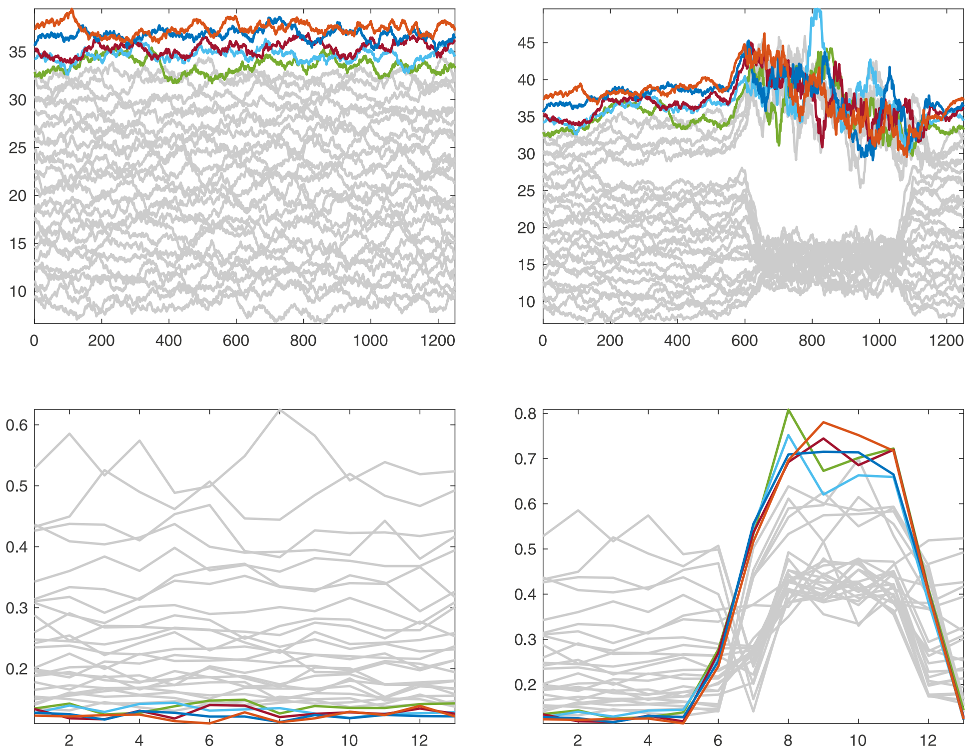

Fig. 9. Top: degree centrality of bank nodes in BA (left) and RI (right). Bottom: coefficient of variation of degree centrality of bank nodes in BA (left) and RI (right) - window size = 100. Coloured series identify the banks with the greater degree centrality: $b = 2, 5, 12, 26, 30$.

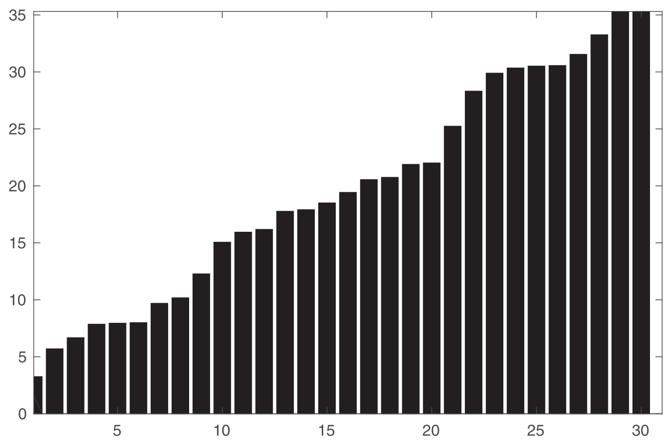

Fig. 10. Average percentage of borrowers in financial distress for each bank in RI. Banks are sorted in ascending order based on degree centrality.

default risk of borrowers compared to smaller banks. Hence, when the default rate rises due to increasing inequality, bank hubs suffer greater losses that negatively impact their net worth accumulation, thus experiencing a stronger contraction in their overall credit supply. This triggers the credit crunch and, eventually, the economic crisis.

The analysis of the network also provides a comprehensive picture of the financial fragility of our artificial economy by assessing the evolution of households in financial distress. Such number remains fairly stable, on average, across all the MC simulations in BA at around 4,78% of total borrowers. However, it increases sharply during the expanding phase of the economy in RI, reaching the peak 21.22% of total borrowers at time 549. It is interesting to point out that 82.19% of borrowers in financial distress are households with degree centrality equal to 2, while 17.81% have degree centrality equal to 1. Put it differently, 90.91% of households with degree centrality equal to 2 are in financial distress (the percentage being just 4.68% among borrowers with degree centrality equal to 1), thus highlighting the dramatic role of such borrowers who manage to exploit the ongoing house price appreciation in order to obtain both a mortgage and a consumption loan. Fig. 11

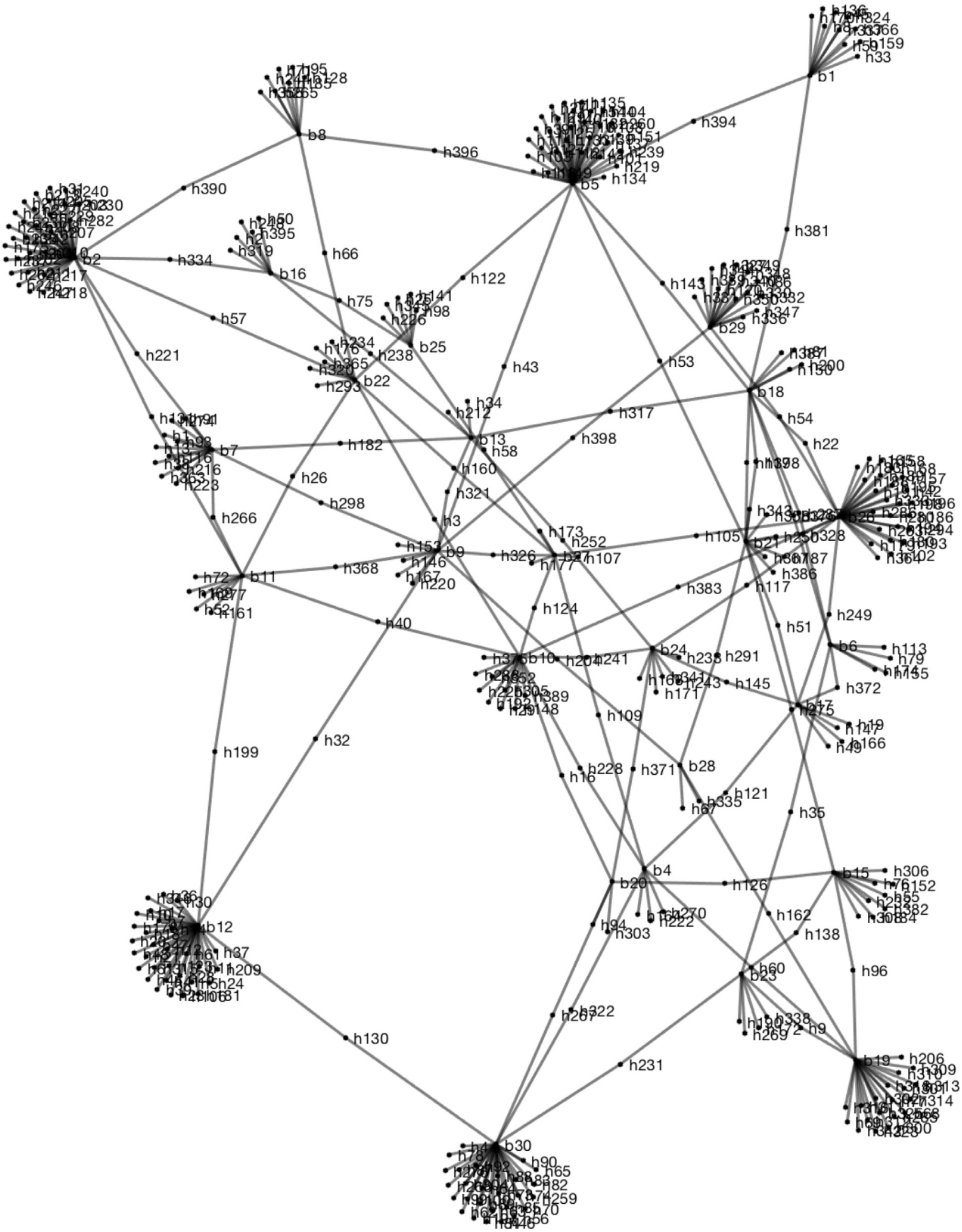

Fig. 11. Representation of the credit network at time 549 in RI.

Please cite this article as: A. Cardaci, Inequality, household debt and financial instability: An agent-based perspective, Journal of Economic Behavior and Organization (2018), https://doi.org/10.1016/j.jebo.2018.01.010

provides a representation of the credit network in RI at time 549, when the percentage of households in financial distress peaks.

This can be considered the phase when the economy shifts from debt-led to debt-burdened: an increasing fraction of borrowers start defaulting on their debt obligations in the following periods, thus triggering the process of bad debt accumulation at the linked bank nodes. The precautionary reaction of the banking sector triggers a default cascade, similar to Delli Gatti et al. (2010): the proximate cause of the bankruptcy of a new borrower in the middle of the avalanche is the interest rate hike by the banking sector. The remote cause, however, is the bankruptcy of a little number of households at the beginning of the avalanche that led the banks to rise interest rates. Thus, the interest rate hike results in a greater number of defaults and eventually to a default chain: the high rate of bankruptcy is a cause of the high interest rate as much as a consequence of it (Stiglitz and Greenwald, 2003).

The default cascade causes a reduction in the total credit supply of the banking sector between periods 500 and 1000, so that the amount of both consumption loans and mortgages supplied decreases, while the average interest rate rises in the same period (Fig. 8, bottom panels). The reduction in the credit supply determines the inability of households to finance their desired consumption, thus leading to falling GDP. Additionally, a growing number of households in financial distress also try to sell their houses in an attempt to meet their debt obligations, thereby increasing the stock of unsold houses. This contributes to the contraction of house prices which further deteriorates households' ability to borrow. Such negative feedback loop shares some similarities with the financial accelerator framework by Bernanke et al. (1996) and Kiyotaki and Moore (1997). Their mechanism suggests that a decrease in asset prices hampers agents' ability to borrow, leading to a contraction in investment and economic activity. This results in a vicious cycle characterised by a further reduction in asset prices, a deterioration of the balance sheets, tightening financing conditions as well as an economic contraction. In a similar fashion, the recession in our model is characterised by a vicious cycle where falling house prices trigger a reduction in the individual credit supply, which reduces agents' possibility to borrow, thus lowering house prices even further. The major implication is a substantial collapse of aggregate consumption and GDP.

We conclude this section by briefly discussing two implications and limitations stemming from the particular design of the bank behaviour, and the credit market in general, in our model.

First, by assuming that banks keep all their profits, we basically rule out the possibility that the banking sector in the aggregate records a deficit. That is, in an economy, the sum of the savings across all sectors must equal zero. Hence, given that the government and the productive sector run a balanced budget in our model, the fact that banks do not distribute their earnings, thus having positive profits when there are no or few household defaults, implies that the household sector must run a deficit. That is, households, in the aggregate, must borrow in order to consume more than their available internal resources. Hence, in the evaluation of the model results it is important to bear in mind that such mechanism may contribute to increasing the likelihood of a large recession.

Secondly, another important implication for model dynamics stems from the design of the search-and-match mechanism in the credit market. That is, only more financially sound borrowers are given the chance to select banks with lower interest rates. Indeed, since loan applicants are ranked in ascending order based on their TDS, riskier borrowers have no choice but to select banks applying higher interest rates. This might create a vicious cycle, thereby representing another element that can accelerate the tendency of the system towards a crisis.

These two issues mentioned above are part of the modifications to be implemented in future extensions of this model.

3.2. Sensitivity analysis

We now discuss the results of our univariate sensitivity analysis for the baseline scenario, thus analysing model outcomes with respect to the variation of one parameter at a time while leaving all the other parameters constant. We act on a wide set of parameters: a, k^y, k^m, μ, ρ, θ, γ, v and $\bar{r}$. We find that eight of these parameters – namely a, k^y, k^m, μ, ρ, γ, v and $\bar{r}$ – impact model outcome. On the contrary, changes in θ do not seem to affect the dynamics of our artificial economy in any relevant manner. Moreover, we test the robustness of model results to changes in the number of agents. Finally, we select the relevant policy parameters in BA (i.e. μ, ρ, γ, v and $\bar{r}$) and we perform the same univariate changes in RI in order to run a set of policy experiments in the presence of rising inequality.

Let us summarise our main findings.

Number of agents in the economy: B/H ratio. We check the robustness of model dynamics to changes in the number of households and banks. We find that, as far as we leave the ratio between B and H constant (and equal to 0.05), model dynamics do not change significantly from a qualitative point of view.[18] However, when the B/H ratio changes, some differences emerge. Overall, the qualitative model dynamics are unaltered, but the higher the B/H ratio, the smoother the oscillations of the key time series in BA. This is not surprising, since a higher B/H ratio implies greater credit availability which, in a scenario with constant inequality, does not lead to great booms and busts but, rather, only to smooth and minor oscillations along a constant trend.

Sensitivity parameter to j's past consumption: a. We run 30 MC simulations for the baseline scenario, for nine different values of a: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9. Results show that the lower the value of a, the greater the stability of

[18] Tested combinations: B = 5, H = 100; B = 10, H = 200; B = 15, H = 300; B = 20, H = 400; B = 25, H = 500; B = 30, H = 600; B = 35, H = 700; B = 40, H = 800.

Please cite this article as: A. Cardaci, Inequality, household debt and financial instability: An agent-based perspective, Journal of Economic Behavior and Organization (2018), https://doi.org/10.1016/j.jebo.2018.01.010

the economy. 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 smaller amount of non-performing loans.

Propensity to consume out of income: k^y. We run 30 MC simulations for the baseline scenario, for nine different values of k^y: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9. Changing the value of k^y implies that each household targets a different amount of income to set her desired consumption. Results suggest that lower values of k^y go 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.

Propensity to consume out of liquid wealth: k^m. Results for k^m are in line with those found for k^y. We run 30 MC simulations for the baseline scenario, for 9 different values of k^y: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9. We find that the lower the value of k^m, the lower trend along which GDP oscillates in BA.

Bank sensitivity to TDS: μ. In this experiment we run 30 MC simulations for the baseline scenario, for five different values of μ: 0.001, 0.005, 0.01, 0.02, 0.05. Our results show that higher values of the banks' sensitivity to household total debt service ratios imply a more prudential policy that leads to higher interest rates on both consumption loans and mortgages. This, in turn, determines a greater number of household defaults on debt obligations, which results in higher bad debt on the balance sheets of the banks and, overall, lower levels of GDP across all 30 MC simulations. In other words, if the banking sector is particularly sensitive to borrowers' financial conditions, its prudential behaviour might paradoxically lead to greater fragility and worse financial conditions for the banks.

Bank sensitivity to own leverage: ρ. In this experiment we run 30 MC simulations for the baseline scenario, for five different values of ρ: 0.001, 0.005, 0.01, 0.02, 0.05. When banks are more sensitive to their own leverage, interest rates are higher. This results in higher total debt service ratios and a rise in the number of defaults, so that bad debt increases as well. Finally, GDP oscillates along a lower trend in BA. Therefore, such results are qualitatively similar to those found for changes in μ.

Multiple of liquid wealth: θ. In this experiment we run 30 MC simulations for the baseline scenario, for eight different values of θ: 25, 50, 75, 100, 125, 150, 175, 200. 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.

Loan to value ratio: γ. We test six values of γ equal to 0.5, 0.6, 0.7, 0.8, 0.9. Higher values of γ imply greater individual credit supply. Notice, however, that the overall credit supply $LS_{t,b}$ does not depend on γ. As such, a higher γ implies that more financially sound borrowers – namely the first ones entering the search-and-match mechanism – have better chances to obtain the desired amount of loans, thus leading to a lower amount of credit available to the remaining borrowers. Put it simply, a greater LTV ratio, given the overall credit supply, results in a greater concentration of credit in the hands of few borrowers and therefore in tighter rationing. Also notice that, since inequality remains stable in BA, we find that greater values of γ do not impact the household default rate. This implies that bad debt is lower and that GDP oscillates along a higher trend in BA.

Capital requirement coefficient: v. We run 30 MC simulations with five different values of v equal to: 0.05, 0.06, 0.07, 0.08, 0.09. Lower values of the capital requirement coefficient lead to greater total credit supply. Our results show that greater credit availability implies that a broader set of households manages to get both consumption loans and mortgages so that rationing in the credit market is less tight. However, contrary to greater values of γ, we also find that overall credit availability results in a larger default rate thus leading to more non-performing loans and a worsening performance of the economy in terms of GDP in BA. Also notice that, similar to the univariate change in the B/H ratio, greater total credit availability also implies smoother oscillations in the baseline.

Policy interest rate: $\bar{r}$. We run 30 MC simulations with 5 different values of $\bar{r}$ equal to: 1, 1.5, 2, 2.5, 3. Our results indicate that, similar to changes in μ and ρ, higher levels of the policy rate result in greater interest rates in the credit market. This, in turn, results in a higher household default rate and bad debt for the banking sector. Also in this case, the higher the value of $\bar{r}$, the lower the trend along which GDP oscillates in the baseline. On the other hand, notice that lower interest rates result in a higher trend for GDP, even though oscillations are less smooth, thus leading to the emergence of (minor) booms and busts also in BA.

Let us analyse the univariate changes of selected policy parameters in RI. Our goal is to assess the impact of rising inequality under different credit and institutional scenarios.

Bank sensitivity to TDS (μ) *in RI.* In the scenarios with a higher bank sensitivity to borrowers' TDS, rising inequality triggers a much more limited household debt accumulation, both in magnitude and duration. Inded, similar to BA, higher values of μ lead to higher interest rates across all 30 MC simulations in RI, so that the default rate rises in the aftermath of the shock, as a consequence of the higher cost of credit. As a result, the banking sector accumulates a higher amount of non performing loans that drive the dynamics of the system towards a credit crunch. Put it simply, the credit expansion that results from the house price appreciation and the stronger expenditure cascades after the shock, allows to compensate the negative effect of widening income disparities only for a limited period of time. The duration of such phase seems to be negatively correlated with the value of μ and, therefore, with the level of the interest rates in the credit market for both

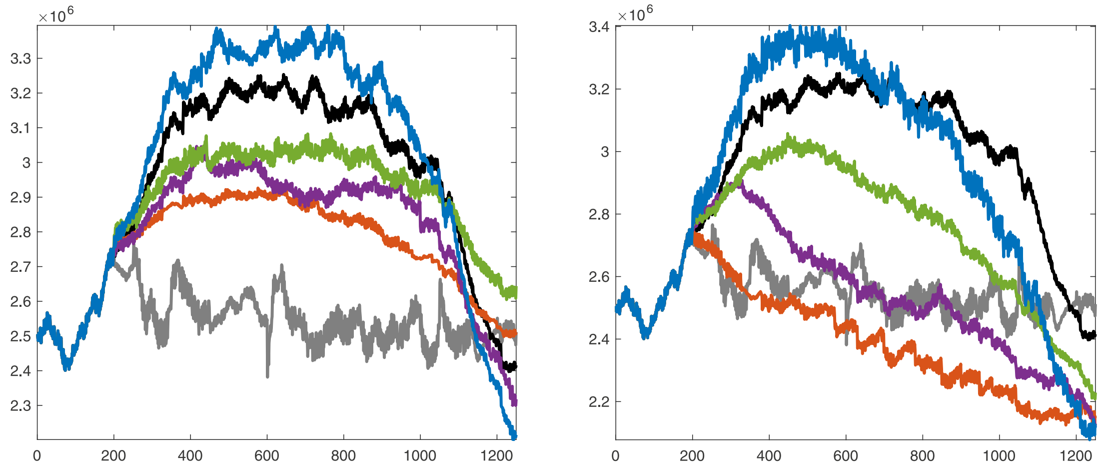

Fig. 12. Left: GDP in BA (grey) and RI for different values of γ: 0.5 (orange), 0.6 (purple), 0.7 (green), 0.8 (black), 0.9 (blue). Right: GDP in BA (grey) and RI for different values of v: 0.09 (orange), 0.08 (purple), 0.07 (green), 0.06 (black), 0.05 (blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

consumption loans and mortgages. In all the simulations, a crisis eventually hits the economy and the magnitude of the drop of GDP is roughly the same across all the 30 simulations. Hence, it seems that with rising inequality the banking sector is doomed to greater bad debt accumulation, no matter how sensitive it is to the financial soundness of the borrowers: changes in μ only act on the duration of the economic expansion.

Bank sensitivity to own leverage (ρ) in RI. Also in RI, changes in ρ determine similar results to variations in μ. Indeed, higher values of the bank sensitivity to its own leverage imply higher interest rates for borrowers, which lead to a greater default rate and a shorter duration of the economic expansion. Hence, also in this case, rising inequality inevitably results in a crisis triggered by the financial distress of a number of borrowers which determines the credit crunch and the collapse of consumption and GDP.

Loan to value ratio (γ) in RI. Greater values of the LTV ratio imply higher individual credit supply. Similar to BA, we find that both consumption loans and mortgages are more concentrated in the hands of fewer borrowers, in particular those who are more financially sound at the beginning of the economic expansion. However, a greater LTV ratio in RI goes together with a sizeable household debt accumulation (the result of stronger expenditure cascades) and a higher percentage of borrowers in financial distress. In particular, such number increases, on average, with γ across all the 30 MC simulations. Hence, contrary to BA, higher values of γ with rising inequality result in increasing household default rate and a greater accumulation of non performing loans by the banking sector. Therefore, our results suggest that a greater LTV ratio amplifies the boom and bust dynamics identified with the standard parameter vector in RI (Fig. 12, left panel). On the contrary, lower values of γ seem to limit the magnitude of the cycle, as GDP and household debt series become flatter and closer to the BA in all the 30 MC simulations.

Capital requirement coefficient (v) in RI. Similar to the baseline, lower values of v determine greater total credit supply and lower credit rationing. Similar to changes in γ, the inequality shock in correspondence of a lower capital requirement coefficient leads to a more sizeable expansion of the economy. However, this comes at the price of greater financial instability since also household debt, household default rate and bad debt are, on average, higher across all the 30 MC simulations in RI with lower values of v. The economy is eventually hit by a credit contraction and a recession due to falling household consumption. On the other hand, it is also worth pointing out that high values of v determine a much lower level of total credit supply, so that rising inequality triggers stronger expenditure cascades and greater demand for loans that is not satisfied by the banking sector. In these scenarios, a crisis hits the economy right after the inequality shock, as consumption and GDP fall (Fig. 12, right panel).

Policy interest rate ($\bar{r}$) in RI. Results are in line with those for BA. In particular, a lower policy rate in correspondence of the inequality shock, implies larger household debt accumulation in magnitude and duration. This is due to the fact that a lower policy rate, results in markedly lower interest rates in RI (compared to RI under the initial calibration), so that household default rate increases only in the later stages of the economic growth. However, also in this case, the debt-financed consumption boom eventually triggers a crisis in the banking sector due to rising household default rate and the accumulation of non-performing loans. Hence, similar to μ, it seems that the duration of the credit cycle is negatively correlated with the value of $\bar{r}$ in RI. After a number of periods, in any case, the inequality-led debt accumulation determines the collapse of consumption and GDP.

Please cite this article as: A. Cardaci, Inequality, household debt and financial instability: An agent-based perspective, Journal of Economic Behavior and Organization (2018), https://doi.org/10.1016/j.jebo.2018.01.010

3.2.1. Policy implications

We believe our model allows to shed some light also on some policy-related matters. In particular, our findings can contribute to the recently hotly debated issue of macroprudential regulation (Hanson et al., 2011). Our results seem to suggest that macroprudential policy can indeed contribute to macroeconomic and financial stability by limiting unsustainable credit booms and reducing the impact of negative shocks on the provision of credit to the economy, as pointed out by the IMF (2013). For example, the results of the sensitivity analysis on the role of γ support the need for the introduction of a cap to the LTV ratio, as suggested by Shin (2011) and empirically validated by Wong et al. (2015) who finds that a constraint on the LTV is effective at reducing systemic risk associated with boom-and-bust cycles. In fact, as already pointed out, lower values of the LTV in our scenario with rising inequality correspond to less pronounced household debt accumulation, lower household default rates and, in general, a more stable performance of the economy.

The analysis on the role of the capital requirement coefficient highlights, instead, the emergence of a policy dilemma about the role of regulation. Indeed, in line with Cardaci and Saraceno (2016), our results in RI show that when credit constraints are relaxed and commercial banks increase the credit supply, the positive effect on growth is limited to the short term, as greater financial instability emerges in the economy. On the contrary, a tighter regulation is effective at reducing instability, as financial institutions are less prone to lend. However, this comes at the price of falling output since lower credit availability constraints the spending capacity of poorer households in the face of rising inequality. This result seems to support the main arguments put forward by Fitoussi and Saraceno (2011), who point out that the common trend of rising inequality has led to different macroeconomic outcome in the U.S. and in Europe, precisely as a consequence of different institutional settings and regulatory frameworks. Relaxed financial regulation in the U.S. contributed to the emergence of the bubble, while more restrictive rules for financial markets in Europe made credit more difficult to obtain, thus posing a limit on the expansion of private debt and the growth of the economy in general (Fitoussi and Saraceno, 2011). In either case, the economic outcome is anything but desirable.

A similar trade-off emerges also in the model by Russo et al. (2016). The authors compare two scenarios, with and without consumer credit. In both scenarios the economy eventually enters a period of crisis. However, on the one hand, the introduction of consumer credit allows for an expansion of consumption and a mitigation of the financial constraints for (some) households. This boosts consumption and aggregate demand compared to the scenario with no credit. On the other hand, consumer credit accelerates the tendency of the system towards the crisis as the payment of interests on debt erodes household wealth, thus reducing consumption in the later stages.

In general, given the simple framework developed in our model, we can only argue that preventing the rise in inequality seems to be the most effective policy goal, which represents a way out of the policy dilemma between low or stagnant growth and the emergence of violent boom and bust cycles. Indeed, in our artificial economy this is confirmed by the better performance of the economy in BA compared to RI: GDP growth is higher and more stable, while household debt is lower.[19] Yet, in line with Fitoussi and Saraceno (2011), in addition to an intelligent regulation of financial markets, we point out that another possible intervention that allows to escape the dilemma between low or negative growth and greater instability consists in the revision of monetary policy targets. This policy discussion is also related the broader analysis of the role of low interest rates and the loose monetary stance in the years preceding the crisis. In particular, with respect to the U.S., Greenspan (2010) argues that low interest rates were not to blame for inflating the housing bubble and leading to the recent financial crisis (Greenspan, 2010). This view is in conflict with Taylor (2007), who points out that with a higher policy rate the U.S. economy would have avoided much of the housing boom and price bubble. Although the rather simple central bank in our model only sets a fixed nominal interest rate over time, our sensitivity analysis shows that a lower policy rate leads to a greater accumulation of household debt that boosts the performance of the economy only for a limited period of time, as a crisis eventually hits the economy in the later stages. On the contrary, a tighter monetary policy with higher interest rates, corresponds to more stable scenarios with lower household debt accumulation and lower default rates. Our result thus seems to suggest that a tightening of the monetary policy in the period preceding the financial crisis in the U.S. might have been a desirable policy, thereby supporting Taylor's point of view.

Finally, regardless of matters of income distribution, we believe that policy makers should be concerned also about the role of individual decisions to borrow and their macroeconomic consequences. After all, Mian and Sufi (2010) argue that one of the key questions that researchers should address has to do with the motivations behind American households' willingness to take on so much debt. Our setting provides a behavioural explanation that relies upon the role of peer effects and imitation, modelled via the expenditure cascade hypothesis, in line with Frank et al. (2014). In this respect, our sensitivity analysis shows that lower values of the imitation parameter correspond to more stable scenarios, with lower debt-to-GDP ratios and default rates. Therefore, by taking on a policy perspective, our result seems to suggest that social interventions aimed at offsetting the impact of upward-looking comparisons might be desirable. These are unconventional kind of policies in their nature. Nonetheless, two different types of interventions might be taken into account to this purpose.

One is based on the consideration that the extent to which households tend to imitate their richer peers may depend on institutional aspects related, for example, to the provision of public goods, the degree of household insurance against status loss in the labour market and the reactivity of monetary and fiscal policy to unemployment (Belabed et al., 2013). In this

[19] Nonetheless, since we simulate the increase in inequality as an exogenous change to the income distribution, unfortunately at this stage we have little to say about the possible solutions to tackle the determinants of growing income disparities.

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case, policies consisting in a higher per capita expenditure in health care, or in the quality of public education, may reduce the strength of consumption imitation.

The other kind of intervention relies upon the insights from behavioural economics showing that the impact of peer effects and upward-looking comparisons on consumption and borrowing decisions can be modified and partially smoothed through the use of behavioural nudges (Thaler and Sunstein, 2008). This is a hotly debated issue, particularly in the aftermath of the recent crisis, which has highlighted the prominent role of household borrowing decisions. In fact, different policy suggestions have been put forward with respect to this matter (Hershfield et al., 2015). In particular, recent contributions, such as Karlan and Zinman (2012), have successfully demonstrated the positive impact of behavioural approaches to debt reduction. These typically rely on simple interventions that smoothly alter individual behaviour by means of incentive design and goal-setting process aimed at accelerating debt repayment or controlling new borrowing (Karlan and Zinman, 2012).

4. Concluding remarks

By means of a macroeconomic agent-based model we create an artificial economy with heterogenous households and banks 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. Our model captures the impact of increasing inequality on household debt and the overall stability of the economy, via peer effects in consumption and home equity borrowing.

On the one hand, growing income disparities force low and middle income households to enter the credit markets so as to find the external resources that are needed to satisfy greater consumption needs due to stronger expenditure cascades. This captures the pressure of inequality on the lower segments of society. On the other hand, higher house prices, fuelled by mortgage credit and the accumulation of wealth at the top of the distribution, allow for relaxed collateral constraints thus expanding households' ability to borrow. The combination of these elements gives rise to an extended borrowing binge, in line with the process described by Fazzari and Cynamon (2013). Our narrative has a Minskyan flavour, in that periods of prosperity breed financial instability: household debt accumulation during the expanding phase of the economy sows the seeds of the future crisis by increasing the fragility of the banking sector and, eventually, of the entire economic system. In particular, when household debt skyrockets, a growing number of households default on their obligations and the resulting non-performing loans affect banks' balance sheets and their willingness to lend. Our network analysis especially identifies the pivotal role of the bank hubs, working as important financial institutions whose distress causes the credit crunch and brings about the default of future borrowers. Hence, the credit bubble created by higher inequality, via peer effects and house price appreciation, collapses and the structural vulnerability of the economy emerges. Therefore, in a nutshell, our results show that the link between rising inequality and financial crisis runs precisely through private debt, as highlighted by 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. Yet, for the sake of completeness, it is also worth pointing out that the average GDP is greater in the RI scenario compared to the baseline, even though it eventually falls dramatically thus plummeting below the baseline value for a few periods of time during the recession in the same scenario.

Our sensitivity analysis provides additional useful insights on the role of the lending behaviour of the banking sector and its policy related aspects. In particular, our findings seem to support the introduction of a macroprudential policy in the form of a cap on the LTV ratios, since all simulations show that lower values of such ratios limit the magnitude of the boom and bust cycle, thus contributing to the stability of the economy. Also notice that a policy dilemma seems to emerge: on the one hand, rising inequality with greater credit availability (via a lower capital requirement coefficient) leads to marked booms at the price of greater instability and more pronounced busts. On the other hand, widening income disparities with lower credit availability inevitably result in a contraction of aggregate consumption and, therefore, GDP, due to the lack of external financial resources for the poorer segments of society.

In addition, our results also show the importance of the role of monetary policy in times of crisis, suggesting that a higher interest rate might have played a positive role in reducing the instability associated with household debt accumulation.

Event though the current setting of our model proves useful in studying the dynamics described above, further improvements could be made in order to analyse a broader set of issues. Probably the most interesting extension would be the inclusion of endogenous inequality, which might be achieved via the introduction of heterogeneous 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 changes in endogenous income inequality, as well as unemployment dynamics, in periods of expansion and recession. Endogenous inequality can be added to the model also by considering the contribution of housing to changes in income distribution. This would allow to capture the recent empirical evidence showing that the long-term increase in capital's net share of income, especially in large developed countries, has consisted entirely of housing (Rognlie, 2015). Such extension would require some modifications to our modelling structure in order to have a comprehensive analysis of the determinants of housing income: for example, we might drop the assumption of a fixed stock of houses and number of homeowners by including construction firms in the housing market. Houses might also be different in size

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or quality. Additionally, a market for rents should be included and imputed rents should be explicitly computed as part of the income of homeowners living in owner-occupied properties.

From a policy perspective, it might be interesting to model inflation thus introducing an active role for the central bank. In addition, the simulation of fiscal regimes with different degrees of progressive taxation may also have an important consequence for model dynamics and the macroeconomic impact of inequality.

An additional extension would deal with the role of financial markets and the presence of a less prudential lending behaviour by banks. This might allow to capture the interaction of rising inequality and household debt with the diffusion of mortgage-backed securities and other assets that allow to pass the credit risk to third parts.

Finally, another interesting aspect deals with the international dimension of the crisis. Indeed, by extending our model to a multi-country setting with trade and capital flows, we could capture the dynamics of business cycles and external imbalances in the presence of rising income disparities under different credit scenarios and fiscal policy reactions.

Acknowledgment

I am particularly grateful to Tiziana Assenza, Domenico Delli Gatti, Jakob Grazzini, Mauro Napoletano, Alberto Russo and Francesco Saraceno for their support and advice. I also thank two anonymous referees for valuable comments and suggestions. Finally, I am also thankful for insightful comments and criticisms to the participants to the 18th FMM Conference on Inequality and the Future of Capitalism (October 2014, Berlin), the 1st Workshop on Modeling and Analysis of Complex Monetary Systems (December 2014, Université Paris XIII), the 20th Workshop on the Economic Science with Heterogenous Interacting Agents (May 2015, Nice) and the 21st International Conference in Computing in Economics and Finance (June 2015, Taipei). All remaining errors are my sole responsibility.

Appendix A. Bad Debt

When households in financial distress sell their houses, they assess whether the resulting liquid assets ($Liq_{t,h}$) are 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 as they pay back both the entire principal and interests.[20] On the contrary, if $\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^L_{t^*,h} > Liq_{t,h}$, 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 has degree centrality equal to 2, thus having having a consumption loan from a bank and a mortgage from another bank, she splits the liquid assets in two parts, defined by Eqs. (A.1) and (A.2): 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.

$$\delta^L_{t,h} = \frac{RS^L_{t^*,h}}{\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^L_{t^*,h}} \tag{A.1}$$

$$\delta^Z_{t,h} = \frac{ZP_{t^*,h}}{\sum_{ii=t^*}^{T_z} ZP_{ii,h} + RS^L_{t^*,h}} \tag{A.2}$$

Hence, the amount of bad debt resulting from h's default is equal to $bd_{t,h,b} = RS^L_{t^*,h} - \delta^L_{t,h} Liq_{t,h}$ for the bank that supplied the consumption loan, and $bd_{t,h,b} = \sum_{ii=t^*}^{T_z} ZP_{ii,h} - \delta^Z_{t,h} Liq_{t,h}$ for the one that issued the mortgage.

As shown in Eq. (A.3), the overall amount of bad debt 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.

$$BD_{t,b} = \sum_{h \in HB} bd_{t,h,b} \tag{A.3}$$

HB identifies the subset of all the bankrupt households linked to each bank b.

As already pointed out, bad debt accumulation lowers the accumulation of the bank equity. For the sake of clarification, the following tables report the balance sheet of each bank b as well as those of the other agents in the economy.

Assets for the banks include consumption loans and mortgages, whereas liabilities amount to household and firm deposits (represented by the revenues of the productive sector at the end of each period). Bank equity matches the difference between assets and liabilities. The balance sheet of the household sector and the productive sector are symmetric to that of the banking sector. Finally, as the public sector plays an extremely limited role in our model, the balance sheets of the government and the central bank only include government deposits (that is, the amount of revenues from taxation collected and redistributed at the beginning of each period).

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

Please cite this article as: A. Cardaci, Inequality, household debt and financial instability: An agent-based perspective, Journal of Economic Behavior and Organization (2018), https://doi.org/10.1016/j.jebo.2018.01.010

Balance sheet of each agent typology in our model.

Banking sector

Assets	*Liabilities*
Consumption Loans	Households deposits
Mortgages	Firm deposits
	Equity

Household sector

Assets	*Liabilities*
Households deposits	Consumption Loans
	Mortgages
	Net Worth

Productive sector

Assets	*Liabilities*
Firm deposits	
	Net Worth

Government

Assets	*Liabilities*
Government deposits	
	Net Worth

Central Bank

Assets	*Liabilities*
	Government deposits
	Net Worth

Appendix B. Individual Income Shares

The following table shows some key summary statistics for the distribution of the individual income shares of the two macro income groups, namely the bottom 90% and the top 10%.

Summary statistics for the individual income shares of the bottom 90% and top 10% of the population.

	Bottom 90	Top 10
Max	0.00543	0.05708
Min	0.00012	0.00027
Mean	0.00277	0.025
Median	0.00285	0.02273
Standard deviation	0.00157	0.01679
Variance	0.00246	0.00028

References

Aguiar, M., Bils, M., 2015. Has consumption inequality mirrored income inequality? Am. Econ. Rev. 105 (9), 2725–2756. doi:10.1257/aer.20120599, arXiv:1011.1669v3.

Arcand, J.L., Berkes, E., Panizza, U., 2015. Too much finance? J. Econ. Growth 20 (2), 105–148. doi:10.1007/s10887-015-9115-2.

Arestis, P., Gonzalez, A.R., 2013. Modeling the house market in OECD countries. Levy Economics Institute Working Paper, (764).

Atkinson, A., Morelli, S., 2011. Economic crises and inequality. Hum. Dev. Res. Paper 5, 112–115. doi:10.1007/s12117-999-1027-0.

Attanasio, O., Hurst, E., Pistaferri, L., 2014. The evolution of income, consumption, and leisure inequality in the United States, 19802010. NBER Chapters 100–140.

Basel Committee on Banking Supervision, 2011. Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems. Technical Report. Bank for International Settlements.

Belabed, C., Theobald, T., van Treeck, T., 2013. Income distribution and current account imbalances. INET Res. Notes 36.

Bernanke, B., Gertler, M., Gilchrist, S., 1996. The financial accelerator and the flight to quality. Rev. Econ. Stat. 78 (1), 1–15.

Brayton, F., Tinsley, P., 1996. A guide to FRB/US: a macroeconomic model of the United States. Financ.Econ. Discuss. Ser. 42.

Bucks, B.K., Kennickell, A.B., Mach, T.L., Moore, K.B., Fries, G., Grodzicki, D.J., Windle, R.A., 2006. Survey of consumer finances. Federa. Reserv. Bull. 92, 1–38.

Cardaci, A., Saraceno, F., 2016. Inequality, financialisation and credit booms: a model of two crises. LUISS-SEP Working Paper, (2/2016).

Cynamon, B.Z., Fazzari, S.M., 2012. The end of the consumer age. In: Cynamon, B.Z., Fazzari, S.M., Setterfield, M. (Eds.), After the Great Recession: The Struggle for Economic Recovery and Growth. New York, NY: Cambridge University Press doi:10.1017/CBO9781139059589.011.

Cynamon, B.Z., Fazzari, S.M., 2014. Inequality, the great recession, and slow recovery. Inst. New Econ. Think. Working Paper Series, 9.

Dawid, H., van der Hoog, S., 2015. Bubbles, crashes and the financial cycle: insights from a stock-flow consistent agent-based macroeconomic model. SSRN Electron. J. doi:10.2139/ssrn.2616662.

Delli Gatti, D., Desiderio, S., Gaffeo, E., Cirillo, P., Gallegati, M., 2011. Macroeconomics From the Bottom-up. Milano, IT: Springer doi:10.1007/978-88-470-1971-3.

Delli Gatti, D., Gallegati, M., Greenwald, B., Russo, A., Stiglitz, J.E., 2010. The financial accelerator in an evolving credit network. J. Econ. Dyn. Control 34 (9), 1627–1650. doi:10.1016/j.jedc.2010.06.019.

Dosi, G., Fagiolo, G., Napoletano, M., Roventini, A., 2013. Income distribution, credit and fiscal policies in an agent-based Keynesian model. J. Econ. Dyn. Control 37 (8), 1598–1625. doi:10.1016/j.jedc.2012.11.008.

Duca, J.V., Muellbauer, J., Murphy, A., 2011. House prices and credit constraints: making sense of the US experience. Econ. J. 121 (552), 533–551. doi:10.1111/j.1468-0297.2011.02424.x.

Duesenberry, J.S., 1949. Income, Saving, and the Theory of Consumer Behavior. Cambridge, MA: Harvard University Press.

Dymski, G.A., 2010. Why the subprime crisis is different: a Minskyian approach. Cambridge J. Econ. 34 (2), 239–255. doi:10.1093/cje/bep054.

Erlingsson, E.J., Teglio, A., Cincotti, S., Stefansson, H., Sturluson, J.T., Raberto, M., 2014. Housing market bubbles and business cycles in an agent-based credit economy. Economics 8 (2014-8), 1. doi:10.5018/economics-ejournal.ja.2014-8.

Fagiolo, G., Roventini, A., 2012. Macroeconomic policy in DSGE and agent-based models. Revue de l'OFCE 124 (5), 67. doi:10.3917/reof.124.0067.

Fazzari, S., Cynamon, B.Z., 2013. Inequality and household finance during the consumer age. INET Res. Notes 23 (752). doi:10.2139/ssrn.2205524.

Financial Crisis Inquiry Commission, 2011. The Financial Crisis Inquiry Report. Technical Report doi:10.1057/9781137311054.

Fitoussi, J.-P., 2013. Le théorème du lampadaire. Paris, FR: Les Liens Qui Liberent Editions.

Fitoussi, J.-P., Saraceno, F., 2010. Europe: how deep is a crisis? policy responses and structural factors behind diverging performances. J. Glob. Dev. 1 (1), 1–17. doi:10.2202/1948-1837.1053.

Fitoussi, J.-P., Saraceno, F., 2011. Inequality, the crisis and after. Rivista di Politica Economica 100 (1), 9–28.

Frank, R.H., 1997. The frame of reference as a public good. Econ. J. 107 (445), 1832–1847. doi:10.1111/j.1468-0297.1997.tb00086.x.

Frank, R.H., Levine, A.S., Dijk, O., 2014. Expenditure cascades. Rev. Behav. Econ. 1 (1–2), 55–73. doi:10.1561/105.00000003.

Galbraith, J.K., 2012. Inequality and Instability. A Study of the World Economy Just Before the Great Crisis. New York, NY: Oxford University Press.

Geanakoplos, J., Axtell, R., Farmer, J.D., Howitt, P., Conlee, B., Goldstein, J., Hendrey, M., Palmer, N.M., Yang, C.Y., 2012. Getting at systemic risk via an agent-based model of the housing market. Am. Econ. Rev. 102 (3), 53–58. doi:10.1257/aer.102.3.53.

Greenspan, A., 2010. The Crisis. Brookings Pap. Econ. Act. Spring, 1–62.

Hanson, S.G., Kashyap, A.K., Stein, J.C., 2011. A macroprudential approach to financial regulation. J. Econ. Perspect. 25 (1), 3–28. doi:10.1257/jep.25.1.3.

Hershfield, H.E., Sussman, A.B., O'Brien, R.L., Bryan, C.J., 2015. Leveraging psychological insights to encourage the responsible use of consumer debt. Perspect. Psychol. Sci. 10 (6), 749–752. doi:10.1177/1745691615598514, arXiv:1011.1669v3.

Iacoviello, M., 2012. Housing wealth and consumption. In: International Encyclopedia of Housing and Home, pp. 673–678. doi:10.1016/B978-0-08-047163-1.00129-6.

IMF, 2013. Key aspects of macroprudential policy. Policy Pap. 1–61. June.

Justiniano, A., Primiceri, G.E., Tambalotti, A., 2015. Household leveraging and deleveraging. Rev. Econ. Dyn. 18 (1), 3–20. doi:10.1016/j.red.2014.10.003.

Kaldor, N., 1956. Alternative theories of distribution. Rev. Econ. Stud. 23 (2), 83–100.

Karlan, D., Zinman, J., 2012. Borrow less tomorrow: behavioral approaches to debt reduction. Financ. Secur. Project (1) 1–39.

Kiyotaki, N., Moore, J., 1997. Credit cycles. J Polit. Econ. 105 (2), 211. doi:10.1086/262072.

Kohn, R.E., 1990. A capital budgeting model of the supply and demand for loanable funds. J. Macroecon. 12 (3).

Kristensen, H., Gärling, T., 1997. Determinants of buyers' aspiration and reservation price. J. Econ. Psychol. 18 (5), 487–503. doi:10.1016/S0167-4870(97)00020-2.

Krueger, D., Perri, F., 2006. Does income inequality lead to consumption inequality? evidence and theory. Rev. Econ. Stud. 73 (1), 163–193. doi:10.2307/3700621.

Kumhof, M., Rancière, R., 2010. Leveraging inequality. Financ. Dev. 47 (4), 28–31.

Kumhof, M.,Ranciére, R., Winant, P., 2015. Inequality, leverage, and crises. Am. Econ. Rev. 105 (3), 1217–1245. doi:10.1257/aer.20110683.

Mian, A., Sufi, A., 2010. Household leverage and the recession of 200709.. IMF Econ. Rev 58 (1), 74–117.

Mian, A., Sufi, A., 2011. House prices, home equity-based borrowing, and the US household leverage crisis. Am. Econ. Rev. 101 (5), 2132–2156. doi:10.1257/aer.101.5.2132.
Milanovic, B., 2010. The Haves and the Have-Nots: A Brief and Idiosyncratic History of Global Inequality. New York, NY: Basic Books doi:10.1007/s10888-013-9250-y.
Onaran, O., Stockhammer, E., Grafl, L., 2011. Financialisation, income distribution and aggregate demand in the USA. Cambridge J. Econ. 35 (4), 637–661. doi:10.1093/cje/beq045.
Rognlie, M., 2015. Deciphering the fall and rise in the net capital share. Brookings Pap. Econ. Act. 1–69. Spring.
Russo, A., Riccetti, L., Gallegati, M., 2016. Increasing inequality, consumer credit and financial fragility in an agent based macroeconomic model. J. Evol. Econ. 26 (1), 25–47. doi:10.1007/s00191-015-0410-z.
Schor, J.B., 1998. The Overspent American. New York, NY: Basic Books.
Schularick, M., Taylor, A.M., Beck, R., Coats, W., Davis, S., Goodhart, C., Hautcoeur, P.-C., Holtfrerich, C.-L., Illing, G., Meissner, C., Mitchener, K., Monnet, E., Pick, A., Shin, H., Solomou, S., Sylla, R., 2012. Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 18702008. Am. Econ. Rev. 102 (2), 1029–1061. doi:10.1257/aer.102.2.1029.
Shin, H.S., 2011. Macroprudential policies beyond basel III. Macroprudent.Regul.Policy 60 (November), 5–15.
Stiglitz, J., Greenwald, B., 2003. Towards a New Paradigm in Monetary Economics. Cambridge University Press.
Stiglitz, J.E., 2012. Macroeconomic fluctuations, inequality, and human development. J. Human Dev. Capabilities 13 (March 2015), 31–58. doi:10.1080/19452829.2011.643098.
Stiglitz, J.E., 2013. The Price of Inequality: How Today's Divided Society Endangers Our Future. W. W. Norton & Company.
Stockhammer, E., 2015. Rising inequality as a cause of the present crisis. Cambridge J. Econ. 39 (3), 935–958. doi:10.1093/cje/bet052.
Taylor, J., 2007. Housing and monetary policy. NBER. Working Papers 13682.
Tesfatsion, L., 2005. Agent-based computational economics: a constructive approach to economic theory. In: Handbook of Computational Economics, Volume 2: Agent-Based Computational Economics, p. 55. doi:10.1016/S1574-0021(05)02016-2.
Thaler, R.H., Sunstein, C.R., 2008. Nudge : improving decisions about health, wealth, and happiness. Yale University Press.
van Treeck, T., 2014. Did inequality cause the U.S. financial crisis? J. Econ. Surv. 28 (3), 421–448. doi:10.1111/joes.12028.
Veblen, T., 1899. The Theory of the Leisure Class, 7. Penguin Books: New York, NY doi:10.1086/250610.
White, S.B., Neale, M.A., 1994. The role of negotiator aspirations and settlement expectancies in bargaining outcomes. Organ Behav. Hum. Decis. Process. 57 (2), 303–317. doi:10.1006/obhd.1994.1017.
Wong, E., Ho, K., Tsang, A., 2015. Effectiveness of loan-to-value ratio policy and its transmission mechanism: empirical evidence from hong kong. J. Financ. Perspect. 3 (2), 1–25.
World Bank, 2000. Making transition work for everyone : poverty and inequality in Europe and Central Asia. Washington DC: World Bank.
Zezza, G., 2008. U.S. growth, the housing market, and the distribution of income. J. Post Keynes. Econ. 30 (3), 375–401. doi:10.2753/PKE0160-3477300304.