Economies with Learning Social Atoms

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Extended Abstract

The asymmetric information revolution challenged the economic profession to rebuild its analytical tools upon sound foundations (Stiglitz, 1973, 1975, 1976). Standard economic theory was, and it is still, based on the reductionism of the Newtonian classical mechanics approach. The representative agent is the framework linking macro and micro; actually it does more than that by subsuming the aggregate behaviour to the micro-behaviour.

Feedback and adaptive behaviour through learning are key ingredients distinguishing socio-economic systems from complex systems in the natural sciences. In economics the "particles can think", they learn from experience and adapt their behaviour accordingly. A socioeconomic complex system is an expectations feedback system between individual learning and emerging aggregate behaviour. A fundamental question is:

What is the relationship between heterogeneous individual learning at the micro level and the emerging aggregate macro behaviour which it co-creates? This fundamental question may be addressed with stylized agent-based models with few agent types, to get insights in the interactions of heterogeneous rules and their aggregate behaviour. But a daunting challenge is to address interaction through simulations incorporating thousands or millions of highly heterogeneous agents, which do not reduce to simulation of interacting populations of a few types of agents, using advanced ICT tools and programming levels. An empirically grounded theory of heterogeneous individual expectations and social learning is needed as a foundation for a complexity research programme in economics. Empirical testing of such a theory, both at the micro and at the macro level - through laboratory, field and web experiments and in empirical financial-economic data - should yield key insights into which emerging patterns are most likely to occur in complex economic environments and how policy makers can manage.

If information is not complete, agents are heterogeneous and directly interact to extract the missing information from the others' behaviour. Statistical mechanics offers a tool for analyzing systems with heterogeneous interacting agents (see Foley, 1994; Aoki, 1996, 2002; Aoki and Yoshikawa, 2006). Nevertheless, they consider agents as atoms, implicitly assuming that economics is a hard science, like physics.

We believe (Majorana, 1942; Gell-Man, 1999) that social sciences have a peculiar status, because they analyze learning social atoms.

Learning capability and memory give to agents the status of "living-cells", which are different from atomic-agents: atoms are lifeless "brains" and they behave in the only way they can; agents are lively, animated and active "minds" so they can modify their way of behaving either because of their motivations and the behaviour of other agents (inducing externalities).

In general, this means that economic agents cannot be treated as atoms any longer (i.e. entities behaving in the way the observer/modeller has specified according to some specific theoretical assumptions set) since they are living cells. It also means that allowing for learning might lead to a "regenerative-coordination", that is if most of the agents cluster themselves about a dominant learning rule, the self organized process destroys its own success (e.g. by decreasing the market price), the dominant rule is not the best choice any longer, especially in a competitive environment.[4] Indeed, if a few firms find a better solution while the others still persist on the past solution, the first ones will improve their condition more than the seconds. After that some firms will imitate those who changed first and a new rule will become dominant. Moreover, living cells coordinate through self-organization adopting an emergent set of rules, which might lead the system to a dynamic evolution through phase transitions.

Our model is a complex system of interacting agents who learn and adapt. Their behaviour generates aggregate (emergent) phenomena, from which they learn and adapt. Such a system is out of equilibrium, i.e. it does not converge to a stationary equilibrium. This produces 2 consequences:

(i) Because of heterogeneity and direct interaction, aggregation problem cannot be done using the Representative Agent (RA) framework (as it is currently done in macroeconomics);

(ii) the individuals "learn" to achieve equilibria, but the environment about which they are learning is composed of other agents who are also learning. This undermines the hypothesis of structural stability (upon which the Rational Expectation Hypothesis -REH- and the fixed point analysis are based.) In this paper we analyze the economy as a complex system by modelling individuals who follow simple rules and interact with each other and, differently from particles in physical systems, they learn.

This approach is quite innovative with respect of the mainstream approach and the agent based models as well. In particular, the fact that we deal with an ABM (or computational economics) approach, it does not imply that we abandon any attempt to obtain analytical results: rather, the formal analysis comes from the chemical ME.

According to us, even though we think that statistical physics is the most suitable way to manage with complex systems made of Heterogeneous and Interacting Agents (HIA), we believe one cannot use sic et simpliciter the statistical physics approach, because humans think, learn and are forward looking and cannot therefore be modelled as molecules or inanimate particles. We think that those capabilities might be included into statistical physics perspectives for human systems.

Rather, we choose what we consider to be the appropriate level of sophistication for the mapping from the past to actions; we model the reactions of other agents to an individual's choice of actions. In the words of Kirman (2012): "we can let the agent learn about the rules that he uses and we can find out if our simple creatures can learn to be the sophisticated optimisers of economic theory."

To move the first steps into this direction, we use a simplified version of Greenwald and Stiglitz (1993) model (sect.2) with learning agents. Sections 3 and 4 are, respectively, devoted to define the learning rules and the analysis of the simulations. Learning capabilities are represented by a set of rules to model learning behaviour as concerning the next period output scheduling function given the present resources and the market price force-field (i.e. just like a magnetic field polarizes a bunch of iron filings or a catalyst in a chemical reaction). The behaviours are classified in different groups of rules: self-referencing without learning (static and random-dynamic), self-referencing with learning (memory-less dynamic-optimizing, auto-regressive not-optimizing), interactive (collective learning with global-interaction, collective learning by local-interaction with random neighbours or best performers). Each rule is also characterized by an intrinsic and quantifiable level of complexity. From a technical point of view, we develop a methodology to get analytic solutions to HIA learning models by introducing Chemical Master Equations (sect.5).

All in all, the main hypothesis is that regenerative-coordination of living cells causes system phase transitions. In seeking for experimental evidences of this principle, in this paper a different look at micro-foundation for macro modelling of emergent phenomena is introduced and an innovative way to manage the problem of aggregation is developed to deal with interaction (weak/indirect and strong/direct) and heterogeneity (weak -in endowments, and strong -in behaviours), each of which can be considered the opposite side of the same coin: heterogeneity and interaction are, accordingly, entangled categories.

Some of the research questions this approach poses are: in a set of learning rules is there a subset of emerging, and possibly dominant, rules? is there evidence of phase transitions for the system? is the individual learning strategy Pareto optimal for the system, or the aggregate welfare can be improved? Are the emerging individual strategies affected by the aggregate behaviour? This paper offers a qualified yes to all the above questions.