Agent Based Models in Economics and Complexity

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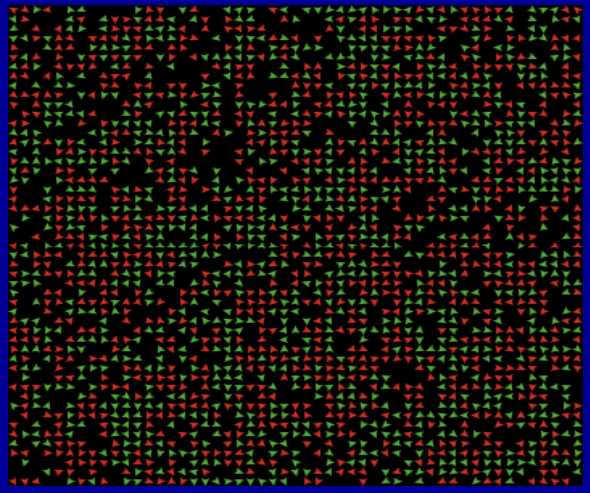
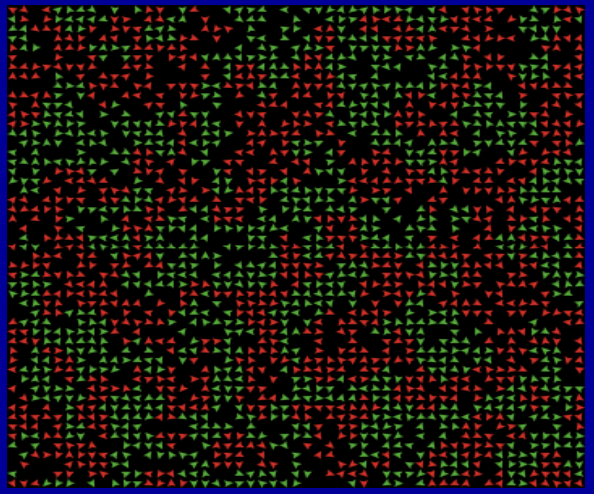
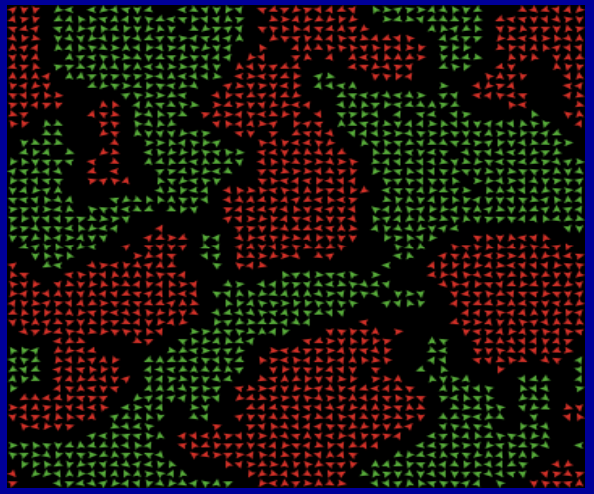
- Economics is in *crisis*.
- Blanchard, 2008: the mainstream model (DSGE) is simple, analitically convenient and microfounded, but "2 equations (out of 3) are **patently false**".
- "The state of macro is good": image if it were bad…
- The internal coherence and ability in explaining the empirical evidence of DSGE are increasingly questioned.
- The causes of the present state of affairs go back to the Newtonian revolution in physics: It was (and still is) the mechanical physics of the XVII century, which ruled economics.

- From then on, economics has been based on the classical physics assumptions (***reductionism***, ***determinism*** and ***mechanicism***).
- As a consequenc, the difference between micro and macro was analysed under a reductionist approach.
- In such a setting, aggregation is simply the process of summing up market outcomes of individual entities.
- This means that there is no difference between micro and macro: the dynamics of the whole is nothing but a summation of the dynamics of its components.

- This approach does not take into consideration that there are interdependencies between the agents and the aggregate properties of the system.
- Empirical evidence shows that aggregation generates regularities, i.e. simple individual rules, when aggregated, produce statistical regularities: regularities emerge from individual "disorder".
- In economic models equilibrium is described (actually assumed) as a state in which demand equals supply.

- The notion of *statistical equilibrium*, in which the aggregate equilibrium is compatible with individual disequilibrium, is outside the box of tools of the mainstream economist (an organism is in equilibrium *only when it is dead*.)
- The equilibrium of a system no longer requires that every single element be in equilibrium by itself, but rather that the statistical distributions describing aggregate phenomena be stable, i.e. in "a state of macroscopic equilibrium maintained by a large number of transitions in opposite directions" (Feller, 1957).

The Schelling's segregation model and "the game of life"

http://www.bitstorm.org/gameoflife/

Existence but not uniqueness and stability of GE

- The GE is neither unique nor locally stable under general conditions. This negative result, which refers to the work of Sonnenschein (1972), Debreu (1974) and Mantel (1974).
- The continuity, homogeneity of degree zero and the Walras' law assure the existence, but neither the uniqueness nor the local stability of p^*, unless preferences generating individual demand functions are restricted to very implausible cases.

Equilibrium is assumed not demonstrated

- By construction, in a GE all transactions are undertaken at the same equilibrium price vector.
- In the GE model the formation of prices precedes the process of exchange, instead of being the result of it, through a *tatonnement* process occurring in a meta-time.
- Real markets work operates in real time, so that the GE model cannot be considered a scientific explanation of real economic phenomena.

Money is irrelevant (well … *your* money is)

- Integrating money in the GE model is problematic.
- Given that in a GE model actual transactions take place only after a price vector coordinating all trading plans has been freely found, money can be consistently introduced into the picture only if the logical keystone of the absence of transaction costs is abandoned.
- In equilibrium markets for debt are meaningless, both information conditions and information processing requirements are not properly defined, and bankruptcy can be safely ignored.

Time is money

- The very absence of money and credit is a consequence of the fact that in GEE there is no time.
- The convenient implication of banning out-of-equilibrium transactions is simply that of getting rid of any disturbing influence of intermediary modifications of endowments - and therefore of individual excess demands - on the final equilibrium outcome.

The (in)famous RA

- If the Walrasian auctioneer is removed the decentralized economy becomes dynamically incomplete, as we are not left with any mechanism determining how quantities and prices are set and how exchanges occur.
- In turn, the flaws of the solution adopted by mainstream macroeconomists to overcome the problems of uniqueness and stability of equilibrium and of analytical tractability - i.e. the usage of a RA whose choices summarize those of the whole population of agents.

RA as R.Crusoe without Friday

- Although the RA framework has a long history, it is standard to build the microfoundation procedure on it only after Lucas' critique paper (1976).
- The use of RA models should allow to avoid the Lucas critique, to provide microfoundations to macroeconomics.
- Since models with many heterogeneous interacting agents are complicated and no closed form solution is often available, economists assume the existence of an RA: a simplification that makes it easier to solve for the competitive equilibrium allocation, since direct interaction is ruled out by definitions.

- Unfortunately, as Hildenbrand and Kirman (1988) noted: "There are no assumptions on isolated individuals, which will give us the properties of aggregate behaviour. This problem is usually avoided in the macroeconomic literature by assuming that the economy behaves like an individual. Such an assumption cannot be justified in the context of the standard model".
- Moreover, the standard econometric tools are based upon the assumption of an RA. If the economic system is populated by heterogeneous agents, then the problem of the microfoundation of macroeconometrics becomes a central topic (Forni and Lippi, 1997).

The RA is alive and well (at least as Alitalia is)

- All in all, we might say that the failure of the RA framework, points out the *vacuum* of the mainstream microfoundation literature, which ignores interactions: no box of tools is available to connect the micro and the macro levels, beside the RA whose existence is at odds with the empirical evidence (Stoker, 1995; Blundell and Stoker, 2005) and the equilibrium theory as well (Kirman, 1992).

From HIA to Complexity

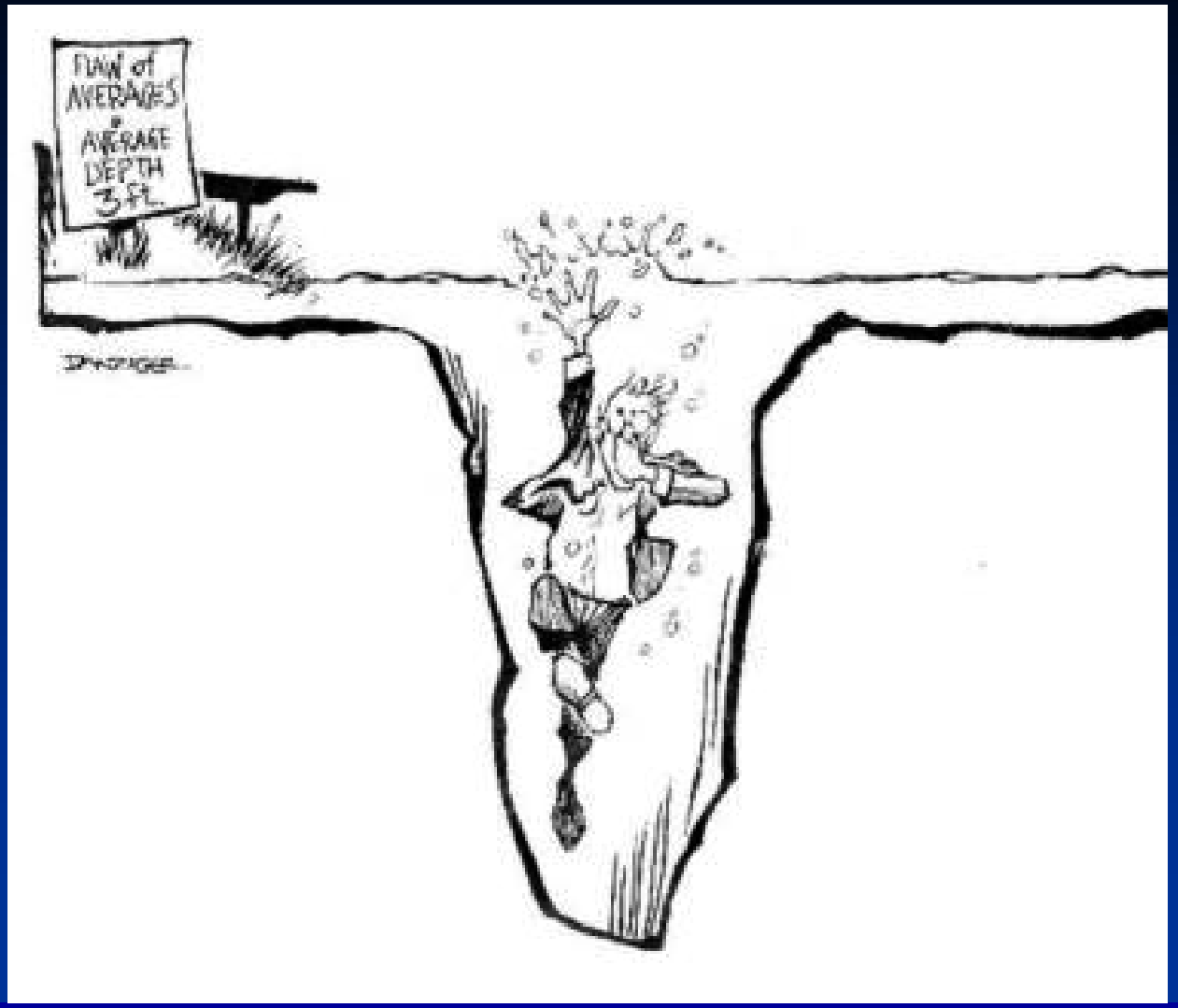
- What characterizes a complex system is the notion of emergence, that is the spontaneous formation of self-organized structures at different layers of a hierarchical system configuration.
- If the aggregate solution cannot be obtained by *aggregation, a* problem arises: starting from the *micro-equations* describing the (optimal) choices of the economic units, what can we say about the *macro-equations*? Do they have the same functional form of the micro-equations? If not, how is the macro-theory derived?

The ABM strategy

- The complexity approach to economics discards the GE approach to the microfoundation program.
- ABM is a methodology that allows to construct, based on simple rules of behaviour and interaction, models with heterogeneous agents, where the resulting aggregate dynamics and empirical regularities are not known *a priori* and are not deducible from individual behaviour.
- The ABM methodology focuses on the interaction between many HIA, which might produce a statistical equilibrium, rather than a *natural* one.

- The existence of an autocatalytic process implies that looking at the average behaviour of the constituent units is non representative of the dynamics of the system: "autocatalyticity insures that the behaviour of the entire system is dominated by the elements with the highest auto-catalytic growth rate rather than by the typical or average element" (Solomon, 2007).
- In presence of autocatalytic processes, a small amount of individual heterogeneity invalidates any description of the behaviour of the system in terms of its "average" element: "the real world is controlled as much by the *tails* of distributions as by means or averages. We need to free ourselves from *average* thinking" (Anderson, 1997).

The danger of averages



- ABM are characterized by:
  Heterogeneity, Explicit space; interaction; Bounded rationality; Non-equilibrium dynamics.
- The approaches differ also as regard
  - *dynamics*
    - *Complex Systems* are open, dynamic, non-linear systems, far from equilibrium;
    - *Mainstream* economics are closed, static, linear systems in equilibrium) and
  - *evolution*
    - *Complex Systems* have an evolutionary process of differentiation, selection and amplification which provides the system with novelty and is responsible for its growth in order and complexity, while
    - *Mainstream* has no mechanism for endogenously creating novelty, or growth in order and complexity.

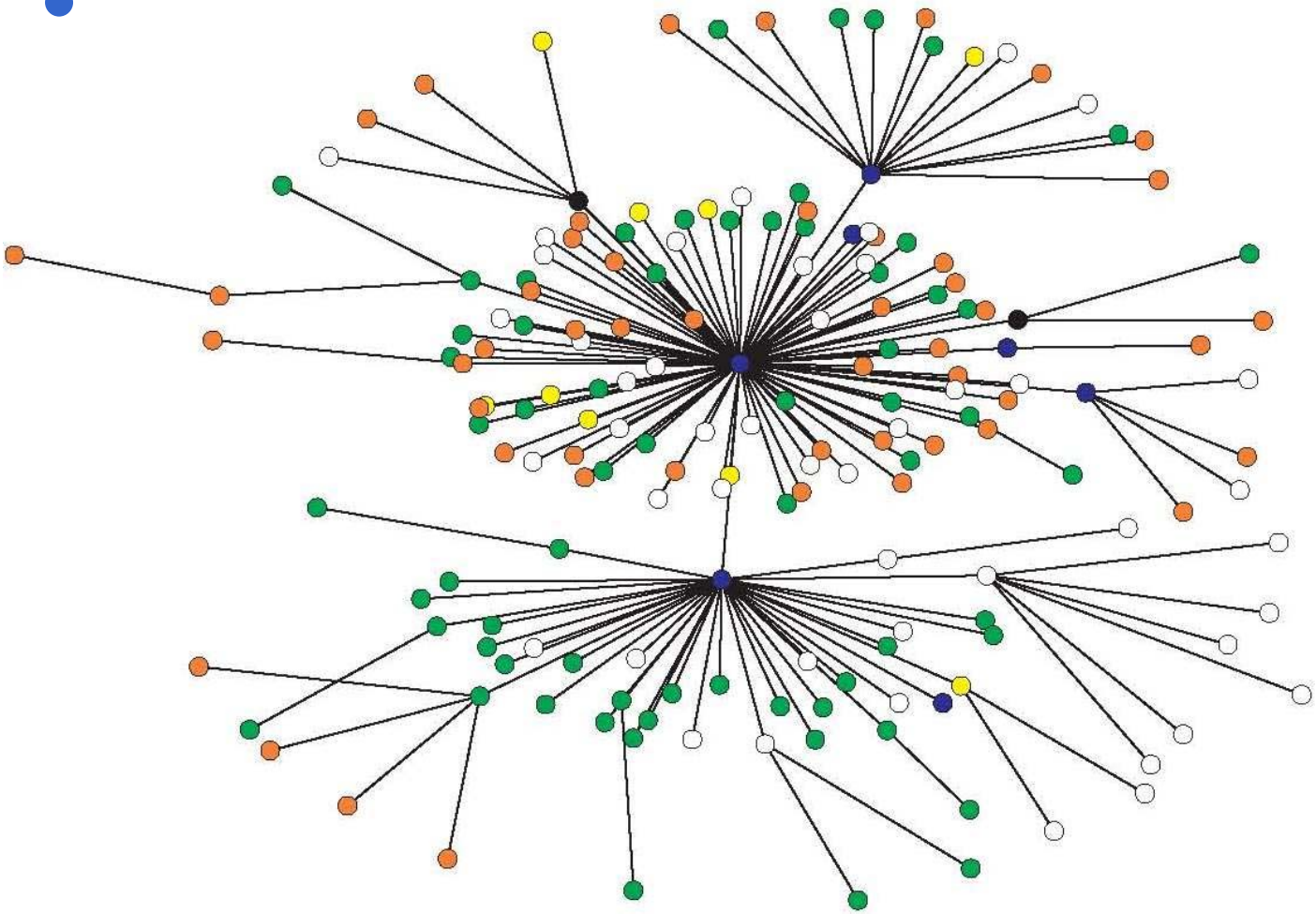
Before *economics* it was *political economy*

- If one considers the economic system as an analogue of the physical one, it is quite obvious to look for *natural* economic policy prescriptions (*one policy fits all*).
- The complexity approach showed us that the age of certainty ended with the *non-equilibrium* revolution. Considering the economy as an evolving (*adaptive*) system we have to admit that our understanding of it is limited (*no room for the Laplace' demon in complexity*).

- Individual behavioural rules evolve according to their past performance: this provides a mechanism for an endogenous change of the environment. As a consequence the "rational expectation hypothesis" looses significance. However, agents are still rational in that they do what they can in order not to commit systematic errors.
- In this setting there is still room for policy intervention outside the mainstream myth of a neutral and optimal policy. Because emergent facts are transient phenomena, policy recommendations are less certain, and they should be institution and historically oriented.

- Rather than looking at the "average" risk of bankruptcy and to infer it is a measure of the stability of the system, by means of a network analysis the economy can be analysed in terms of different interacting sub-systems, and local intervention can be recommended to prevent failures and their spread.
- One of the traditional fields of applications of economic policy is *redistribution*. A redistributive economic policy has to take into account that individuals are different: not only they behave differently, e.g. with respect to saving propensities, but they also have different fortunes: the so-called *St.Matthews* (13:12) effect.

- Real economies are composed by millions of interacting agents, whose distribution is far from being stochastic or normal.
- There are several hubs, i.e. firms with many connections: the distribution of the degree of connectivity is *scale free*, i.e. there are a lot of firms with 1 or 2 links, and very a few firms with a lot of connections. Let us assume the Central Authority has to prevent a *financial collapse* of the system, or the spreading of a financial crisis.



- Differently from Keynesian economic policy, which theorizes aggregate economic policy tools, and mainstream neoclassical economics, which prescribes individual incentives because of the Lucas critique but ignores interaction which is a major but still neglected part of that critique, the ABM approach proposes a new policy.
- What generally comes out is not a "one-size-fits-all" policy since it depends on the general as well as the idiosyncratic economic conditions; moreover, it generally has to be conducted at different levels (from micro to meso to macro).
- ABM can offer new answers to old unresolved questions, although it is still in a premature stage to offer definitive tools.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COMPLEX ECONOMIC DYNAMICS
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