

Discussion of
*E Pluribus Unum: Macroeconomic Modelling for Multi-agent
Economies*
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What is this paper about

- I enjoyed reading the paper!
- The paper is clearly focussed and offers a very neat procedure towards the interpretation of transmission mechanism and the use of macroeconomic intuition in multi-agent models.
- The main contribution of the paper is to propose an aggregation procedure to circumvent the difficulty of thinking in macroeconomic terms when dealing with a multi-agent economy.
- *MRA* (Modified-Representative Agent) aggregation procedure: approximates the evolution over time of the entire distribution of agent's characteristics using a finite set of moments of the distribution.
- Using this procedure the authors build what they call a *M&ABM* (Macroeconomic and Agent Based Model).

The model is built in steps

- 1 Build a *macroeconomic model* a la Greenwald and Stiglitz which is essentially a small heterogeneous agent model in which firms differ from one another in the *equity ratio*. The moments of the distribution of the equity ratio determine the average EFP which affects aggregate output and interest rate.
- 2 Build a *multi-agent* model that determines the moments of the firms' equity ratio. The aggregate interest rate affects the accumulation of net worth at individual firm level.
- 3 Two way relationship between the macroeconomic and the AB model.
- 4 Simulations of the AB model yield the evolution over time of the equity ratios from which they compute cross-sectional first and second moments.
- 5 They compute the long run mean and variance of the equity ratio which determines the long run EFP which in turn determines the equilibrium interest rate and output gap.
- 6 They use the final model to explore the impact of a *financial shock* (exogenous increase in the probability of bankruptcy) and a *monetary shock* (exogenous increase in money supply).

Results

- *Financial Shock*: Heterogeneity contributes to amplification with respect to the RA case because the increase in dispersion contributes to the increase in the EFP.
- *Monetary shock*: Heterogeneity contributes to amplification because the decrease in dispersion contributes to the decrease in the EFP.
- Mechanism of transmission similar to a financial accelerator.
- Robustness
- But the main focus of the paper is methodological.

Comments: (I) ABM vs DSGE models and the data

- AB Models construct multi agent frameworks where agents use simple behavioural rules to cope with complex and dynamic environments (Howitt (2011)).
- DSGE models assume that agents have very sophisticated computational capabilities (perfect information, rational expectations and representative agent) in very simple environments.
- This paper tries to bridge the gap between DSGE and AB models by linking an heterogeneous agent DSGE model and an AB model.
- One of the main problems of AB Models is the difficulty to estimate them against real data like we do in DSGE models using Bayesian techniques. So the next step should be to test how your proposed aggregation method performs when you take your model to the data.
- Traditional Bayesian inference requires explicit calculation of the 'likelihood', the probability of observing the data, given some parametrization of the model. However, away from the linear-normal case, closed form expressions for the likelihood do not usually exist. For models with a small number of state variables, particle filter techniques may be used to obtain unbiased estimates of this likelihood which is sufficient for accurate computation of posterior densities when used inside a Metropolis-Hastings algorithm (Andrieu et al. (2010)).

Comments: (I) ABM vs DSGE models and the data

- AB Models have at least as many state variables as there are agents, and so particle filter techniques are not computationally feasible. Marjoram et al. (2003) developed an Approximate Bayesian Computation approach that circumvents the need to calculate the entire likelihoods and enables the computation of approximate posterior densities for any models which can be simulated, including AB models.
- Chang et al. (2013) present a very careful look at the aggregation problems in DSGE models from an empirical standpoint. They assess the quantitative importance of biases in policy predictions due to the potential lack of invariance of preference and technology parameters in representative-agents models.
- By estimating a RA model using simulated data from an heterogeneous-agent economy (from the household side) under different policy regimes, several important parameters vary considerably. They demonstrate how the RA model that abstracts from cross-sectional heterogeneity on the household side can potentially mislead fiscal policy predictions.
- Would be interesting to see a similar exercise using an extended version of your model (including policy analysis). And see if a *M&ABM* performs better than a RA empirically.

Comments: (II) The Macroeconomic Model

- AB Models construct multi agent frameworks where agents use simple behavioural rules to cope with complex and dynamic environments (Howitt (2011)).
- Your macroeconomic model is too simplified even for a DSGE:
 - 1 Linear production function $\rightarrow x_t$ changes 1 to 1 with the output gap.
 - 2 Real Wage is constant.
 - 3 no dis-utility from labour.
 - 4 flexible prices
 - 5 no room for policy exercises
 - 6 DSGE literature has developed richer models that can deal for example with Unconventional Monetary policy, crisis management ect...
- I understand that from a methodological point of view you needed a small and tractable model for your paper, but I would personally find it very interesting to asses the differences between a RA model and a *M&ABM* with a richer set of assumptions.