IMPROVING THE TOOLBOX
NEW ADVANCES IN AGENT-BASED AND COMPUTATIONAL MODELS

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Are current economic models well equipped to provide useful policy prescriptions? Many economists would have certainly answered, "yes" before the recent Global Recession. This economic crisis has not only demonstrated the importance of banking and financial markets for the dynamics of real economies. It has also revealed the inadequacy of the dominant theoretical framework. Standard models have indeed failed to forecast the advent of the crisis. In addition, they have been unable to indicate a therapy able to restore economic growth.

Since the onset of the crisis, the discontent towards the dominant approach to economic modeling has flourished.[1] Criticism has been mainly directed towards the over-simplicity of standard models in general, and of Dynamic Stochastic General Equilibrium Models (DSGEs) in particular. Most features that have played a key role in generating the crisis, such as heterogeneity of agents, markets, and regulatory frameworks, financial innovation, securitization, are by and large overlooked in standard macro-models. A second kind of dissatisfaction is related to the hyper-rationality of individuals. Markets (and financial markets in particular) are plenty of people acting on the basis of overconfidence, heterogeneous beliefs, imperfect knowledge of the states of the world, and of the consequence of humans' actions, etc. These features are not present in standard macro models, which build on the assumption of a representative individual

1. Interestingly, this time critiques have not only come from "heterodox" schools of thought. Critiques have also been raised by scholars who made a significant use of the ingredients of standard models in the past (see e.g. Caballero, 2010, Krugman, 2009, Stiglitz, 2011) as well as by leading policy-making authorities (see e.g. Trichet, 2010).

knowing all the characteristics of the economy and able to replicate whatever human intelligence can do (Leijonhufvud, 1993). A third concern is the assumption of equilibrium. Standard models typically focus on states of the economy in which all markets clear. In contrast, the crisis has shown the possibility of situations in which some markets (and the market for labor in particular) do not clear. Standard models ignore the problems that would result from reactions of agents to such market disequilibria. They are therefore badly equipped to study how the economy behaves during crises.

A natural way to follow in face of the problems exposed in the previous section would be departing from the representative agent paradigm, thereby introducing heterogeneity of agents' characteristics and behavior, and allowing for markets that do not clear. All the aforementioned characteristics add new degrees of complexity to macroeconomic analysis. As eloquently expressed by Tesfatsion (2006):

> *"The modeler must now come to grips with challenging issues such as asymmetric information, strategic interaction, expectation formation on the basis of limited information, mutual learning, social norms, transaction costs, externalities, market power, predation, collusion, and the possibility of coordination failures."*

Exploiting the growing capabilities of computers, Agent-Based Models (ABMs) analyze economic processes as dynamical systems of heterogeneous interacting agents (Epstein and Axtell, 1996; Tesfatsion, 2006). In ABMs repeated interactions among agents over time induce continuously changing microeconomic patterns, the aggregation of which generates a dynamics for the macroeconomic variable of interest (Pyka and Fagiolo, 2007).

This special issue gathers contributions of leading scholars in Agent-Based and computational economics and shows the applicability of this methodology to several issues both in micro- and in macroeconomics. This introduction aims to provide some guidelines to the different contributions in the issue by organizing them around 4 main themes.

1. The critique to standard economic models and the structure of Agent-Based Models

As we mentioned above standard economic models (and DSGEs in particular) are badly equipped to analyze some key issues that emerged in the last economic crisis. The contributions of **Kirman** (2012), **Ashraf, Gershman and Howitt** (2012) and of Fagiolo and Roventini (2012) provide a clear and thorough account of the critiques to mainstream macroeconomic models. Kirman (2012) discusses the historical

evolution of modern macro, and shows how DSGEs are the final outcome the particular path followed by mainstream economics in the last century. The task of the economist in this tradition (and of the macroeconomist in particular) is to make assumptions about individual preferences and technologies in line with some axioms that are characteristic of the "rational" agent and to build models on that basis. Next, one finds the equilibrium of the system and examines the characteristics of such equilibrium states. In contrast, ABMs allow one to dispense with the restrictive assumptions of standard models and put at the center of the analysis the heterogeneity of economic agents and the evolution of the network of interactions among them. The article of Fagiolo and Roventini (2012) discusses in details the building blocks of Agent-Based Models.

The analysis of the mechanisms that govern (and coordinate) economic interactions in a decentralized economy is essential not only for understanding the generation of crises. It also helpful to provide useful policy insights beyond those provides by standard models, and to analyze the effects of technical change in the economy. The first point is vividly stressed in Ashraf, Gershman and Howitt (2012) and Fagiolo and Roventini (2012), whereas the second one is extensively discussed in the paper of **Amendola, Gaffard and Saraceno** (2012).

2. Analytical vs. simulation methods in ABMs

Agent-Based Models are typically more complex than standard models, and this implies that one must often employ computer simulations for their analysis. The contribution of Fagiolo and Roventini (2012) discusses the different problems that emerge in the use of simulation techniques for the analysis of ABMs, and the different solutions that have so far been proposed in the literature.

One critique against ABMs is that the use of computer simulations and the complicated structure of ABMs often prevent one from detecting the mechanisms generating results in the model. In our opinion, the fact that an overly complicated structure may blur causal mechanisms is a quite general remark applicable to any model, rather than a specific and unavoidable fallacy of ABMs (see also Napoletano, Gaffard and Babutsidze, 2012, for more discussion). However, even in very complicated ABMs—causal mechanisms can be detected through counterfactual simulation analyses. Indeed, ABMs often allow one to control the presence of some dynamics in the model through an appropriate setting of the parameters, and to test how results are different when such dynamics are switched off/on. This technique is

widely exploited by most papers in this issue. Furthermore, one should consider computer simulations and analytical results as possible complements rather than substitutes. This last methodological point emerges with great clarity in the contributions of **Delli Gatti *et al.*** (2012) and of **Babutsidze** (2012). More precisely, the paper of Delli Gatti et al shows how the interactions among heterogeneous agents can be successfully modeled by employing master equations techniques. This analytical investigation is then coupled with simulation techniques that show the reaction of the systems to different microeconomic shocks. On related grounds, the paper of Babutsidze studies analytically the properties of the equilibrium of an economy populated by heterogeneous agents using asymmetric (S,s) rules to set prices, and then uses simulation techniques to analyze the far-from-the-equilibrium dynamics.

One of the strongest critiques to DSGE models has concerned their failure to forecast the advent of the crisis (Wieland and Wolters, 2012, summarize the debate on this issue). At the same time, forecasting appears difficult in ABMs due to the inherent non-linearities implied by the complex interactions among heterogeneous agents (see also Dawid and Neugart (2011), and Grazzini *et al.* (2012), for more discussions). **Barde** (2012) makes an important step in overcoming the hurdles involved in forecasting exercises with ABMs, by showing the possibility of successfully applying Maximum Entropy techniques to predict model outcomes in the Agent-Based models of Kirman (1993) and of Abrams and Strogatz (2003).

3. Agents' heterogeneity, micro- and macroeconomic dynamics

The recent crisis has shown that *distributions matters* (see also Stiglitz, 2011). One instance of this is the market for credit, where the distribution of information between borrowers and lenders plays a key role. Asymmetric information, credit contracts, and the possible bankruptcy of agents are all elements that significantly affect aggregate dynamics in the papers of **Cincotti, Raberto and Teglio** (2012), **Ashraf, Gershman and Howitt** (2012), **Delli Gatti *et al.*** (2012) in this special issue. Furthermore, the crisis and the associated surge in unemployment also generated sharp inequalities within the population: some individuals have seen their income falling either because they got unemployed or because of falling wages in a situation of depressed labor demand. Reduced incomes by a significant fraction of the population would normally lead to a fall in consumption demand. The interplay between inequality and demand and its consequences for both the micro and the macro-economic dynamics are central the

central themes of the papers of **Napoletano *et al.*** (2012) and of **Patriarca and Vona** (2012). The former paper shows that, independently from the investment behavior of firms, steady growth of the economy requires a balance in the distribution between profits and wages. The paper of Patriarca and Vona studies instead the relations between income inequality and the effectiveness of policies aimed at introducing green technologies and shows that when income inequality is taken into account carbon taxes may have the paradoxical effect of reducing (rather than increasing) the number of consumers of green products.

Heterogeneity among agents in ABMs does not only relate to agents' asymmetries in either characteristics or in behavior. It may also involve differences in production processes over time. Accordingly, ABMs are suitable for analyzing the interplays between aggregate long-run growth and the processes of structural transformations and qualitative change in the economy. The papers of **Ciarli** (2012), **Amendola, Gaffard and Saraceno** (2012) and **Saviotti and Pyka** (2012) are devoted to this crucial issue.

4. Policy analyses under different institutional scenarios

ABMs are not only models that explicitly account for agents' heterogeneity. They have another advantage that is more related to policy design, and is represented by their finer description of the economy compared to standard models. In modern economies very articulated and heterogeneous institutional arrangements often govern the functioning of key markets (e.g. labor and credit markets). The same macroeconomic policy can have different effects according to the different institutional setting in which it is implemented (Stiglitz, 2011). The papers of **Cincotti, Raberto and Teglio** (2012) and of **Ashraf, Gershman and Howitt** (2012) use this feature of ABMs to study of bank regulation policies. The paper of **Napoletano *et al.*** (2012) studies the effects of wage-flexibility policies under different institutional regimes characterizing the investment behavior of firms. **Guerci and Sapio** (2012) compare the effects of wind power supply on prices in the Italian electricity market between a scenario in which plant-level and demand data are calibrated on real-data and a scenario where wind electricity output is progressively scaled up to the Italian wind potential, *i.e.* he maximum amount of wind energy that could in principle be produced given the geographical characteristics of the Italian territory.

This brief overview of the papers in this special issue clearly illustrates the great flexibility and the great potential of ABMs for the analysis of key issues emerged in the recent crisis as well as of other

important problems both in micro- and macroeconomics. Certainly, the use of ABMs in economics involves new problems and challenges for researchers, especially fore those more accustomed with standard modeling approaches. At the same time ABMs and computational models allow one to avoid the straitjackets, of standard models in the analysis of important real situations and allow policy analyses under more realistic scenarios. These last features should be considered as key improvements to the toolbox of both micro- and macroeconomists.

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