J Econ Interact Coord (2018) 13:1–7
https://doi.org/10.1007/s11403-018-0221-z

EDITORIAL

Recent advances in financial networks and agent-based model validation

Mauro Napoletano[1,2] · **Eric Guerci**[3] ·
Nobuyuki Hanaki[3]

Received: 6 March 2018 / Accepted: 13 March 2018 / Published online: 24 March 2018

Abstract We introduce the papers appearing in the special issue of this journal associated with the WEHIA 2015. The papers in issue deal with two growing fields in the in the literature inspired by the complexity-based approach to economic analysis. The first group of contributions develops network models of financial systems and show how these models can shed light on relevant issues that emerged in the aftermath of the last financial crisis. The second group of contributions deals with the issue of validation of agent-based model. Agent-based models have proven extremely useful to account for key features economic dynamics that are usually neglected by more standard models. At the same time, agent-based models have been criticized for the lack of an adequate validation against empirical data. The works in this issue propose useful techniques to validate agent-based models, thus contributing to the wider diffusion of these models in the economic discipline.

1 Introduction

This special issue combines contributions dealing with (i) the analysis of financial networks and (ii) the use of statistical techniques for the validation of agent-based

✉ Mauro Napoletano
mauro.napoletano@sciencespo.fr

Eric Guerci
eric.guerci@unice.fr

Nobuyuki Hanaki
nobuyuki.hanaki@unice.fr

1 Observatoire Français des Conjonctures Economiques (OFCE), Paris, France

2 SKEMA Business School, Université Côte d'Azur, Sophia-Antipolis, France and Scuola Superiore "Sant'Anna", Pisa, Italy

3 Université Côte d'Azur, CNRS, GREDEG, 250 rue Albert Einstein, 06560 Valbonne, France

models (ABMs). Although quite heterogeneous in terms of the topics they address, the papers in the issue provide a good overview of two recent and growing fields in the literature inspired by the complexity-based approach to economic analysis (see e.g. Kirman 2010a).

The financial crisis of 2008 and the Great Recession that followed have led to a reconsideration of standard economic theories based on general equilibrium and on the representative agent hypothesis (Stiglitz 2011; Kirman 2010b), and to a call for new approaches that could better capture the fundamental features that generated the crisis. One of them is agents' heterogeneity, which is is needed in order to properly account for any credit relation. Another one is financial contagion and systemic risk, which are very much related to externalities across different agents. Indeed, the transmission of externalities does not occur in a vacuum. On the contrary, it is mediated by the structure of financial and economic contracts existing among agents (Stiglitz 2011).

Furthermore, the financial crisis was also triggered by the building-up of large debt imbalances across agents (as well as across countries), which can hardly be accounted for in a equilibrium framework. Finally, the crisis itself was not the result of an aggregate shock, as it is typically postulated in many standard models. It was instead endogenously generated by the interactions of the heterogeneous agents populating an economy.

Network models provide a valid alternative to standard models to account for some of the above-mentioned issues (see Battiston et al. 2016). This is because these models allow one to represent the very structure of localized interactions across economic agents. Accordingly, they allow one to study under which conditions financial distress may propagate and systemic risk may emerge. They are therefore valid tools to identify early warning signals about an imminent crisis. In addition, they allow one to properly test the impact of regulatory measures or of new institutional arrangements in financial markets. The papers by Gaffeo and Molinari (2017), Hayakawa (2017) and Catullo et al. (2017) represent very good examples of the applications of network models to the foregoing issues. The paper by Clemente et al. (2017) instead provides a methodological contribution that can prove useful in many network-based analysis of financial contagion.

Agent-based models (ABMs henceforth) are another valid alternative to standard models that has received increasing attention after the last crisis. The list of applications of ABMs is already very rich and it keeps growing (see Bargigli and Tedeschi 2013; Haldane and Turrell 2018; Fagiolo and Roventini 2017; Samanidou et al. 2007, for recent accounts). ABMs represent economies as dynamical systems of heterogeneous agents, interacting out of equilibrium (Tesfatsion 2006). In that, they constitute a generalization of the relatively simple framework usually present in network models, as they allow one to introduce richer sets of behavioural rules and institutional features of markets, and to deal with evolving networks. The paper of Catullo et al. (2017) in the issue is also interesting in this respect, as it integrates the network and the ABM approaches for the analysis of credit relations and of the impact of macro-prudential policies.

At the same time, ABMs have also been criticized for their inadequate validation against empirical data or for their inability to assess how general their results are. This has so far prevented a full-fledged comparison of ABMs with other models, and accordingly their wider diffusion. Nevertheless, such a critique has started to receive an adequate response in the literature (see also Fagiolo et al. 2017), with the development of statistical techniques that allow one to analyse the sensitivity of the results of an ABM to alternative parameters' values or to estimate the model's parameters or, finally, to evaluate the performance of an ABM in explaining features of empirical data.

In what follows, we discuss more in depth the papers of the special issue by grouping them into two categories, representing the main areas of contribution to the literature, namely the analysis of financial networks (Sect. 2) and the validation of agent-based models (Sect. 3).

2 Financial networks models

The first part of the special issue gathers contributions analyzing credit markets from a network perspective. The disruptions created by bilateral exposures in over-the-counter (OTC) derivatives markets during the last financial crisis have led regulators to introduce central clearing counterparties (CCPs) for derivative trades (Acharya et al. 2009; Cecchetti et al. 2009). The reason is that central clearing may mitigate counterparty credit risk by removing the direct risk exposure between parties. Nevertheless, all the pros and cons of CCPs are still highly debated in the literature, and some papers have even highlighted that CCPs may under some conditions increase counterparty risk (Duffie and Zhu 2011). In addition so far there has been little investigation of how CCPs possibly affect the overall liquidity needs and how this interplays with the network topology of derivatives trades. This is the starting point of the paper by Hayakawa (2017). The authors investigate how the introduction of a CCP could alter the interconnected feature of the relevant network of financial obligations, and how the change of network topology could affect overall liquidity needs. The model developed in the paper builds on Hayakawa (2016). The paper studies the effects of CCPs under two scenarios: (i) a "bad times" scenario, which captures times of liquidity distress; and (ii) a "good times" scenario, corresponding to times during which liquidity circulates most efficiently. The paper shows that CCPs may reduce liquidity needs during times of financial distress, thereby reducing the risk of firesales and the systemic risk arising from an avalanche of defaults. Conversely, CCPs could have a cost in terms of additional liquidity needs during good times. The foregoing trade-off has an important policy implication, as it suggests a conditional use of CCPs, i.e. limited only to situation of financial distress. At the same time, the transition from good times to bad times is typically endogenous in real financial systems, and one question for future explorations is whether a CCPs minimizes or not the incidence of periods of liquidity distress.

The paper of Gaffeo and Molinari (2017) puts the emphasis on the roles played by financial institutions in modern financial systems (e.g. intermediation of resources, maturity transformation, management of the payment system) and studies how the network of financial relations among them may impact on these functions and possibly generate liquidity disruptions. In the first part of the paper, the authors analyze an original dataset provided by the Cassa Centrale Banca (CC) operating as a provider of financial services for small cooperative credit banks in the North-East of Italy and as an entry point for liquidity injections by the central bank. This dataset offers a privileged viewpoint on several financial functions. Some of the main empirical findings of the paper are about the evolution of the degree of interconnectedness in the network at the onset of the crisis and in the subsequent years. The interconnectedness of the network has increased exponentially during the sovereign debt crisis in Europe. In addition, the persistence of bilateral trading between the hub (the CC) and the peripheral nodes has been significantly higher and more stable. Finally, the role of CC has changed over time from being a net lender to becoming a net borrower. In the second part, the authors carry out counter-factual simulation analyses to investigate whether alternative network architectures compared to the empirically-observed one would have produced a different outcome in terms of robustness to funding shocks. The authors evaluate the performance of the different network structures by using different metrics. Interestingly, they consider both a performance measure focusing only on the effect of the shock on interbank losses, and a more general one that combines the latter effect with the impact on cumulated losses on external assets. Two key results emerging from the simulation analyses are, first, that the building up of systemic risk in the star architecture is very much related to the net position of the hub (being a net borrower or a net lender). However, the results may vary a lot depending on the metrics used. In particular the actual star network does not have a worse performance than the other architectures considered in the paper, especially when the effect of the shock on external assets is accounted for. The fact that the performance of the network may vary according to the metrics used is, in our opinion, an original and yet poorly explored topic in the financial network literature. This calls for more research in this direction, aimed at exploring the possible trade-offs between liquidity and systemic risk inherent financial networks.

The above-discussed papers of Hayakawa (2017) and of Gaffeo and Molinari (2017) contains analyses of the efficiency of “static” network structures. The paper of Catullo et al. (2017) considers instead an “evolving” financial network and moreover it integrates it into a macroeconomic ABM inspired by the works of Delli Gatti et al. (2005) and follow-ups. The ABM is calibrated by adopting the approach of Schularick and Taylor (2012). Levels of leverage, connectivity and output volatility are realistic and correspond to the values reported in the empirical credit network dataset of firms and banks quoted in the Japanese stock exchange markets from 1980 to 2012. The model succeeds in reproducing endogenous pro-cyclical fluctuations of credit and connectivity. In particular, when credit and connectivity increase, the number of firm failures also rises because of the high leverage. Moreover, the results indicate that credit and connectivity dynamics are effective early warning measures for crises. Indeed, aggregate credit leverage and connectivity are positively correlated with the number of firm failures. Therefore, during expansionary phases the combined expansion of credit, leverage and connectivity growth may create the conditions for future recessions and crises, in a true Minskyan perspective (see Minsky 1986). Furthemore, the paper investigates different policy scenarios using capital-related macroprudential policies. The results confirm that quantitative restrictions are effective in reducing the probability of crises. In particular, the paper indicates that capital- related measures that force banks to avoid lending to more indebted firms may decrease output volatility without causing consistent credit reductions and, thus, output contractions.

Finally the paper by Clemente et al. (2017) provides a methodological contribution by proposing a new indicator aimed to measure the overall "level of small-worldliness" of a network. The authors adopt an approach based on a direct comparison of network structures between the targeted real network and two selected benchmarks corresponding to regular and random networks. The technique uses a distance function defined on the network space in order to detect small-worlds features of the network. The proposed indicator is then tested on both simulated and real data. The analysis proposed by the authors is useful because small-worlds are characteristic of many economic (see e.g. Tomasello et al. 2017) and financial networks (see e.g. Haldane 2013). In particular local shocks can have large impact in network structures that exhibit the small world property (like e.g. core-periphery networks, see Markose et al. 2012; Luu et al. 2018).

3 The validation of agent-based models

The papers in the second part of the special issue address the open and critical issue of agent-based model validation. The challenge is first to provide effective approaches to test the validity of model predictions by assuring that a simulation's outcomes attain a stricter adherence to economic facts. Second, to provide methods to effectively analyze the robustness of the results of an ABMs to alternative configuration of parameter values and thus to show how much the results of the model's simulations are general enough. The two papers by Lamperti (2017) and of Dosi et al. (2017) address both issues.

More precisely, Lamperti (2017) proposes a technique aimed to validate a model (of any type) by quantifying the distance between distributions of patterns in time series data by means of an information theoretic criterion that builds on the L-divergence (Lin 1991). Indeed, the author further develops the GSL-div measure (Generalized Subtracted L-divergence) which was introduced in Lamperti (2018) as a "precise quantification of the distance between the model and data with respect to their dynamics in the time domain". In order to provide an illustrative application of the proposed approach, the paper simulates the asset pricing model with heterogeneous beliefs proposed in Brock and Hommes (1997). The simulated time series are compared with market data coming from the two major stock market indexes in Europe and China, EuroSTOXX 50 and CSI 300, respectively. Interestingly, the results support the conclusions that the model by Brock and Hommes (1997) is able to decently replicate the main features of empirical data. At the same time, they show that this model is not able to put strong restrictions on the true data generating process, as many combinations of traders' behavioural rules (only fundamentalists and trend followers are considered) are compatible with the same empirically-observed dynamics.

The paper by Dosi et al. (2017) applies the kriging meta-modelling methodology to evaluate the ability of the evolutionary model developed in (Dosi et al. 2016) to replicate one of the most robust empirical features of industrial dynamics: the presence of fat-tails in the distribution of firm growth rates (see Bottazzi and Secchi 2006; Dosi 2007). Kriging is an interpolation method (see Kleijnen 2009) that under fairly general assumptions provides the best linear unbiased predictors for the response of more complex, possibly non-linear, computer simulation models. The kriging meta-model is estimated from a set of observations (from the original model). The fitted meta-model is then used together with Sobol decomposition to perform a variance-based, global sensitivity analysis of the original model on all of its parameters. The results below clearly confirm that the original model robustly reproduces fat-tailed firm growth rates distributions (and of the Laplace type in particular) over most of the parametric space. This in turn points to the importance of evolutionary mechanisms of cumulative learning and selection (in terms of entry-exit and of market shares' allocation) in shaping the real dynamics of firm growth.

4 Concluding remarks

The papers presented in this special issue offer a panorama of two recent and highly relevant fields in the in the literature inspired by the complex evolving system approach to economic analysis: the analysis of financial networks and the validation of agent-based models. The first group of papers shows the great potential of network techniques to shed light on the analysis of the emergence of systemic risk in financial markets and on its consequences. They also contribute to the debate on highly relevant policy issues that emerged in the aftermath of the last financial crisis, like the impact of central clearing counterparties (CCPs) or the impact of capital requirements on the supply of credit and on the overall output dynamics. The papers in the second part of this issue propose statistical techniques that can be effectively used to validate agent-based models or to investigate the generality of their results. In that, they constitute an important step forward for a larger diffusion of agent-based models for positive and normative analyses in economics.

References

Acharya VV, Engle R, Figlewski S, Lynch A, Subrahmanyam M (2009) Centralized clearing for credit derivatives. Restoring financial stability: how to repair a failed system 251:251

Bargigli L, Tedeschi G (2013) Major trends in agent-based economics. J Econ Interact Coord 8:211–217

Battiston S, Farmer JD, Flache A, Garlaschelli D, Haldane AG, Heesterbeek H, Hommes C, Jaeger C, May R, Scheffer M (2016) Complexity theory and financial regulation. Science 351:818–819

Bottazzi G, Secchi A (2006) Explaining the distribution of firm growth rates. RAND J Econ 37:235–256

Brock WA, Hommes CH (1997) A rational route to randomness. Econometrica 65(5):1059–1095

Catullo E, Palestrini A, Grilli R, Gallegati M (2017) Early warning indicators and macro-prudential policies: a credit network agent based model. J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0199-y

Cecchetti S, Gyntelberg J, Hollanders M (2009) Central counterparties for over-the-counter derivatives. BIS Quarterly Review, September

Clemente GP, Fattore M, Grassi R (2017) Structural comparisons of networks and model-based detection of small-worldness. J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0202-7

Delli Gatti D, Di Guilmi C, Gaffeo E, Giulioni G, Gallegati M, Palestrini A (2005) A new approach to business fluctuations: heterogeneous interacting agents, scaling laws and financial fragility. J Econ behav organ 56:489–512

Dosi G (2007) Statistical regularities in the evolution of industries. A guide through some evidence and challenges for the theory. In: Malerba F, Brusoni S (eds) Perspectives on innovation. Cambridge University Press, Cambridge, MA

Dosi G, Pereira MC, Virgillito ME (2016) The footprint of evolutionary processes of learning and selection upon the statistical properties of industrial dynamics. Ind Corp Change 26:187–210
Dosi G, Pereira MC, Virgillito ME (2017) On the robustness of the fat-tailed distribution of firm growth rates: a global sensitivity analysis. J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0193-4
Duffie D, Zhu H (2011) Does a central clearing counterparty reduce counterparty risk? Rev Asset Pricing Stud 1:74–95
Fagiolo G, Guerini M, Lamperti F, Moneta A, Roventini A (2017) Validation of agent-based models in economics and finance. Technical report 2017/23, LEM working paper
Fagiolo G, Roventini A (2017) Macroeconomic policy in DSGE and agent-based models Redux: new developments and challenges ahead. J Artif Soc Soc Simul 20(1). https://doi.org/10.18564/jasss.3280
Gaffeo E, Molinari M (2017) A functional perspective on financial networks. J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0210-7
Haldane AG (2013) Rethinking the financial network. Fragile stabilität-stabile fragilität. Springer, Wiesbaden, pp 243–278
Haldane AG, Turrell AE (2018) An interdisciplinary model for macroeconomics. Oxf Rev Econ Policy 34:219–251
Hayakawa H (2016) Characterization of lower bound and upper bound of required settlement fund under real-time gross settlement. Available at SSRN: https://ssrn.com/abstract=2659975 or https://doi.org/10.2139/ssrn.2659975
Hayakawa H (2017) Does a central clearing counterparty reduce liquidity needs? J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0208-1
Kirman A (2010) Complex economics: individual and collective rationality. Routledge, London
Kirman AP (2010b) The economic crisis is a crisis for economic theory. CESifo Econ Stud 56:498–535
Kleijnen JP (2009) Kriging metamodeling in simulation: a review. Eur J Oper Res 192:707–716
Lamperti F (2017) Empirical validation of simulated models through the GSL-div: an illustrative application. J Econ Interact Coord. https://doi.org/10.1007/s11403-017-0206-3
Lamperti F (2018) An information theoretic criterion for empirical validation of simulation models. Econom Stat 5:83–106
Lin J (1991) Divergence measures based on the Shannon entropy. IEEE Trans Inf Theory 37:145–151
Luu DT, Napoletano M, Barucca P, Battiston S (2018) Collateral unchained: rehypothecation networks, concentration and systemic effects, GREDEG working papers 2018-05, Groupe de REcherche en Droit, Economie, Gestion (GREDEG CNRS), University of Nice Sophia Antipolis
Markose S, Giansante S, Shaghaghi AR (2012) Too interconnected to failfinancial network of US CDS market: topological fragility and systemic risk. J Econ Behav Organ 83:627–646
Minsky H (1986) Stabilizing an unstable economy. Yale University Press, New Haven
Samanidou E, Zschischang E, Stauffer D, Lux T (2007) Agent-based models of financial markets. Rep Prog Phys 70:409
Schularick M, Taylor AM (2012) Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 1870–2008. Am Econ Rev 102:1029–61
Stiglitz J (2011) Rethinking macroeconomics: what failed, and how to repair it. J Eur Econ Assoc 9:591–645
Tesfatsion L (2006) Agent-based computational economics: a constructive approach to economic theory. Handb Comput Econ 2:831–880
Tomasello MV, Napoletano M, Garas A, Schweitzer F (2017) The rise and fall of R&D networks. Ind Corp Change 26:617–646