Agent Based Macroeconomics: A Syncretic View

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Motivation

Try to convince the skeptics that **macroeconomic Agent Based Models** (macro ABMs)

- are appropriate macroeconomic toolkits, expecially in our complex times;
- retain some ideas, notions, tools from "canonical" macroeconomics (with frictions);
- can be "reconciled" with canonical macroeconomics by means of hybridization.

Outline of the talk

- A primer on macro ABMs
- Microfoundations
- Hybrid macro ABMs

What is a macro ABM?

- A macroeconomic ABM is a model of the macro-economy as a complex adaptive system in which a multitude of *heterogeneous* agents (firms, households, banks) *interact* with each other and the environment.
- Aggregate (macroeconomic) variables such as GDP, consumption etc. are computed "from the bottom up" i.e. summing individual quantities across agents.

An appropriate toolkit for complex times...

"A modern economy is a complex web of interconnected parties: employees, firms, suppliers, consumers, banks and financial intermediaries. . . Everyone is someone else's employee, customer, lender, etc. A sudden stop [such as Covid-19] can easily trigger a cascading chain of events, fueled by individually rational, but collectively catastrophic, decisions."
P.Gourinchas (2020)

...which springs from Simon's prescient vision

"The very complexity that has made a theory of the decision-making process essential has made its construction exceedingly difficult... It seemed almost utopian to suppose that we could put together a model of adaptive man that would compare in completeness with the simple model of classical economic man...The modern digital computer has changed the situation radically. It provides us with a tool of research ... whose power is commensurate with the complexity of the phenomena we seek to understand....As economics finds it more and more necessary to understand and explain disequilibrium as well as equilibrium, it will find an increasing use for this new tool and for communication with its sister sciences of psychology and sociology."
H.Simon (1959)

How to build a macro ABM

- Starting point: consider a population of heterogeneous agents (households, firms, banks,...).
- Theory: write behavioral rules (e.g. demand and supply of goods, labour, credit).
- Codification: translate the rules into code lines.

How do we build a M-ABM? (cont'd)

- Validation:
  - calibrate/estimate the parameters,
  - run simulations,
  - analyze the emerging properties of the simulated data, both at the cross-sectional level (e.g. firms' size distribution) and at the macroeconomic level (GDP growth and fluctuations, inflation/unemployment trade off),
  - compare these properties with real world stylized facts (e.g. volatility and correlation of macro-variables).

Macro AB frameworks

There is a network of Macro ABM researchers based predominantly in Europe but present also in the US. Two (very broad) classes of models:

- Macro ABMs in which *financial factors* play a major role in business fluctuations.
- Macro ABMs in which *capital accumulation, embodied technical progress* and *skill dynamics* generate growth, fluctuations and inequality dynamics.

2 objections

The research area is thriving but ...

- **Objection 1**: aren't we "into the wild"? Too many people, doing too many things, starting from too many diverse assumptions.
- **Objection 2**: these assumptions have nothing to do with the core of current macroeconomics.

Digging deeper..

- we find common threads that connect different macro ABMs;
- common notions and assumptions are not alien to the way of thinking of the "standard" macroeconomist.

Behavioural rules

Agents are affected by bounded rationality, hence they are not "global optimizers". Behavioral rules (at the micro level) therefore are best described by heuristics or rules of thumb. However

- some behavioral rules *may be* derived from specific optimization problems, based on local information and over short time horizons (local, myopic optimal rules);
- some of the fundamental assumptions in this literature are borrowed from canonical macro (with plenty of "frictions") as shown in Dawid, H. and D. Delli Gatti, "Agent Based Macroeconomics", in *Handbook of Computational Economics* (2018).

An example

Think of the literature on financial frictions.

- In a sense, this is an "epicycle" necessary to reconcile the canonica macro DSGE models with reality...
- .. but in economics *epicycles contain a grain of truth*.
- The "stories" attached to financial frictions (costly state verification, collateral constraints, bankruptcy costs) capture elements of the real world which are frequently incorporated in sophisticated ABMs.
- From this literature, AB macroeconomists borrow insights to model behavioural rules for their models.

Objection 3

- In a macro ABM the time series of artificial macroeconomic data generated by simulations follow the same pattern of *irregular fluctuations* (around a quasi-stationary long run "equilibrium") shown by the empirical time series of GDP.
- When a change of an exogenous variable (may be a policy move) generates changes in this macroeconomic pattern we are (almost) in the dark ...*interpretation is difficult and somehow arbitrary*
- **Objection 3**: ABMs are *"black boxes"*

A hybrid macroeconomic ABM

- In order to gain clarity in the interpretation of results, it is necessary to *sacrifice* – at least in part – the *richness (and the intricacies)* of macro ABMs.
- Idea: nest an ABM into a standard macro model therefore building a hybrid macroeconomic ABM (Assenza, T. and D. Delli Gatti, E Pluribus Unum, JEDC).
- In so doing we suggest a way to *reconcile macroeconomic thinking and AB modelling*.

Equilibrium/disequilibrium

- AB macro generally rejects the notion of equilibrium/market clearing.
- The auctioneer is a "top-down" coordination device which is in contrast with the "philosophy" of M-ABM. No equilibrium condition required (out-of-equilibrium dynamics).
- This is a major methodological divide..
- ...but the notion of equilibrium can be employed also in hybrid macro ABMs.

The environment

- Closed economy: households, firms, the public sector (a Government and a central bank), financial intermediaries.
- *Firms are heterogeneous in terms of financial robustness*.
- Wages and prices are constant.

Environment

- Firms differ according to *net worth* (as a fraction of the capital stock)

$$a_{it} = \frac{A_{it}}{K_{it}}; i = 1, 2, .., F$$

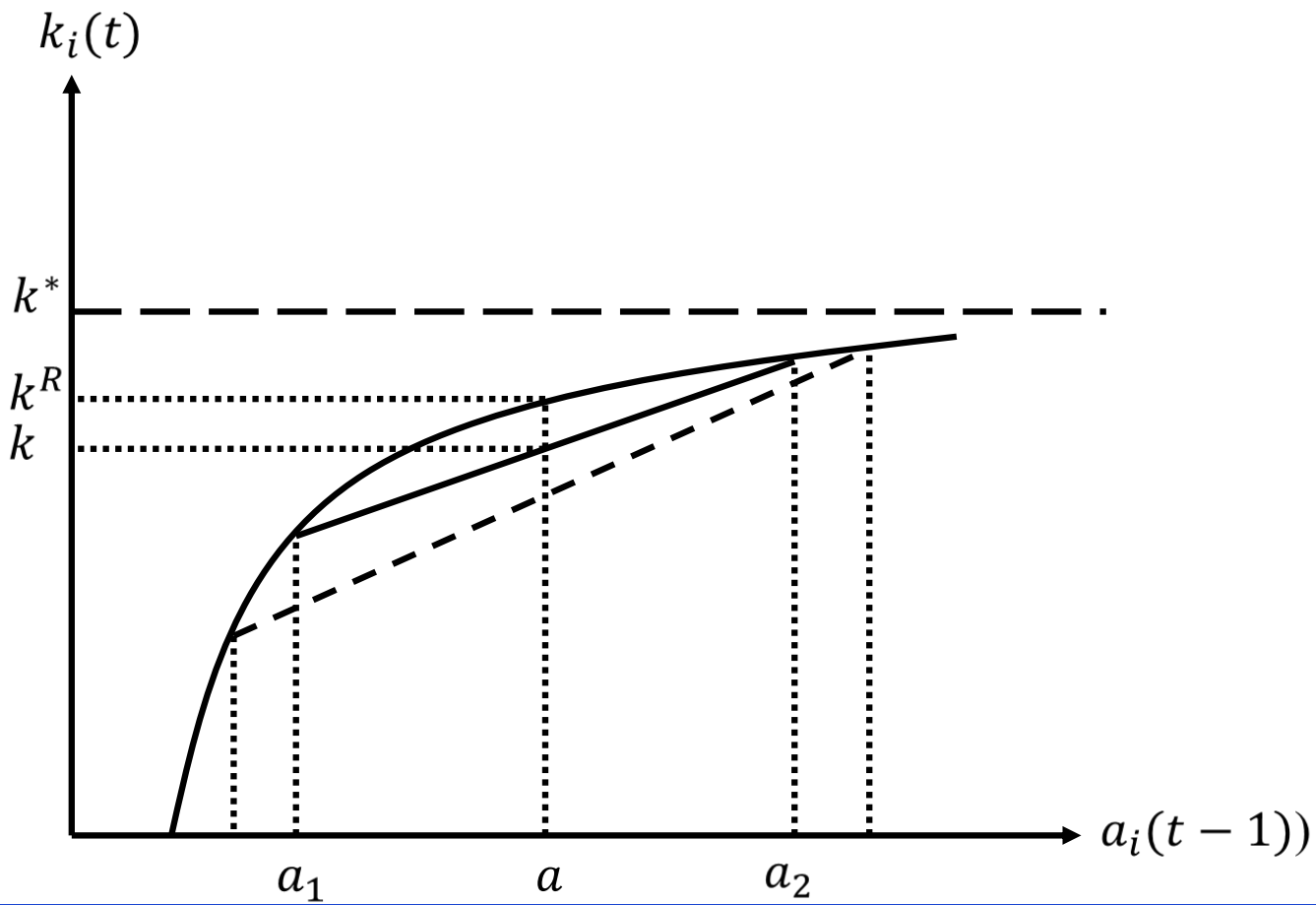
- The distribution of net worth across firms will change endogenously.
- Firm i maximizes expected profit less expected bankruptcy costs (Greenwald and Stiglitz, 1993).
- From the FOC: individual *investment* (as a fraction of the capital stock) k_{it} is a concave function of (lagged) net worth.

$$k_{it} = f(a_{it-1}); f' > 0, f'' < 0 \quad (1)$$

- Notice that we made use of standard myopic optimization techniques.

Net worth and investment

Distribution of net worth across firms $\Rightarrow$ distribution of investment.



The augmented IS curve

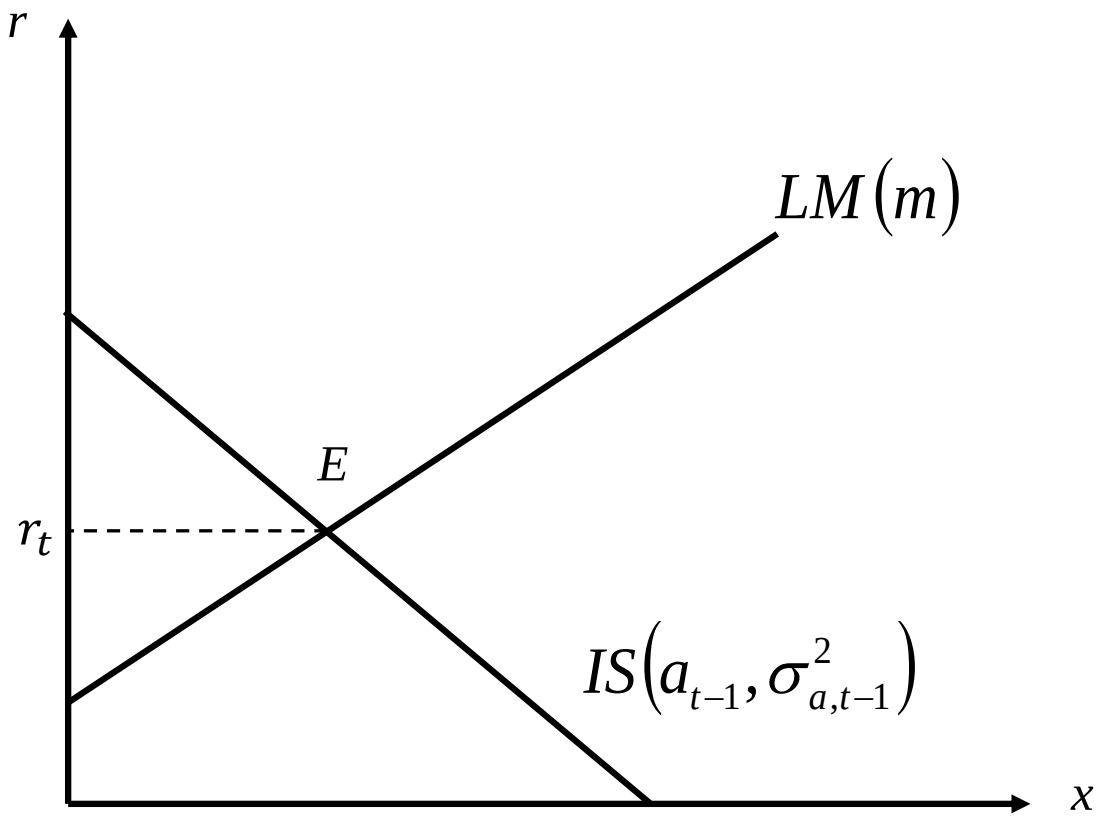
- Equilibrium on the goods market yields:

$$x_t = g(r_t; a_{t-1}, \sigma^2_{a,t-1}) \tag{2}$$

- This is the optimizing *IS curve* on the (r_t, x_t) plane.
- *The moments of the distribution of net worth are shift parameters of the IS curve.*
- Equilibrium on the money market yields the *LM curve*

$$x_t = l(r_t; m) \tag{3}$$

The "moments augmented" IS-LM model



The Law of Motion of net worth

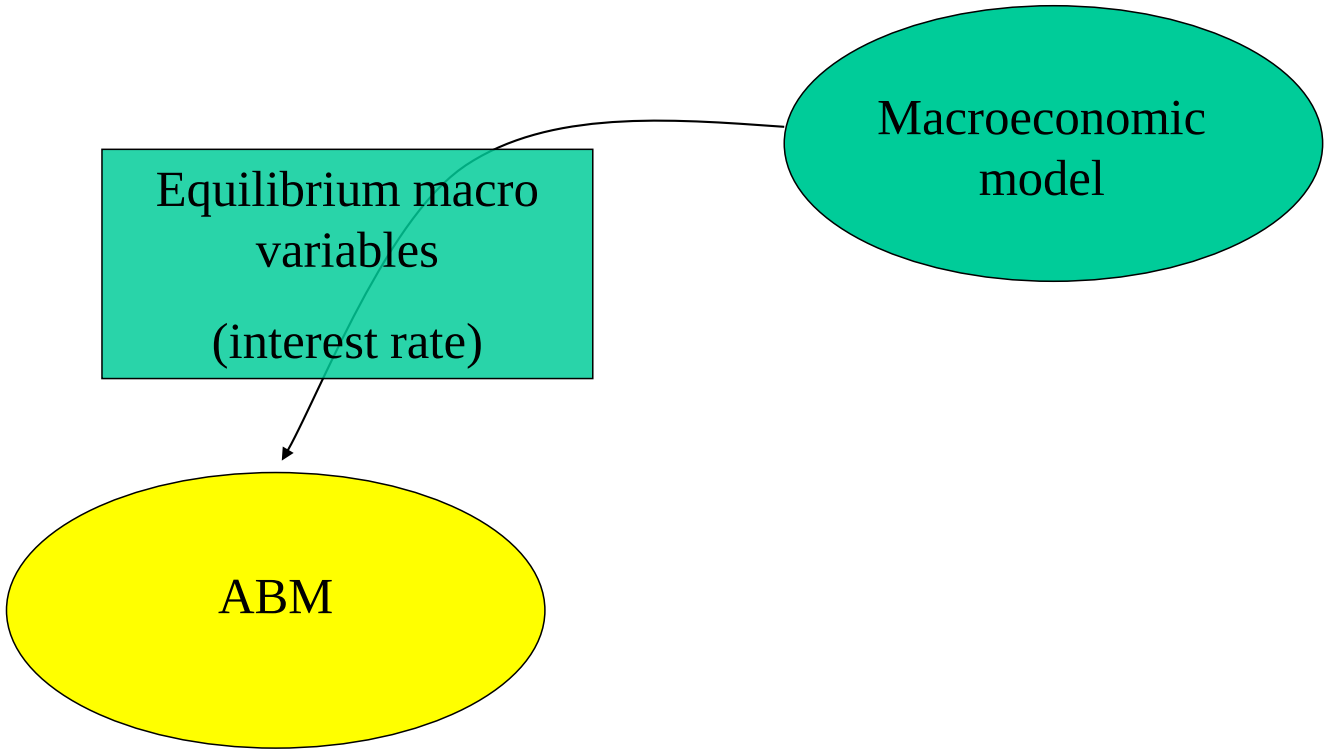
So far, the model provides a frame (in equilibrium!) of a movie. It's high time to consider the dynamics.

- *Net worth at the micro level* follows a non-linear law of motion.

$$a_{i,t} = \phi(a_{i,t-1}, r_t) \; i = 1, 2, ..., N \tag{4}$$

$$r_t = r(a_{t-1}, \sigma^2_{a,t-1}) \tag{5}$$

Feedback 1: from macro to ABM



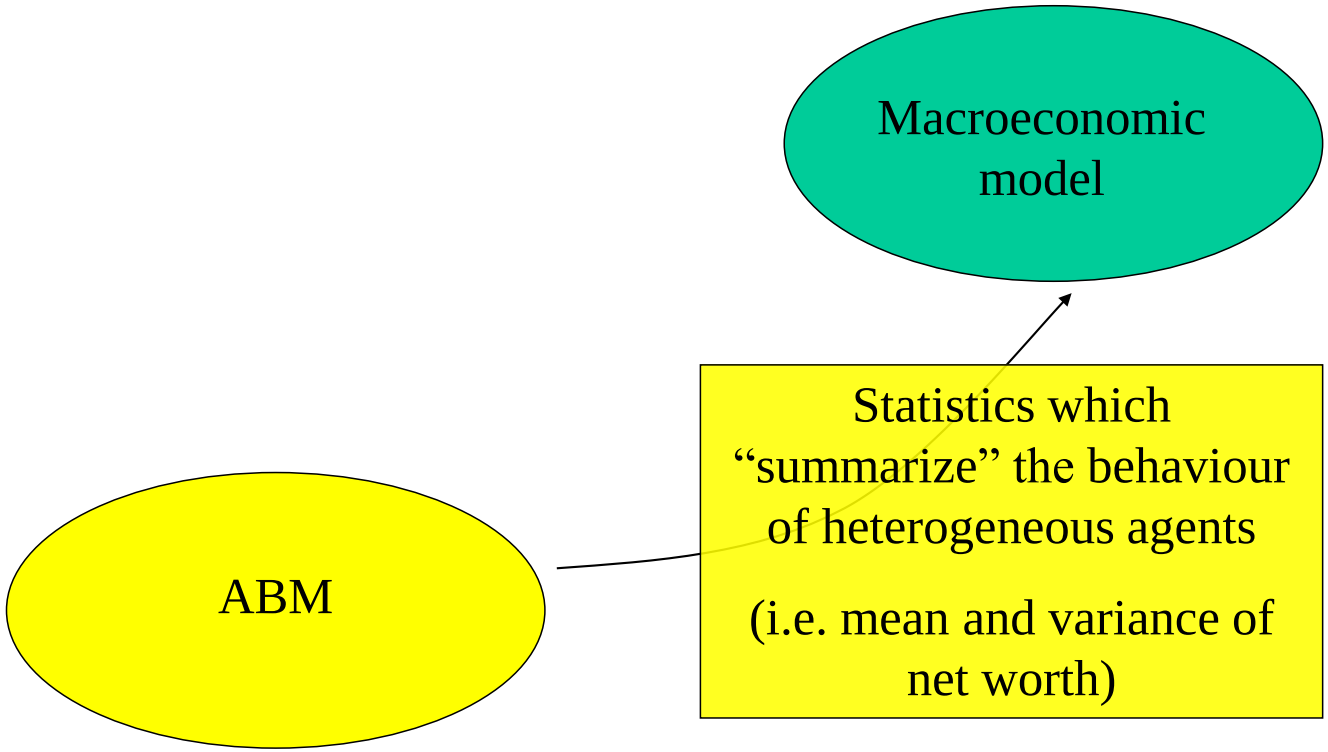
Nested ABM

- By means of the nested ABM we explore the following (nasty) system of non-linear coupled difference equations

$$a_{i,t} = \phi\left(a_{i,t-1}, r(a_{t-1}, \sigma^2_{a,t-1})\right) \quad i = 1, 2, ..., N \tag{6}$$

- This allows to keep track of the evolution of the moments of the distribution: $a_t = E(a_{i,t})$ and $\sigma^2_{a,t}$.

Feedback 2: from ABM to macro



Conclusion

This hybrid macro ABM can be used to explore the consequences of shocks:

- The transmission mechanism of the shock can be neatly interpreted. The hybrid macro ABM is not a black box.
- The effect of the shock can be decomposed in (i) a component due to the first moment (which would occur also in a representative agent economy) and (ii) a component due to the second moment (which is present only in heterogeneous agents models).
- There are pros and cons of this approach, but it could work as a useful complement to most behavioural disequilibrium ABMs.