

## Authors' reply to Referee 1

We are deeply grateful to the referee for his insightful comments and suggestions, which will be very useful for revising the paper. According to the comments, the most critical issues of our work are the presentation and interpretation of the results.

As the review is very detailed, in the following we are going to give a specific reply to every single comment, which we report for expositional convenience. We hope that our answers will help clarify the issues raised.

**REFeree** In the abstract you state that *“The result emerges that a more restrictive monetary policy increases inequality, even though this effect may differ across groups of households. This may put into question the principle of the independence of central banks”*. I think your inference here is too strong, the fact that a monetary contraction can cause inequality can be an useful information for central banks but does not imply central banks should not be independent. So, I suggest to remove this statement, unless you unfold the concept more in-depth. By the way, the verb “emerge” is intransitive and I think the way you use it in the sentence is not correct; you can use “highlights” or a similar verb.

**AUTHORS** The issue is complicated and of course cannot be settled in this place. We are not claiming that central banks should not be independent just because a restrictive MP increases inequality. But the evidence is that central bankers have powers that have similar effects to those of fiscal policy. So, if fiscal policy decisions are taken by governments that need to pass through the democratic process of elections, maybe something similar should apply to monetary policy decisions as well. Anyway, we will elaborate more on this point in future revisions of the paper.

As for the grammatical remark, we believe that the sentence is correct. It is like, for example: “given the assumptions, the result is obtained that  $2+2=4$ ”.

**R** When you talk in the introduction about the stock-flow consistency approach in agent-based models, I think you should cite the Eurace model, which, as far as I know, has been the first model to adopt convincingly this approach. For instance Cincotti (2010) presents such a model, and Tegli (2010) explains its basic balance sheet consistency properties.

**A** We will cite also the Eurace model.

**R** In page 6 you state *“This consistency implies model closure, in the sense that no external resource is incorrectly added to the system and no internal resource is lost”*. I think this is a questionable way to present consistency. If you add incorrectly something, it means your model is just wrong...

**A** We are not claiming that consistency reduces to the fact that resources are not incorrectly added or subtracted. This is just one important consequence of consistency, provided that the model is correctly coded. In fact, you can have a perfectly-coded model in which external resources coming from the outset get added to the agents' state variables, for instance when firms need to be replaced after defaulting. This does not happen with SFC models.

**R** Equation 12 describes the dynamics of outstanding debt. As far as I understand  $\tau$  includes the payment of the interest and the principal. This can imply a strong bias towards repaying a high fraction of the loans in first time steps. In other words, it does not smooth repayment over time. In turn, this can cause additional instability to the economic system, affecting the bankruptcy rates and other key indicators. Please comment on this topic, and explain why your assumption is acceptable.

**A** The referee is right, a proportional repayment scheme imposes a higher burden on the first time steps after a firm has borrowed money. However, this bias is partly mitigated by the fact that firms in general ask for loans several times to finance production. Hence, not necessarily the average per-period repayment decreases monotonically over time, unless the firm completely stops borrowing. Hence, a fixed-amount repayment scheme may not make much difference.

**R** At page 13, the authors state "*Consumers randomly enter the goods market and, because of search costs, visit only a fixed number  $Z$  of firms, one of them being the largest (in terms of production) firm visited in the previous period. We assume consumers to adopt this sort of "preferential attachment" mechanism in order to minimize the probability to be rationed*". This allocation mechanism reinforces large companies and seems to ease a fat tailed distribution of companies' sales. As your paper studies inequality, this assumption could be relevant and should be discussed. I understand that firms have no ownership structure, and therefore there is no clear channel for propagating this asymmetry on sales to households, however you should state in a more convincing way why you need this assumption and what are the main implications for the model.

**A** The referee is right in pointing out that this assumption does not have direct implications for inequality. However, we found that this assumption plays an important role in shaping business fluctuations and in adding realism to the model at business cycle frequencies. Hence, the mechanism does have *indirect* implications as it concurs at creating realistic fluctuations in unemployment, which is crucial for inequality.

**R** Equation 17 presents the consumption rule. If I understand correctly the equation, consumption depends on wealth, not on income;  $(D + I)$  is the current wealth of the household (by the way, I could not find the value of parameter  $c$  in table 3). Is there a particular reason for this choice? Moreover, the choice does not seem neutral with respect to the studied topic, as consumption directly depends on the interest rate, i.e., an increase in  $i$  also increases consumption, especially if the deposits of the household are high enough. This mechanism might be responsible of some of the observed outcomes.

**A** We used this mechanism because of its simplicity. We also tried buffer-stock rules but with no major difference. Moreover, we can justify it by invoking Keynes' "fundamental psychological law" of consumption, which postulates a constant marginal propensity to consume (smaller than 1). As for its impact on inequality, we believe it to be the most neutral mechanism possible because the MPC is constant across time and individuals. This allows us to better assess the impact of monetary policy abstracting from possible feedbacks. If in fact we used an endogenous MPC responding to changes in income, then the monetary

policy effect would be entangled with that of the MPC. Of course, in reality nothing prevents the MPC from being a transmission channel of monetary policy, but with an endogenous MPC our analysis would possibly be less clear.

By the way, the value of  $c$  is set to 0.8 in the baseline simulation. We will complete table 3 accordingly.

**R** Concerning the bank and its financial intermediary role, I have some observations. In the model you don't have the concept of savings, as consumption depends directly on wealth. A part of this wealth is consumed, and a part is left as deposits. Banks do not look at deposits when granting loans, but create new (endogenous) money. So, why should banks pay interest on deposits? What is the significance and what are the economic implications of this financial payment? May be some words of discussion should be spent on this topic.

**A** We disagree on the first remark as households do have savings. As for the interest paid on deposits, we suppose that the bank acts both as a commercial bank making loans and as a reduced-form financial system. We recall that real banks are always both creditors and debtors. When the policy rate increases, all interest rates increase, so the burden of servicing outstanding debts increases for banks. At the same time, savers' capital income increases, too. Hence, we deemed this modeling choice as the easiest way to implement the typical interest-rate channel of monetary policy. Of course, we recognize that this comes at the cost of blurring the difference between short-term investments (cash and checking-account deposits) and longer-term investments (bonds, time deposits, etc.).

**R** At pages 14 and 15, the bankruptcy mechanism is described. I need some clarifications about the modelling choices here. 1) Borrower's leverage affects interest rate but not credit rating. Is there a reason why credit rating does not depend on leverage, as a measure of financial stability of the firm? 2) Credit rating, instead, depends on previous defaults of the company. However, defaulted firms are replaced with new firms that should be able to compete in the market, and that are in principle a different entity. It is true that they inherit a part of the old debt, but it looks a bit strange to me that the credit rating depends exclusively on this measure based on previous defaults. As you basically perform a sort of bail-out financed by taxes, it wouldn't be strange to expect even a cancellation of the memory of defaults. Here the authors should explain better the rationale of their choice. Moreover, at page 16 the authors state that "*bankruptcies, in fact, lower firms' credit worthiness and leads to credit rationing by the bank*", highlighting the crucial role of this rule and the need to support it in a more substantial way.

**A** As for the first point, the interest rate depends on leverage because we implemented a simple financial accelerator mechanism as a price credit rationing mechanism. Besides, we also implemented quantity rationing of credit, which depends on the firms' expected default risk (as in the classic Stiglitz-Weiss model). We think that the most natural way for the bank to assess this risk is to look at the actual default rates. Of course, other assessment methods based on leverage or on collateral (à la Kiyotaki-Moore) could be implemented.

As for the second point, we do not completely agree with the referee. There are many reasons why the record of defaults may not be cancelled. One is that replacements can be simply interpreted as a firm restructuring, so basically the "new" firm is still the old one but

with more financial resources paid by the tax-payer. And this is consistent with our choice of a partial write-off of debts.

**R** At page 22, you state *“Unlike mainstream micro-founded models, in fact, in multi-agent frameworks there is in general no one-to-one relationship between micro and macro variables. Consequently, the lack of clear causal links between emergent macro-phenomena and individual behavioral equations makes the interpretation of the results quite an arduous, if not totally futile, task”*. I do not agree with your statement. The task might be arduous but it is by no means futile. On the contrary this is the most important task of agent-based macroeconomics, because we need to understand which are the aggregation properties in economics. If we consider this task as futile, then I’m afraid we are undermining the agent-based approach at its very core. I suggest to remove or modify this statement, and I ask the authors to make their vision more explicit, because I might have misunderstood something.

**A** Probably the use of the word 'futile' was unfortunate. Maybe 'hopeless' captures better our real meaning. The referee would agree with us that interpreting the results of complex/complicated models is sometimes a really daunting task, precisely because it is not possible to directly link micro and macro variables. Indeed, if one takes an extreme position about complexity, the very notions of 'cause' and 'effect' become at least problematic (but we are not on this position). However, we can solve the problem by simply deleting the word 'futile'.

#### Section 4.1

In this section, the authors describe the results of the policy experiment. However, they should state in a very clear way how monetary policy channels into the economic system. This information is crucial to understand what’s going on, and I think it is not remarked with sufficient strength.

**R** As far as I see, monetary policy does not propagate through the money supply in the system (as deposits are not affected) but directly through the change of the interest rate by the central bank. In other words, you have an endogenous money supply mechanism that generates new deposits for firms as soon as a new loan is granted, and a monetary policy that does not operate through money creation. It would be interesting to check the how the money supply and interest rate dynamics are related.

**A** Actually, we have never thought about this relationship. It is indeed interesting, but at the present time not strictly necessary to our scope.

**R** The interest rate affects financial returns (deposits rate) and the loan rate. If I did not miss anything, these should be the two transmission mechanisms in the model. Of course they are not exhaustive, even with respect to the list of propagation mechanisms cited in the paper, but I understand that simplifications are needed to keep the model simple. However, in order to understand the results, you should try to connect them in a more systematic way to these propagation mechanisms.

**A** We agree, we can try to better connect the results to the propagation mechanisms.

However, in part we have already done this, as we have remarked that monetary policy affects capital income and unemployment (through higher loan rates).

**R** The authors state at page 23 that the bottom 50% of households is mostly made by unemployed workers but this would imply a quite high unemployment rate that does not seem consistent with the Phillips curve in figure 3a. Please explain. In any case, your statements on the composition of the three groups that you define (e.g., bottom 50%, middle 40% and top 10%), in terms of income type (labor and capital) should be supported by some evidence.

**A** We thank the referee for pointing out this inconsistency. In fact, we have realized that figure 3 (a) and (c) are upside-down as we have mistakenly inverted the x-axis with the y-axis. Basically, unemployment rate is on the vertical axis.

Our definition (in terms of income and capital) of the three groups could be supported by the extensive evidence presented in Thomas Piketty's book "Capital in the twenty-first century" (2014). According to the data reported in that book, the share of wealth belonging to the bottom 50% group is in general no more than 5%, while the top 10% group may own a share as large as 90% (like in Europe at the beginning of the 20th century or, possibly, in the USA in the near future).

**R** The authors motivate the effects of the policy experiment by citing an increase in the unemployment rate and a decrease in (real?) wages. I think they should report these economic indicators to help reader's understanding. Moreover, the explanation that the authors give is not quite clear to me. Why does a higher interest rate increase unemployment rate in the model? In principle, aggregate demand, according to equation 17, should increase. So, is the problem a higher cost of loans and a higher default rate? But in this case, if the problem is a supply side problem, then the way in which firms' defaults are designed in the model could have a crucial role (see my previous comments) and should be discussed in the results part.

**A** The referee's intuition is right. Indeed, a rising interest rate increases capital income and therefore consumption by the rich. However, higher rates affect negatively the supply side of the economy, as it reduces firms' cash flows and increases the default rate, which on its turn triggers credit rationing. We agree that this mechanism can be stressed more. However, we point out that in this section we are interpreting the evolution of inequality, not the causes of economic fluctuations.

**R** Another issue that could be clarified by the authors is how are labor income and capital income related, as their interpretation of results is based on the interaction of these two elements.

**A** This is an issue that could be investigated more deeply. In general, there should be a positive relationship, as capital income depends on wealth distribution, whose inequality is increased by previous labor income inequality.

**R** Also the explanations about the behavior of the 40% middle households is not very clear. Why decreasing (homogeneously?) wages should offset the inequality due to higher capital

income? In figure 7 it happens the opposite as inequality increases, but not for the top 10%...

**A** When wages decrease, also their dispersion decreases, leading to an overall decrease in inequality for the 40% and 10% groups. This is the explanation we give for the first "low-rate" scenario (figure 4), when capital income does not increase much. Conversely, in the "high-rate" scenario (figure 7) we believe that the increase in capital income inequality becomes the driving force, as the change in monetary policy is more pronounced. As a consequence, in the long-run inequality surges for both groups.

**R** I think the authors should provide more material to support their interpretation of results.

**A** We can try to find more empirical evidence, although to our knowledge there are not many works on disaggregated Gini indexes. However, once again Piketty (2014) is a good support. For instance, one important insight from that work is that inequality increases when the return on capital is larger than income growth rate. This is exactly what we have in the paper: an increase in the interest rate, which is also the return on capital, reduces income growth rate (by depressing the economy) and pushes inequality up.

**R** Concerning section 4.3, I find it very interesting. May be the authors should indicate clearly the level of significance of the regression coefficients, for example showing the classic stars, in order to facilitate the reader.

**A** We can do it.

Minor points (just a few examples, please check carefully the paper)

**R** Page 2, par. 3, line 6: "whereas" suggests a contradiction and not that "they find the same evidence". Use an alternative conjunction.

**A** One study is about the US, "whereas" the other is about the UK. Anyway, we can think about a better conjunction.

**R** Page 5, line 2: you do not "simulate" a model in a section. I suggest revising.

**A** Why not?

**R** You use the same letter D for Demand, Firm's deposits, Household's deposits, and total bank's deposits. This can generate some confusion. I suggest, for instance, to use  $D_h$  and  $D_f$ , as you do in table 1.

**A** We can follow the referee's suggestion.