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EDITORIAL

Introduction to the special issue

Tiziana Assenza[1,4] · Jakob Grazzini[2,4] · Domenico Massaro[3,4]

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This special issue of the Journal of Economic Interaction and Coordination includes a selection of research papers presented at the 22nd Annual Conference on Economic Science with Heterogeneous Interacting Agents (WEHIA 2017), which was held at Università Cattolica del Sacro Cuore, Milan, Italy, on June 12–14, 2017. The papers analyze a wide range of topics explored by means of a rich portfolio of tools such as laboratory experiments, agent-based and network models. Although quite different in terms of research questions and methodological approaches, all papers share a common denominator: the role of heterogeneity in economic dynamics.

It is a well-established truth that heterogeneity is a distinctive feature of our reality. Economic systems are indeed characterized by individuals that may differ on several characteristics: beliefs, skills and endowments, just to mention some. While at the microeconomic level the role of heterogeneity has been widely analyzed, the macroeconomic impact of the interaction of a large population of heterogeneous agents has been ignored for a long time. Only recently the issue has resurfaced and is currently under the spotlight. Standard macroeconomic models often ignore heterogeneity on the ground that agents' specificities—captured by idiosyncratic shocks—would average out in the aggregate and, therefore, would not lead to any interesting dynamics. Based on this reasoning, most models are built on the assumption of an average (representative) agent summarizing the optimal behavior of all individuals in the economy.

✉ Jakob Grazzini
jakob.grazzini@unipv.it

Tiziana Assenza
tiziana.assenza@tse-fr.eu

Domenico Massaro
domenico.massaro@unicatt.it

1 Toulouse School of Economics, University of Toulouse Capitole, 21 Allée de Brienne, 31000 Toulouse, France

2 Department of Economics and Management, University of Pavia, Via S.Felice al Monastero 5, 27100 Pavia, Italy

3 Department of Economics and Finance, Catholic University of Milan, Largo Gemelli 1, 20123 Milan, Italy

4 Complexity Lab in Economics, Catholic University of Milan, Largo Gemelli 1, 20123 Milan, Italy

However, back in the early 1990s, this view has been criticized by Kirman (1992), who argues that there is no direct relation between individual and collective behaviors. Therefore, aggregate behavior emerging from the interaction of heterogeneous agents cannot be simply summarized by the average agent.

The seminal contribution by Kirman led to the development of a large body of literature that models the economy as a complex adaptive system (see, e.g., Hommes and LeBaron 2018 for a comprehensive overview), and shows that micro-level interactions may lead to emergent behavior at the macro-level that does not necessarily reflect the characteristics observed at the individual level (see, e.g., Delli Gatti et al. 2011). Both in macroeconomics and in financial economics, a new literature has built upon this intuition to develop *simulation models with heterogeneous agents* in which relatively simple micro-behaviors lead to complex aggregate dynamics.

In macroeconomics, simulation models with heterogeneous agents take the form of *macroeconomic agent-based models*, which can reproduce a variety of macroeconomic and microeconomic stylized facts (see Dawid and Delli Gatti 2018 for a recent survey). Just to mention a few, Dawid et al. (2014) reproduce persistent fluctuations of output, pro-cyclical movement of employment, consumption and investment (see, e.g., Stock and Watson 1999), as well as persistent productivity gaps between firms (see, e.g., Bartelsman and Doms 2000); Delli Gatti et al. (2011) develop a macro-agent-based model able to reproduce a right-skewed firm (log) size distribution and a tent-shaped distribution of firms' growth rates both in terms of total assets (see also Bottazzi and Secchi 2006, for similar empirical results using total sales); Dosi et al. (2013) present a credit-augmented macro-agent-based model able to match empirical evidence about credit dynamics (see, e.g., Lown and Morgan 2006 and Leary 2009).

In financial economics, simulation models with heterogeneous agents take the form of *models of financial dynamics with heterogeneous beliefs*. Empirical evidence based on financial time series displays a number of stylized facts such as bubbles and crashes, excess volatility, volatility clustering and mean-reverting behavior (Dieci and He 2018). These empirical regularities have proved difficult to explain within a standard framework with a representative agent and rational expectations. Several contributions in the finance literature have therefore introduced heterogeneity in beliefs and behavioral rules evolving over time based on evolutionary selection mechanisms (see, e.g., Lux 1995 and Brock and Hommes 1998). Heterogeneous agent models of financial markets provided insights on several stylized facts (see Dieci and He 2018 and Bouchaud 2018 for a recent survey). Just to mention a few, Schmitt and Westerhoff (2017) show how herding behavior of speculators explains volatility clustering of returns in financial markets; Chiarella and He (2003) and Alfarano et al. (2005), among others, explain price deviations from the fundamental, bubbles and crashes as well as other empirical regularities (e.g., power law behavior, see Lux and Alfarano 2016).

This special issue collects 10 contributions investigating the implications of heterogeneity in different dimensions of macroeconomics and finance, such as labor markets, interbank credit market and stock markets among others.

Biondi and Zhou develop an agent-based model of the interbank credit market featuring interactions among heterogeneous agents. The goal of the paper is twofold: First,

it explores the link between interbank credit coordination and the money generation process, showing that interbank credit may lead to an unbounded money generation process. Second, it develops simulation analysis on imperfect interbank credit coordination, studying the impact of interbank dynamics on financial stability and resilience at both the individual and aggregate levels. Systemically destabilizing forces prove to be related to the working of the banking system over time.

Biondo presents a financial agent-based model with boundedly rational and heterogeneous agents. The model simulates transactions between agents through a limit order book and produces a time series of market prices. In line with the literature, this paper shows that market interactions can reproduce several stylized facts about returns observed in real financial markets, such as their fat tail distribution, absence of autocorrelation and volatility clustering. In order to investigate the determinants of price volatility, the author performs a series of simulations to analyze the impact of different behavioral assumptions. Moreover, the paper investigates the role of different institutional settings, drawing conclusions about possible policies aimed at reducing market volatility.

Colasante et al. present a Learning-to-Forecast Experiment (LtFE) with human subjects. Their first goal consists in eliciting short- and long-run agents' expectations on price dynamics in markets characterized by both positive and negative feedbacks. They find heterogeneity in the expectation formation processes of participants in the experiment, and they show that eliciting long-run expectations has no impact on both price dynamics and short-run expectations formation. Moreover, while the Rational Expectation Equilibrium (REE) represents a good benchmark for markets featuring negative feedbacks, this is not the case when also positive feedbacks are added. In particular, in the negative feedback system, the convergence to the REE goes in line with the coordination of agents on the long-run expectations around the fundamental value. On the contrary, in the presence of positive feedbacks the REE is unstable and the price dynamics shows permanent oscillations in turn inducing divergence of long-run expectations. Given the results above, the authors provide a measure of heterogeneity of expectations related to the scaling of dispersion of expectations over the forecasting time horizon.

Datta studies the impact of the limits of arbitrage in a deterministic continuous time model of exchange rates featuring boundedly rational agents with heterogeneous expectations. The rate of exchange depends on a combination of fundamental factors and agents' speculative behavior. The paper finds that in certain situations the limits of arbitrage might increase the stability of the fundamental equilibrium. However, they might also indirectly destabilize the fundamental equilibrium by causing a reduction in the number of professional arbitrageurs. In particular, the paper shows that, when the proportion of chartists and fundamentalists are exogenously given, the presence of the fundamentalists plays a stabilizing role while that of the chartists plays a destabilizing role. When instead the proportion of chartists in the market is endogenously determined by the deviation from the fundamental equilibrium due to limits of arbitrage, the unique fundamental equilibrium is locally stable.

Dionisio et al. test weak form efficiency in frontier markets. They collect stock market data from 23 countries from Africa, Asia, Europe, Middle East and South America and show that the behavior of frontier markets often diverges from the behavior of more advanced markets. In general, empirical evidence suggests that frontier markets are relatively less efficient. The authors list a series of possible explanations for the lower efficiencies, such as illiquidity, asymmetric information, poor regulation or high transaction costs. This implies, among other things, that some stylized facts analyzed in the financial literature may be market specific and that heterogeneity matters both at the individual and at the institutional levels.

Ferri et al. analyze unemployment in a medium-run growth model, where aggregate demand and supply interact, using a top-down approach. The paper studies a nonlinear system where both aggregate demand and supply are endogenous and heterogeneity in consumption is introduced via two different channels: employment status of households and agents' expectations. The authors show how the interaction between demand and supply explains observed growth dynamics in product and labor markets, while introducing optimistic versus pessimistic expectations helps mimicking in a closer way the actual path of the economy. Finally, the paper also makes a methodological effort directed at identifying possible lines of convergence with the agent-based bottom-up approach.

Gaffeo et al. present a paper in which they investigate the role of On-Balance Sheet (OBS) bilateral netting in mitigating (or avoiding) financial contagion and, therefore, ameliorating systemic financial stability. They consider an interbank network with heterogeneous banks in terms of balance sheet sizes and equity buffer. By means of mean field approximation techniques and computer simulations, they study how contagion spreads out throughout the interbank market. They find two contrasting effects: On the one hand, the presence of OBS agreements contributes to isolating banks by cutting off links in the interbank network, and therefore, it helps in limiting the spread of contagion during a systemic crisis. On the other hand, it mitigates the risk sharing in the interbank network, implying that losses are concentrated toward a small number of banks. The net effect out of the interaction of these two opposite forces is, however, uncertain. By means of computer simulations, the authors show that a regulator that forces intermediaries to net their credit/debt obligations is able to decrease the number of defaults that occur and, therefore, preserve the aggregate amount of bank capital. However, interbank netting implies an increase in potential losses for depositors. Hence, the optimal crisis management policy conducted by the regulator should be implemented such that on the one hand it enforces bilateral netting, but, at the same time, provides an insurance scheme for deposits.

Glötzl et al. apply a general constrained dynamics approach borrowed from physics to the analysis of economic models. The paper makes a methodological contribution aimed at providing a framework suited to incorporate behavioral assumptions departing from standard optimization, relax restrictive assumptions needed to aggregate individual behaviors and describe out-of-equilibrium dynamics, among other things. As an application, the authors consider a static pure exchange model and transform it into a dynamic model with procedural rationality in order to study the convergence properties to the stationary state. The proposed framework can serve as a tool to study

dynamics in complex systems alternative to agent-based models, or as a meta-modeling device for the latter.

Liuzzi et al. present and analyze an artificial market where actions by agents are taken according to two different time scales. In particular, they consider a high-frequency time scale (intraday) to model the behavior of traders that, by means of heterogeneous threshold rules, strategically attempt to maximize short-term returns. On the contrary, the market maker, who adjusts prices and sets closing process and transaction costs, operates on a daily time scale. The authors start by describing and discussing a baseline model (in the absence of frictions), and they show how the model is able to reproduce most of the important stylized facts observed in real data. Moreover, they present a modification of the model that takes into account the role of transaction costs (set by the market maker) in controlling excess volatility in the market and improving its performance. They find, indeed, a beneficial effect of the presence of transaction costs. In fact, the introduction of an appropriate taxation scheme may contribute in reducing volatility. However, at the same time, the presence of excessive transaction costs induces the occurrence of abnormal peaks in returns.

Vanni and Barucca investigate the properties of a dynamic network formation model using a master equation approach for the degree distribution of the network. This allows to provide a description of both the transient dynamics and the steady state of the degree distribution, characterizing therefore the evolution of the network topology. As pointed out by the authors, networks are increasingly important in economics, and understanding their evolution may help in explaining different economic phenomena. In general, in a world characterized by heterogeneous agents, the interaction patterns among agents, defined by the network topology, play a crucial role in shaping individual and aggregate behaviors, thus highlighting the importance of studying network formation models.

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