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Abstract

The aim of this paper is to investigate the relationship between increasing inequality and financial fragility in an agent based macroeconomic model. We analyse the effects of a non-linear relationship between wealth and consumption on the evolution of the economic system. Preliminary results show that more inequality rises macroeconomic volatility, increasing the likelihood of observing large unemployment crises.
Keywords: agent-based model, business cycle, inequality, crisis.
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1 Introduction

Many advanced economies experimented a rise of income and wealth inequality in recent decades. If consumption grows less than proportionally with wealth, that is the rich consume relatively less with respect to wealth than the poor, then increasing inequality may result in insufficient aggregate demand. In a monetary production economy, as the capitalist system, this may lower the profit rate, possibly resulting in lower investments and then more unemployment.

"The aggregate demand deficiency preceded the financial crisis and was due to structural changes in income distribution. Since 1980, in most advanced countries the median wage has stagnated and inequalities have surged in favour of high incomes" (Fitoussi and Stiglitz, 2009, p.3). In other words, "although the crisis may have emerged in the financial sector, its roots are much deeper and lie in a structural change in income distribution that had been going on for the past three decades" (Fitoussi and Saraceno, 2010, p.2). All in all, a *real cause*, that is the increase of inequality, may result in a *financial crisis*. Accordingly, the expansion of finance (for instance through credit consumption) may only postpone the occurrence of the crisis.

"While several authors have noticed that there might be a link between rising inequality and the crisis (Stiglitz 2010, Wade 2009, Rajan 2010), there is as of yet little systematic analysis" (Stockhammer, 2012). The aim of this paper is to contribute to this stream of literature by analysing the interplay between increasing inequality and financial fragility in a complex macroeconomic system. First of all, our aim is to assess the effects of a non-linear relationship between wealth and consumption, and then the consequences of increasing inequality on the economic system. "From a macroeconomic point of view, the increase in inequality triggers redistribution from households with high propensity to consume to households with a lower propensity to consume and/or from households credit constrained to households without such a constraint. The reasons for this difference in the propensities may be traced back to the work of Kalecki and Kaldor on income distribution (Kalecki, (1942); Kaldor, (1955)), and it may be related to a minimum consumption (subsistence) level, to liquidity or credit constraints, or to satiation phenomena"(Fitoussi and Saraceno, 2010, p.7).

As for the modelling framework, building upon Riccetti et al. (2012), we propose a macroeconomic microfounded model with heterogeneous agents in which households, firms, and banks interact according to a decentralized matching process presenting common features across four markets: goods, labour, credit and deposits. In general, the idea is to start from simple (adaptive) individual rules of behaviour in order to reproduce the emergence of aggregate regularities (Tesfatsion and Judd, 2006) from the *bottom up* (Epstein and Axtell, 1996). In other words, we follow a *constructive* approach to macroeconomics (Gaffeo et al. 2007). In our setting, agents are boundedly rational and follow (relatively) simple rules of behaviour in an incomplete and asymmetric information context: households try to buy consumption goods from the cheapest supplier, they also try to work in the firm offering the highest wage; firms try to accumulate profits by selling their products to households (they set the price according to their individual excess demand) and hiring cheapest workers; workers update the asked wage according to their occupational status (upward if employed, downward if unemployed); households' saving goes into bank deposits; given the Basilea-like regulatory constraints, banks extend credit to finance firms' production; firms choose the banks offering lowest interest rates, while households deposit money in the banks offering the highest interest rates. We also consider the action of two policy makers: the government and the central bank. The government hires a fraction of the population as public workers, so providing an additional component of the aggregate demand. Moreover, the public sector taxes private agents and issues public debt. The central bank sets the policy rate and manages the quantity of money in the system. Furthermore, in our framework the central bank is committed to buy outstanding government securities.

Computer simulations show the emergence of endogenous business cycles, the nominal growth of GDP (in our simplified framework productivity is fixed), the existence of the Phillips curve, the presence of credit constraints, firm and bank defaults, and the importance of government as an acyclical sector which stabilise the economy. Banks' capitalisation plays a relevant role in determining credit conditions, so influencing firms' leverage and, in general, the macroeconomic evolution. The presence of an acyclical sector, that is the government, has a fundamental role in sustaining the aggregate demand and in mitigating output volatility. Another interesting feature of the model is that credit mismatch (that is the difference between banks' credit supply and firms' credit demand) tends to follow the cycle of banks' net worth: when banks are poorly capitalised this results in credit rationing for firms; in this case, the central bank intervenes providing credit to banks; on the contrary, when banks are well capitalised they are able to fulfil all credit demand. Accordingly, firms' mean leverage is influenced by credit availability. In particular, firms' financial structure is based on the Dynamic Trade-Off theory (Flannery and Rangan, 2006), according to this theory, firms (adaptively) tend to reach a "target leverage", that is a desired ratio between debt and net worth. As shown in Riccetti et al (2013), this financial structure has a relevant influence on the leverage cycle and macroeconomic dynamics.

As explained in Riccetti et al (2012), two of the major innovations we introduce in this agent-based framework, that is (i) the Dynamic Trade-Off theory for firms' capital structure and its interplay with banks' credit supply, (ii) the role of an acyclical sector, have opposite effects on business fluctuations. On one hand, firms' leverage and, in particular, banks' exposure enlarge business fluctuations: a growing firm requires more credit and, if banks extended new loans, then they are able to expand the production through the employment of more workers; after a while, the rise of employment fosters wages that, together with the rise of interest payments on an increasing debt, reduces firms' profitability. Thus the business cycle reverses and financial factors amplify the fall of production (the relatively low level of profits with respect to interest payments induces a deleveraging process).

Moreover, model simulations highlight that even extended crises can endogenously emerge. In these cases, the system may remain trapped in a large unemployment status, without the possibility to quickly recover unless an exogenous intervention. Indeed, the macroeconomic system evolves towards an "extended crisis" scenario, where the private sector tends to disappear, that is almost only public workers remain employed. In this case, differently from the usual business cycle mechanism, the decrease of wages due to growing unemployment does not reverse the cycle, but rather amplifies the recession due to the lack of aggregate demand. In other words, the self-adjustment mechanism which spontaneously reverses the business cycle (e.g., the rise of the unemployment rate reduces the real wage and then the resulting increase of profits makes room for an expansionary production phase) does not work. Indeed, real wage lowers excessively boosting a vicious circle for which the fall of purchasing power prevents firms to sell commodities, then firms reduce production, unemployment continues to rise, and the system moves towards a large crisis.

We extend the model proposed in Riccetti et al (2012) by considering heterogeneous consumption behaviours. "If propensities to consume differ, then the overall propensity to consume is affected by income distribution, and an increase in inequality causes it to decrease. The reduction of consumption demand, then, puts downward pressure on aggregate demand and on income (unless some compensation comes from other items, like government spending or external demand)" (Fitoussi and Saraceno, 2010, p.2). As a matter of fact, rich people may accumulate higher wealth while poor people may suffer from low consumption, so creating negative consequences at the macroeconomic level, as a lack of aggregate demand, so increasing the likelihood of observing a crisis with large unemployment.

The paper is organised as follows. After this introduction, we provide a brief description of the agent based macroeconomic model in Section 2. In particular, we present the structure of four markets (credit, labour, goods and deposits) and the mechanisms of agents' wealth accumulation. In Section 3 we discuss simulation results regarding the baseline model, and a setting with heterogeneous consumption behaviour. Finally, Section 4 provides some concluding remarks.

2 The model

In this section we provide a description of the modelling properties which characterise our agent based macroeconomic model. The economic system is composed of households ($h = 1, 2, ..., H$), firms ($f = 1, 2, ..., F$), banks ($b = 1, 2, ..., B$), a central bank, and the government, and it evolves over a time span $t = 1, 2, ..., T$. Then, the economy is composed of four markets: (i) credit market; (ii) labour market; (iii) goods market; (iv) deposit market. In what follows we describe the working of the goods market. Agents are heterogeneous, live in an incomplete and asymmetric information context, follow simple behavioural rules, and use adaptive expectations.

The interaction between the demand (firms in the credit and labor markets, households in the goods market, and banks in the deposit market) and the supply (banks in the credit market, households in the labor and deposit markets, and firms in the goods market) sides of the four markets follows a common decentralised matching protocol: a random list of agents in the demand side is set, then the first agent in the list observes a random subset of potential partners and chooses the cheapest one. After that, the second agent on the list performs the same activity on a new random subset of the updated potential partner list. The process iterates till the end of the demand side list. Subsequently, a new random list of agents in the demand side is set and the whole matching mechanism goes on until either one side of the market (demand or supply) is empty or no further matchings are feasible.

2.1 Credit market

In the credit market, firms and households are on the demand side, while banks are on the supply side. Firms aim at financing production and banks may provide credit to this end. Firm's f credit demand at time t depends on its net worth A_{ft} and the leverage target l_{ft}. Hence, required credit is:

$$B^d_{ft} = A_{ft} \cdot l_{ft} \tag{1}$$

The evolution of the leverage target depends on the following rule:

$$l_{ft} = \begin{cases} l_{ft-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) > i_{ft-1} \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ l_{ft-1}, & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) = i_{ft-1} \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ l_{ft-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) < i_{ft-1} \text{ or } \hat{y}_{ft-1} \geq \psi \cdot y_{ft-1} \end{cases} \tag{2}$$

where $\alpha > 0$ is a parameter representing the maximum percentage change of the relevant variable (in this case the target leverage), $U(0,1)$ is a random number picked from a uniform distribution in the interval (0,1), π_{ft-1} is the gross profit (realized in the previous period), B_{ft-1} is the previous period effective debt, i_{ft-1} is the nominal interest rate paid on previous debts[1], $\hat{y}_{ft-1}$ represents inventories (that is, unsold goods), $0 \leq \psi \leq 1$ is a parameter representing a threshold for inventories based on previous period production y_{ft-1}. Equation 2 means that the leverage target increases (decreases) if the profit rate is higher (lower) than average interest rate and there is a low (high) level of inventories.

On the supply side, bank b offers a total amount of money B^d_{bt} depending on net worth A_{bt}, deposits D_{bt}, central bank credit m_{bt}, and some legal constraints (proxied by the parameters

[1]It is a mean interest rate calculated as the weighted average of interests paid to the lending banks.

$\gamma_1 > 0$ and $0 \leq \gamma_2 \leq 1$ that represents respectively the maximum admissible leverage and maximum percentage of capital to be invested in lending activities):

$$B^d_{bt} = min(\hat{k}_{bt}, \bar{k}_{bt}) \tag{3}$$

where $\hat{k} = \gamma_1 \cdot A_{bt}$, $\bar{k} = \gamma_2 \cdot A_{bt} + D_{bt-1} + m_{bt}$. Moreover, in order to reduce risk concentration, banks lend to a single firm up to a maximum fraction β of the total amount of the credit B^d_{bt}. This behavioural parameter can be also interpreted as a regulatory constraint to avoid excessive concentration.

Bank b charges an interest rate on the firm f at time t according to the following equation:

$$i_{bft} = i_{CBt} + \hat{i}_{bt} + \bar{i}_{ft} \tag{4}$$

where i_{CBt} is the nominal interest rate set by the central bank at time t, $\hat{i}_{bt}$ is a bank-specific component, and $\bar{i}_{ft} = \rho^{\,l_{ft}}/100$ is a firm-specific component, that is a risk premium on firm target leverage (with $\rho > 0$).
The bank-specific component evolves as follows:

$$\hat{i}_{bt} = \begin{cases} \hat{i}_{bt-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \hat{B}_{bt-1} > 0 \\ \hat{i}_{bt-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } \hat{B}_{bt-1} = 0 \end{cases} \tag{5}$$

where $\hat{B}_{bt-1}$ is the amount of money that the bank did not manage to lend to firms in the previous period.

As a result of the interaction based on the matching mechanism explained above, each firm ends up with a credit $B_{ft} \leq B^d_{ft}$, , and each bank lends to firms an amount $B_{bt} \leq B^d_{bt}$. The difference between desired and effective credit is equal to $B^d_{ft} - B_{ft} = \hat{B}_{ft}$ for firms and $B^d_{bt} - B_{bt} = \hat{B}_{bt}$ for banks. Moreover, we assume that banks ask for an investment in government securities equal to $\Gamma^d_{bt} = \bar{k}_{bt} - B_{bt}$. If the sum of desired government bonds exceeds the amount of outstanding public debt then the effective investment Γ_{bt} is rescaled according to a factor $\Gamma^d_{bt}/\sum \Gamma^d_{bt}$. Instead, if public debt exceeds the banks' desired demand, then the central bank buys the residual amount.

2.2 Labour market

First of all, the government hires a fraction g of households. The remaining part is available for working in the firms. Firm's f labor demand depends on the total capital available: $A_{ft} + B_{ft}$. Each worker posts a wage w_{ht} which is updated as follows:

$$w_{ht} = \begin{cases} w_{ht-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } h \text{ employed at time } t-1 \\ w_{ht-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } h \text{ unemployed at time } t-1 \end{cases} \tag{6}$$

The required wage has a minimum equal to: $\theta\hat{p}_{t-1}(1+\tau)$, where θ is a positive parameter, $\hat{p}$ is the maximum price of a single good, and τ is the tax rate on labor income. This means that a worker asks at least a wage net of taxes able to buy a multiple θ of a good.

As a result of the decentralized matching between labor supply and demand, each firm ends up with a number of workers n_{ft} and a residual cash (insufficient to hire an additional worker). Obviously, a fraction of households may remain unemployed. In the baseline model, the wage of unemployed people is set equal to zero.

Then, we remove this assumption by introducing an unemployment benefit paid by the government. Accordingly, if the h-th worker is unemployed at time t then her income is given by:

$$w_{ht} = \eta\hat{p}_{t-1} \tag{7}$$

where η is a positive parameter. We will explore the role of this parameter on model behavior in the computational experiments proposed below.

2.3 Goods market

In the goods market households represent the demand side, while firms are the supply side. Households set the desired consumption, c^d_{ht}, as follows:

$$c^d_{ht} = c_1 \cdot w_{ht} + c_2 \cdot A^{c_3}_{ht} \tag{8}$$

where w_{ht} is the wage gained by household h, $0 < c_1 \leq 1$ is the propensity to consume current income, $0 \leq c_2 \leq 1$ is the propensity to consume the wealth A_{ht}.

In this paper, we add the parameter c_3, that was implicitly equal to 1 in Riccetti et al. (2012). Accordingly, for $0 < c_3 < 1$ consumption increases less than proportionally whith wealth, that is the saving rate is higher for wealthier agents. We will investigate the role of the parameter c_3 below, by means of computer simulations, trying to assess the effects of heterogeneous consumption behaviours on macroeconomic dynamics. In particular, we consider two different scenarios, one with $c_3 = 1$, that is the *baseline* scenario, and one with $c_3 = 0.5$. Accordingly, when $c_3 = 1$ we have the following consumption function:

$$c^d_{ht} = c_1 \cdot w_{ht} + c_2 \cdot A_{ht}$$

Instead, if $c_3 = 0.5$ the consumption function is given by:

$$c^d_{ht} = c_1 \cdot w_{ht} + c_2\sqrt{A_{ht}}$$

Moreover, if the amount c^d_{ht} is smaller than the average price of one good $\bar{p}$ then $c^d_{ht} = min(\bar{p}\,, w_{ht} + A_{ht})$.

Given the number of hired workers, n_{ft}, firms produce consumption goods:

$$y_{ft} = \phi \cdot n_{ft} \tag{9}$$

where $\phi \geq 1$ is a productivity parameter (equal for all firms and time-invariant).

Firms try to sell their current period production and previous period inventories. The selling price increases if in the previous period the firm managed to sell all the output, while it reduces if it had positive inventories. Moreover, the minimum price at which the firm want to sell its output is set such that it is at least equal to the average cost of production, that is *ex-ante* profits are at worst equal to zero.

At the end of the goods market matching, each household ends up with a residual cash, which is not enough to buy an additional good and that it will try to deposit in a bank. At the same time, firms may remain with unsold goods (inventories), that they will try to sell in the next period.

2.4 Deposit market

Banks represent the demand side of the depoit market (given that they require capital to extend credit) and households are on the supply side. Banks offer an interest rate on deposits according to their funds requirement:

$$i_{bt}^{D} = \begin{cases} i_{bt-1}^{D} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \bar{k}_{bt} - B_{bt} - \Gamma_{bt} > 0 \\ min\{i_{bt-1}^{D} \cdot (1 + \alpha \cdot U(0,1)), i_{CBt}\}, & \text{if } \bar{k}_{bt} - B_{bt} - \Gamma_{bt} = 0 \end{cases} \tag{10}$$

where Γ_{bt} is the amount of public debt bought by bank b at time t. Hence, the previous equation states that if a bank exhausts the credit supply by lending to private firms or government then it decides to increase the interest rate paid on deposits, so to attract new depositors, and viceversa. However, the interest rate on deposits can increase till a maximum given by the policy rate r_{CBt} which is both the rate at which banks could refinance from the central bank and the rate paid by the government on public bonds.

Then, households set the minimum interest rate they want to obtain on bank deposits as follows:

$$i_{ht}^{D} = \begin{cases} i_{ht-1}^{D} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } D_{ht-1} = 0 \\ i_{ht-1}^{D} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } D_{ht-1} > 0 \end{cases} \tag{11}$$

where D_{ht-1} is the household h's deposit in the previous period. This means that a household that found a bank paying an interest rate higher or equal to the desired one decides to ask for a higher remuneration. In the opposite case, she did not find a bank satisfying her requirements, thus she kept her money in cash and now she asks for a lower rate. We assume that a household deposits all the available money in a single bank that offers an adequate interest rate. A household that decides to not deposit her money in a bank signals a preference for liquidity, because she does not accept to deposit her cash for an interest rate below the desired one.

2.5 Wealth dynamics

2.5.1 Firms

As a result of the outcomes of the credit, labor and goods markets, the firm f's profit is equal to:

$$\pi_{ft} = p_{ft} \cdot \bar{y}_{ft} - W_{ft} - int_{ft} \tag{12}$$

where W_{ft} is the firm f's wage bill, that is the sum of wages paid to employed workers, and int_{ft} is the sum of interests paid on bank loans.
Firms pay a proportional tax τ on positive profits; negative profits will be subtracted from the next positive profits. We indicate net profits with $\bar{\pi}_{ft}$.
Finally, firms pay a percentage δ_{ft} as dividends on positive net profits. The fraction $0 \leq \delta_{ft} \leq 1$ evolves according to the following rule:

$$\delta_{ft} = \begin{cases} \delta_{ft-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \hat{y}_{ft} = 0 \text{ and } y_{ft} > 0 \\ \delta_{ft-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } \hat{y}_{ft} > 0 \text{ or } y_{ft} = 0 \end{cases} \tag{13}$$

This means that firms distribute less dividends when they need self-financing to expand production (that is, they do not have inventories) and viceversa. The profit net of taxes and dividends is indicated by $\hat{\pi}_{ft}$. In case of negative profits $\hat{\pi}_{ft} = \pi_{ft}$.

Thus, the evolution of firm f's net worth is given by:

$$A_{ft} = (1 - \tau') \cdot [A_{ft-1} + \hat{\pi}_{ft}] \tag{14}$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price).

If $A_{ft} \leq 0$ then the firm goes bankrupt and a new entrant takes its place. The initial net worth of the new entrant is a multiple of the average goods price, while the leverage is one. Moreover, the initial price is equal to the mean price of survival firms. Banks linked to defaulted firms lose a fraction of their loans (the loss given default rate is calculated as $(A_{ft} + B_{ft})/B_{ft}$).

2.5.2 Banks

According to the operations in the credit and the deposit markets, the bank b's profit is equal to:

$$\pi_{bt} = int_{bt} + i_t^{\Gamma} \cdot \Gamma_{bt} - i_{bt-1}^{D} \cdot D_{bt-1} - i_{CB}^{t} \cdot m_{bt} - bad_{bt} \tag{15}$$

where int_{bt} represents the interests gained on lending to non-defaulted firms, i_t^Γ is the interest rate on government securities (Γ_{bt}), and bad_{bt} is the amount of "bad debt" due to bankrupted firms, that is non performing loans. Bad debt is the loss given default of the total loan, that is a fraction $1-(A_{ft}+B_{ft})/B_{ft}$ of the loan to defaulted firm f connected with bank b.

Banks pay a proportional tax τ on positive profits; negative profits will be subtracted from the next positive profits. We indicate net profits with $\bar{\pi}_{bt}$.

Finally, banks pay a percentage δ_{bt} as dividends on positive net profits. The fraction $0 \leq \delta_{bt} \leq 1$ evolves according to the following rule:

$$\delta_{bt} = \begin{cases} \delta_{bt-1} \cdot (1-\alpha \cdot U(0,1)), & \text{if } \; B_{bt} > 0 \text{ and } \hat{B}_{bt} = 0 \\ \delta_{bt-1} \cdot (1+\alpha \cdot U(0,1)), & \text{if } \; B_{bt} = 0 \text{ or } \hat{B}_{bt} > 0 \end{cases} \tag{16}$$

Hence, if the bank does not manage to lend the desired supply of credit then it decides to distribute more dividends (because it does not need high reinvested profits), and viceversa.

The profit net of taxes and dividends is indicated by $\hat{\pi}_{bt}$. In case of negative profits $\hat{\pi}_{bt} = \pi_{bt}$.

Thus, the bank b's net worth evolves as follows:

$$A_{bt} = (1-\tau') \cdot [A_{bt-1} + \hat{\pi}_{bt}] \tag{17}$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price).

If $A_{bt} \leq 0$ then the bank is in default and a new entrant takes its place. Households linked to defaulted banks lose a fraction of their deposits (the loss given default rate is calculated as $(A_{bt}+D_{bt})/D_{bt}$). The initial net worth of the new entrant is a multiple of the average goods price. Moreover, the initial bank-specific component of the interest rate ($\hat{i}_{bt}$) is equal to the mean value across banks.

2.5.3 Households

As a result of interaction in the labor, goods, and deposit markets, the household h's wealth evolves as follows:

$$A_{ht} = (1-\tau') \cdot [A_{ht-1} + (1-\tau) \cdot w_{ht} + div_{ht} + int_{ht}^D - c_{ht}] \tag{18}$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price), τ is the tax rate on income, w_{ht} is the wage gained by employed workers, div_{ht} is the fraction (proportional to the household h's wealth compared to overall households' wealth) of dividends distributed by firms and banks net of the amount of resources needed to finance new entrants (hence, this value may be negative),

int^D_{ht} represents interests on deposits, and $c_{ht} \leq c^d_{ht}$ is the effective consumption. Households linked to defaulted banks lose a fraction of their deposits as already explained.

2.6 Government and central bank

Government's current expenditure is given by the sum of wages paid to public workers (G_t) and the interests paid on public debt to banks.[2] Moreover, government collects taxes on incomes and wealth and receives interests gained by the central bank. The difference between expenditures and revenues is the public deficit Ψ_t. Consequently, public debt is $\Gamma_t = \Gamma_{t-1} + \Psi_t$.

Central bank decides the policy rate i_{CBt} and the quantity of money to put into the system in accordance with the interest rate. In order to do that, the central bank observes the aggregate excess supply or demand in the credit market and sets an amount of money M_t to reduce the gap in the subsequent period of time.

3 Simulations

3.1 Baseline scenario

We study the dynamics of the model by means of computer simulations. Table 1 shows the parameter setting of the baseline simulation. The initial agents' wealth is set as follows: $A_{f1} = max\{0.1, N(3,1)\}$, $A_{b1} = max\{0.2, N(5,1)\}$, $A_{h1} = max\{0.01, N(0.5, 0.01)\}$. The policy rate i_{CBt} is constant at 1%. For more details see Riccetti et al (2012).

Computer simulations show that endogenous business cycles emerge as a consequence of the interaction between real and financial factors. When firms' profits are improving, they try to expand the production and, if banks extend more credit, this results in more employment; the decrease of the unemployment rate leads to the rise of wages that, on the one hand, increases the aggregate demand, while on the other hand reduces firms' profits, and this may cause the inversion of the business cycle. Indeed, there is a significant cross-correlation between the unemployment rate and the firms' profit rate. First of all, there is a high positive correlation at lag 0: the profit rate is high when unemployment is high given that firms save on production costs (e.g., wage bill) but, at the same time, the aggregate demand does not decrease proportionally, because of public workers' expenditure and consumption due to wealth, thus firms can sell their commodities (including inventories) in the goods market. However, the presence of unemployed people, the tendency of wages to decrease due to the high unemployment rate, and the reduction of households' wealth, cause the fall of next period aggregate demand that, in turn, reduces firms' profits. Indeed, there is a negative correlation at lag +1. Instead, the negative correlation at lag -1 means that increasing profits boost the

[2] It could also spend an amount Ω_t for extreme cases in which the government has to intervene to finance new entrants when private wealth is not enough. However, in our simulations this never happens.

Table 1: Parameter setting

H	number of households	500
F	number of firms	80
B	number of banks	10
α	adjustment parameter	0.05
χ	matching imperfect information	0.2
ψ	inventory threshold	0.1
γ_1	max bank's leverage	10
γ_2	max % of bank's invested capital in lending	0.5
β	max bank's lending to single firm	0.5
ρ	risk premium on firm's loan	2
c_1	propensity to consume current income	0.8
c_2	propensity to consume wealth	0.3
ϕ	firm's productivity	3
τ	tax rate on income	0.3
τ'	tax rate on wealth	0.05
$\bar{\tau}'$	threshold for tax on wealth	3
g	% of public workers on population	0.33

expansion of the economy and then a fall of the unemployment rate follows. Then, there is a dynamic relation between unemployment and the profit rate underlying the "real" economy, which gives rise to business cycle fluctuations that, in turn, are amplified by a financial accelerator mechanism. Business fluctuations are mitigated by the government, which acts as an acyclical sector, reducing output volatility through the stabilisation of the aggregate demand.

The "real" mechanism is that an increase of profits boosts the expansion of the economy and then a fall of the unemployment rate follows; the low unemployment increases wages, so firms try to save on production costs reducing labor demand. This results in a rise of unemployment that lowers the profit rate at the subsequent period due to a lack of aggregate demand. However, the presence of unemployed people decreases wages and this makes firms to hire a larger number of workers, so boosting the beginning of a new expansionary phase of the business cycle.

Firms' leverage and banks' exposure are the financial drivers that enlarge business fluctuations: growing firms ask for more credit and, if banks extended new loans, then they expand the production; subsequently, the low unemployment fosters wages that, together with the rise of interest payments on an increasing debt, reduces firms' profitability. Thus, the business cycle reverses and financial factors amplify the recession, indeed the relatively low level of profits with respect to interest payments induces a deleveraging process. According to the empirical evidence (for example, Kalemli-Ozcan et al., 2011), there is a negative but modest correlation between firms' leverage and the unemployment rate, while there is a more significant negative correlation between banks' exposure and unemployment. Then, banks' capitalization is the most important determinant of credit conditions, so influencing firms' leverage and the macroeconomic evolution.

In some cases, differently from the usual business cycle mechanism, the fall of wages due to the increase of unemployment does not reverse the cycle, but generates a lack of aggregate demand that amplifies the recession in a vicious circle: indeed, the fall of purchasing power prevents firms to sell commodities, then firms decrease production, unemployment continues to rise, and the recession further deteriorates. In these cases, the system may remain trapped in an extended crisis.

3.2 Heterogeneous consumption behaviour

Lets' now compare the result of the baseline model, obtained with a parameter $c_3 = 1$ in equation 8, with the results of the simulations in which $c_3 = 0.5$. Our aim is to address the inequality topic in a symplified framework in which all households have the same skills and they all works in an economy with homogeneous goods. Thus, labour income does not vary much across households and capital income is distributed to households proportionally to their share (which in turn depends on households' wealth). Moreover, all households have a similar initial wealth. Indeed, in the baseline case ($c_3 = 1$), we obtain a wealth distribution that is negatively skewed, while in the real world it is highly positively skewed.

Even in this symplified framework, a propensity to consume decreasing with wealth ($c_3 = 0.5$) modifies the household's wealth distribution. Indeed, in this case we can observe a larger wealth inequality: wealth distribution not only presents a left tail, but also a right tail, thus the richest agent has a higher wealth and the skewness becomes about zero (with a mean slightly higher than the median of households' wealth); the larger inequality is also signaled by an increase of the standard deviation; moreover, average wealth increases given that richest households save more. This analysis on wealth distribution is summarized in table 2.

Table 2: Statistics about wealth distribution at time T=500 in two simulation with different value of parameter c_3: $c_3 = 1$ and $c_3 = 0.5$

Statistic	$c_3 = 1$	$c_3 = 0.5$
Mean	1.38	1.61
Standard deviation	0.38	0.54
Skewness	-0.72	-0.08
Maximum	2.13	3.28

These results are robust both at different time steps (for instance we check the wealth distribution also at time t=150) and in different simulations. Indeed, we perform a Monte Carlo with 100 simulations on a time horizon $T = 500$ (again skipping the first 100 periods, then we analyse the last 400 time steps).

Table 3 reports some relevant macroeconomic features of the two Monte Carlo simulations with $c_3 = 1$ and $c_3 = 0.5$.

Table 3: 100 Monte Carlo replications for both $c_3 = 1$ and $c_3 = 0.5$ (data calculated on time span 101-500). The number of simulations with average unemployment rate and maximum unemployment rate above 20% are computed on all 100 simulations. Instead, the other statistics refers to simulations with average unemployment rate below 20% (that is 98 simulations for both cases); in brackets we add the standard deviation of the corresponding statistic among the simulations; the last column indicates the p-value of the test on the null hypothesis that the value of the statistic is equal between the two cases of $c_3 = 1$ and $c_3 = 0.5$.

Variable	$c_3 = 1$	$c_3 = 0.5$	p-value H_0=0
Sim. with mean(ur) < 20%	98	98	
Sim. with max(ur) < 20%	97	90	
Unemployment rate %	9.73 (0.87)	9.71 (0.61)	85.2%
Unemployment volatility %	1.84 (0.12)	2.17 (0.18)	0.0%
Firm default rate %	6.21 (0.70)	6.51 (0.60)	0.1%
Bank default rate %	0.40 (0.38)	0.32 (0.37)	13.5%
Firm mean leverage	1.23 (0.31)	1.10 (0.21)	0.1%
Firm leverage volatility	0.23 (0.07)	0.30 (0.07)	0.0%
Interest rate %	8.04 (0.81)	8.51 (0.77)	0.0%
Credit constraint %	4.15 (1.64)	8.79 (2.57)	0.0%
Wage share %	63.7 (0.3)	63.6 (0.2)	0.7%
Public deficit %	3.16 (0.05)	2.96 (0.06)	0.0%
Inflation rate %	1.99 (0.04)	1.99 (0.03)	100%

We can observe that in both cases the economy falls in a large crisis scenario, that is with a mean unemployment rate above 20%, 2 times over 100 simulations and the mean unemployment rate is the same. However, the unemployment volatility is much higher when $c_3 = 0.5$, that is whith larger wealth inequality, and the difference is statistically significant at 99% level. Therefore, the business cycle is "larger" with a lower minumum and a higher maximum for the unemployment rate. Indeed, while in the baseline case ($c_3 = 1$) we never find a time step with unemployment above 20%, but for the two large crisis scenario, in the inequality case ($c_3 = 0.5$) we detect 10 simulations in which the unemployment peaks above 20% (the two large crises plus other 8 simulations). If the policy maker considers the business cycle volatility as a problem to be stabilised, than the reduction of the wealth inequality seems to be an effective tool to reach this target. Especially, the policy maker could avoid large unemployment crises (e.g., with an unemployment rate above 20%) by reducing inequality. For instance, in an agent based macroeconomic setting, Dosi et al. (2013) find that more inquality leads to higher volatility, increasing the likelihood of unemployment crises; they also show that fiscal policy is an effective countercyclical tool especially when income distribution is skewed towards profits.

It is worth to note that the percentage of firm defaults increases in the case of $c_3 = 0.5$, probably due to higher macroeconomic volatility. Indeed, the mean firm leverage is lower in this case, then the economy should be safer according to this indicator. Instead, this is not the case given that firm leverage is more volatile, giving rise to the already mentioned "larger" business cycle, with stronger leveraging and deleveraging processes. Moreover, the higher volatility, that highlights a riskier economic environment, goes along with higher interest rates charged by banks to firms, that in turn affects both the mean firm leverage (lower, because it is less favorable to ask money to banks) and the number of firm defaults (higher, because of the higher cost of the debt).

We calculate the credit constraint as the percentage of credit required by firms that firms do not obtain. Given that we observe a correlation above 50% between firm leverage and credit constraint, and given that in the case of $c_3 = 0.5$ firm leverage is more pro-cyclical, in this situation there are periods in which the credit constraint is stronger. We can confirm this analysis computing the average of the standard deviation and the average of the maximum credit constraint in the two Monte Carlo settings: when $c_3 = 0.5$ the average standard deviation is 8.16% and the average maximum is 35.08%, while if $c_3 = 1$ the average standard deviation is 5.75% and the average maximum is 26.97%. Given that the distribution is truncated at zero (and it often happens that firms receive all the required credit), the longer right tail of the distribution in the case of $c_3 = 0.5$ explains the higher mean credit constraint. Moreover, this is another further which can eplains why the mean leverage is lower when $c_3 = 0.5$. Finally, the relation between firm leverage and credit constraint has both causal direction: a higher firm leverage implies a higher probability of credit constraint, but also a higher credit constraint implies a lower leverage, because firms are not able to reach their desired leverage. The wage share is statistically different between the two Monte Carlo, but the difference is economically not significant. The similar wage share between the two Monte Carlo experiments implies a similar pressure to increase wages and thus similar effets on price dynamics. Indeed, the inflation rate is the same in both cases.

Instead, the public deficit is slightly lower in the case with $c_3 = 0.5$, given that in this case there are richer households and we assume the presence of a 5% tax rate on wealth (only above a certain wealth level). However, in both cases the public deficit remains on admissible values (compared to GDP).

To summarise, we observe a negative impact on the economy of a propensity to consume that decreases with wealth (that also creates an economic system with larger wealth inequality). Indeed, in this case the business cycle is "larger" and we count a higher number of simulations in which we detect large unemployment crises. This riskier economic environment with a stronger volatility implies a larger number of firm defaults, a higher mean interest rates, and a higher mean credit constraint.

4 Concluding remarks

We proposed an analysis of the effects of wealth inequality on macroeconomic dynamics in an economy composed of heterogeneous households, firms, banks, and two policy makers, that is the government and the central bank. Preliminary results show that more inequality rises macroeconomic volatility, increasing the likelihood of observing large unemployment crises. However, we are just making the first steps towards a better understanding of increasing inequality on the evolution of a complex macroeconomic system. Next step in this direction is the introduction of consumer credit, through which the saving of rich can finance the consumption of poor. Actually, consumer credit and other forms of indebtedness can prevent the lack of aggregate demand to happen for a while, but probably at the cost of more financial instability, that may increase the likelihood of large unemployment crises. In other words, in a context of growing inequality, debt accumulation may increase financial fragility, spreading in the system through credit interlinkages (Delli Gatti et al, 2010), eventually leading to a financial collapse. So finance may postpone the crisis due to the lack of aggregate demand, but it also creates the bases for a later crisis.

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