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Bank interlinkages and macroeconomic stability

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ABSTRACT

In this paper we analyze the role of the relationship between investment and finance as the main source of both financial instability and business cycle fluctuations. By building an agent-based model, our aim is to explicitly consider the complex nature of credit markets as strongly interactive and evolving structures that can be suitably depicted by networks. In this type of setting, the nodes of a graph represent banks/firms and links represent the relationship between lending and borrowing agents. Since both loans and bad debts proceed through credit linkages, we analyze how market connectivity — in particular the interbank one — affects agents' performances, bankruptcy cascades and business cycle fluctuations. Specifically, interbank linkages allow banks to share credit risk but at the same time they can spread one bank's crisis through the whole network. Ultimately, the goal of our model is to analyze how microscopic interaction feeds back on macro stability.

1. Introduction

The financial turmoils in the recent crisis have shown the complex nature of interactions taking place within the financial system (Allen & Babus, 2009; Gai, Haldane, & Kapadia, 2011; Gonzalez & Gonzalez, 2014; Helbing, 2012).

A complex system is characterized by the presence of a wide number of mutually interacting elements. Usually, their interactions produce nonlinear dynamics: single elements are affected by the environment where they act and at the same time their actions influence the environment itself. In brief, nonlinearity determines a feedback process where causes and effects are no longer proportional to each other (Helbing, 2012). In a complex system the dynamics at the microscopic level are essentially chaotic.[1] However, from this chaotic interaction of individuals universal (or scaling) laws emerge at the aggregate level as the outcome of a self-organizing process.

If we look at financial and credit markets through the lens of complexity, we can observe a broad set of agents — usually heterogeneous in size — that interact in a network which represents agents' interaction. By analyzing the network's topology within a certain time span, it is possible to study those set of network properties which are linked to systemic (in)stability.

Generally, agents' action is driven by profit-seeking but what forces them to interact is the lack of perfect information (Grossman & Stiglitz, 1980). In the latter case, markets would be inefficient and thus out from their equilibrium condition. On the contrary, mainstream macroeconomics assumes perfect information and market efficiency thereby ruling out any interaction mechanism. This is the main reason why the Representative Agent (RA) approach is inadequate when dealing with complexity. Most of the issues surrounding both contagion phenomena and the emergence of systemic risk have essentially a complex network nature. Furthermore, the RA approach can be employed only if we assume that agents' heterogeneity is temporary, i.e. if the population of banks/firms converges over time to a stationary distribution where agents are identical (Delli Gatti, Di Guilmi, Gallegati, & Giulioni, 2007). However, several

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[1] With the term *chaotic* we refer to a system that shows an exponential sensitivity to initial conditions (Ott, 2002).

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empirical contributions have underlined that heterogeneity remains persistent over time and that the evolution of the distribution of heterogeneous agents influences macroeconomic variables (Amaral et al., 1997; Axtell, 2001; Gaffeo, Gallegati, & Palestrini, 2003; Stanley et al., 1996; Zajdenweber, 1997). To deal with both heterogeneity and interaction we therefore employ an agent-based framework. Coherently with the assumptions of informational imperfections and bounded rationality of agents, a set of simple rules of thumb are applied to model agents' behavior. Specifically, agents interact to increase their information set which would otherwise be limited to their local knowledge of the environment. Consequently, market coordination is achieved through a decentralized matching mechanism which allows to explore out-of-equilibrium dynamics. By means of computer simulations, we determine the time evolution of the microvariables — such as the individual level of capital stock, equity, and leverage — and, in each period, we sum these microvariables to obtain their corresponding value at the macro-level (bottom-up approach).

By combining the agent-based modeling (ABM) approach with the network theory tools, we can jointly account for a set of "micro/meso" properties such as the size distribution of agents and their level of financial soundness — together with macro aggregates — such as the production growth rate and its volatility, business cycle phases and bankruptcy cascades. Network theory is a natural candidate to analyze the interaction in social systems because it provides analytical tools to investigate how agents mutually interact, how information flows within the market and how adjustments in disequilibrium occur. The financial sector can be considered as a set of agents (i.e. lenders and borrowers — banks and firms) who mutually interact through financial transactions. Thus, a graph of all the linkages between agents is the most suitable to describe the interaction that occurs within markets given a set of behavioral rules and regulations. The network of mutual credit connections between financial institutions and the firms plays a key role in the definition of risk for defaults due to contagion spreading. The economic literature on contagion (see Allen & Gale, 2000a, 2000b; Battiston, Delli Gatti, Gallegati, Greenwald, & Stiglitz, 2012a, 2012b; Iori, Jafarey, & Padilla, 2006; Lenzu & Tedeschi, 2012) has emphasized the importance of agent connectivity and credit network topology in the analysis of sharing and systemic risk. By rising agent connectivity, the financial network becomes less exposed to systemic risk due to risk sharing. However, when the connectivity becomes too high, financial linkages — especially those involving highly leveraged agents — represent a propagation channel for contagion and a source of systemic risk. Therefore, connections show their robust-yet-fragile nature: links operate both as shock-absorbers and as shock-amplifiers (Chinazzi & Fagiolo, 2013; Doyle et al., 2005). Furthermore, credit relationships have been pointed out as the main linkage between the financial and the real economy, since they involve the balance sheet of both banks and firms. While the balance sheet of credit institutions affects the potential supply of loans, due to the capital adequacy ratios, firm net worth influences the banks' willingness to lend money to highly leveraged firms. The seminal papers by Stiglitz and Weiss (1981) showed that informational asymmetries in the credit markets may prevent firms to obtain credit, even for those with good investment projects. Further research highlighted the so-called financial accelerator mechanism, i.e. a balance sheet channel through which monetary policy has real effects in the economy (Bernanke & Gertler, 1990; Bernanke & Gertler, 1995; Greenwald & Stiglitz, 1993).

The aim of this paper is to explore the potential of the interbank market to behave as a contagion mechanism for liquidity crises and also to study how the banks' connectivity level affects macroeconomic outcomes, such as business cycle fluctuations and bankruptcies. By explicitly modeling agents' interaction at the micro level, this work underlines the role of the relationship between investment and finance not only as a shock transmission device but also as the main source of financial instability and business cycle fluctuations.

Our model represents an extension of an existing ABM (Delli Gatti et al., 2005), in which a population of heterogeneous firms seeks for a loan from a unique bank. Here we add a banking sector composed by a multiplicity of banks which play on both credit and interbank markets.[2] Our model is very simple. Whenever firms need funds to expand their production level, they seek for banking loans. The investment decision of firms depends on the interest rate applied by the bank, which in turn depends on the firm's financial fragility. Because of informational imperfection, firms can contact just a few potential lenders and can borrow only from one of them. If the selected lender has not enough liquidity to fully meet the firm's request, it may decide to borrow from a surplus bank on the interbank market.[3]In this kind of market, therefore, lending banks share with borrowing banks the risk of granting loans to firms.

In this paper, we model credit and interbank systems as Erdös–Renyi random graphs (see Allen & Gale, 2000a, 2000b, for instance) and we study the network resilience by changing the degree of connectivity among agents. In our model, bankruptcies occur when financially fragile firms lose all their net worth (i.e. it becomes negative). If one or more firms are not able to pay back their debts to the bank, the bank's balance sheet decreases. Since firms' bad debts affect the banks' equity, a second round of failures may occur among banks in the credit market. As banks with shortage of liquidity enter the interbank market, the failure of borrowing banks could lead to a further wave of failures of lending banks. Thus, agents' bad debts can trigger a cascade of bankruptcies among banks. The source of domino effect may be due to both direct and indirect interactions. The former occurs between lending and borrowing banks in the interbank market; the latter involves bankrupt firms and their lending counterparts in the credit market. Our findings suggest that the role that the banking system plays in the real economy and in sustaining the economic activity deserves

[2] As far as we know, several agent-based models have been developed with regard to single sectors of the economy (production, labor, credit, etc.), while the development of models of a multiple-market economy as a whole is still at its dawn (see for example Cincotti, Raberto, & Teglio, 2010; Riccetti, Russo, & Gallegati, 2013 and Tedeschi, Mazloumian, Gallegati, & Helbing, 2012 among the few attempts). In our opinion, the multiple nature of links (financial and commercial) and the existence of direct links among all thedifferent actors (bank–bank, bank–firms and firm–firm) are extremely useful for understanding the propagation of systemic risk and joint failures both among similar and different economic actors.

[3] There are great variations between banks in the use they make of the interbank market. In any case, this market should make funds available quickly and efficiently to banks which have lending opportunities and should enable the banking system to adapt much more rapidly and smoothly to new demands than would otherwise be possible. For this reason, the interbank market is the natural channel to avoid the liquidity difficulties which might otherwise exist among financial institutions (see Bank for International Settlements (BIS), 1983).