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# Network analysis and calibration of the "leveraged network-based financial accelerator"

Leonardo Bargigli[a], Mauro Gallegati[b], Luca Riccetti[c,*], Alberto Russo[b]

[a] *Scuola Normale Superiore, Pisa, Italy*
[b] *Università Politecnica delle Marche, Ancona, Italy*
[c] *Sapienza Università di Roma, Roma, Italy*

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ABSTRACT

In this paper we analyze the network structure that endogenously emerges in the credit market of the agent-based model of Riccetti et al. (2011), where two kinds of financial accelerators are at work: the "leverage accelerator" and the "network-based accelerator". We focus on the properties of network topology and its interplay with the overall economic performance. Moreover, we empirically calibrate the banking network in the model by using Japanese real data.



## 1. Introduction

In this paper we analyze the credit network structure that endogenously emerges in the agent-based model of Riccetti et al. (2011), a model further developed in Riccetti et al. (2013). This model considers two kinds of financial accelerators: the "leverage accelerator" together with the "network-based financial accelerator" (Delli Gatti et al., 2010). Basically, the financial accelerator (Bernanke and Gertler, 1989, 1996) is a mechanism that can enlarge business fluctuations: negative shocks on firms' output make banks less willing to loan funds, hence firms might reduce their investment and this leads again to lower output in a vicious circle. However, models of the financial accelerator available so far are generally limited, in our opinion, because of the Representative Agent assumption. The aggregate mainstream view of the financial accelerator abstracts from the complex nexus of credit relationships among heterogeneous borrowers and lenders that characterizes modern financially sophisticated economies. Instead, in Delli Gatti et al. (2010), the presence of a credit network may produce an avalanche of firms' bankruptcies, so that even a small shock can generate a large crisis. Accordingly, an idiosyncratic shock on borrower (firm) deteriorates the lenders' financial condition weakening the banking system; thus lenders increase the

* Corresponding author at: Sapienza Università di Roma, Department of Management, via del Castro Laurenziano 9, 00161 Roma, Italy. Tel.: +39 0649766209.
*E-mail addresses:* luca.riccetti@uniroma1.it, l.riccetti@univpm.it (L. Riccetti).

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interest rates charged on borrowers (indirect interaction) worsening the non-financial sector conditions in a vicious circle that can make both firms and banks go bankrupt, possibly causing an avalanche of bankruptcies. Riccetti et al. (2011) merges the two mechanisms in a unified framework. The aim of present work is twofold:

1 to analyze the properties of the credit network and its influence on the overall economic performance;
2 to calibrate the banking network topology which emerges from the agent-based model by using Japanese real data.

It is natural to conceive credit markets as networks in which nodes represent agents and links represent credit claims and liabilities. Most works in this field focus specifically on the interbank market, since the latter is relevant for financial stability and, at the same time, well suited for a representation with basic network theory. The interconnectedness of credit institutions is a source of counterparty risk on interbank credit markets, which has been addressed recently by a number of theoretical models tackling the problem of contagious defaults (Gai and Kapadia, 2010; Amini et al., 2010a,b; Battiston et al., 2012). These models, which go beyond previous simulation-based works (Nier et al., 2007; Elsinger et al., 2006), rely on complex network theory, which has become a prominent tool in this field. While earlier contributions (Allen and Gale, 2000) stressed the benefits of increasing diversification, suggesting that the more connections the better for financial stability, these later works have challenged this view, showing that diversification is not always beneficial for stability, and underlining instead the systemic risk provided by default cascades and other contagion effects. Indeed, a large recent literature strand analyzes various sources of systemic risk focusing in particular on two channels, as explained by Gai and Kapadia (2010): first, there is the already mentioned direct contagion risk due to the network of exposures; second, there is the indirect contagion risk caused by the fire sale mechanism (also called “market liquidity risk”, as in Alessandri et al., 2009, or Cifuentes and Ferrucci, 2005. The importance of the liquidity issue is debated also in the agent based model framework, see for instance Giansante et al., 2012), explained in many papers such as Choi and Cook (2012), Krishnamurthy (2009), and Shleifer and Vishny (2011). Even in the fire sale context, Wagner (2011) shows that diversification is not always beneficial: on one hand a well diversified portfolio allocation reduces the bankruptcy probability, but on the other hand if many investors pursue the same strategy (that is a large diversification), there is a strong risk of facing higher liquidation costs due to a joint liquidation event. Focusing again on direct contagion effect, for instance, Battiston et al. (2012) show that, if market-related effects are considered along with credit-related effects by introducing a financial accelerator mechanism, then a potential trade-off between individual risk and systemic risk may exist for increasing connectivity of the network. Similar results are provided by Gai and Kapadia (2010), who show that financial systems exhibit a robust-yet-fragile tendency: while the probability of contagion may be low, once a default cascade is started its spread may be quite large. This effect is non-monotonic in connectivity: for a given range of values, connectivity increases the chances that institutions surviving the effects of the initial default will be exposed to more than one defaulting counterpart after the first round of contagion, thus making them more vulnerable to a second-round default.

In general terms, the dynamics of any contagion process depends crucially on network topology. This fact agrees with the following simple intuition: whenever a shock affects a node of a financial network, this will be transmitted to its neighbors with a probability that is proportional to the strength of their linkage to the shocked node. In this context, heterogeneity becomes of paramount importance: some nodes may be too big or too connected to fail, since their failure could hardly hit a large neighborhood. Empirical analyses find unequivocal evidence of heterogeneity in credit networks, such as De Masi et al. (2011) or Cont et al. (2012), thus providing a strong argument for a deeper analysis of network effects in financial markets. Moreover, empirical results show that networks cannot be easily estimated from partial data. For instance, it is well known that networks estimated with maximum entropy (ME) techniques, when shocked, behave quite differently from their real counterparts (Mastromatteo et al., 2012). In particular, ME networks are usually found to underestimate the extent of contagion, although non-linear effects also appear (van Lelyveld and Liedorp, 2006; Mistrulli, 2011). In this sense, a specific network heterogeneity needs to be addressed besides nodes' heterogeneity to get a deeper understanding of credit markets.

On the other hand, the empirical support for the relevance of contagious defaults in the interbank market is mixed. This is not surprising at all since empirical works in this field rely on a variety of simulation-based approaches and diverse behavioral assumptions.[1] For instance, those works which examine the effects of idiosyncratic shocks affecting a single bank, come to the conclusion that the scope of contagion is limited (Elsinger et al., 2006; Upper and Worms, 2004; Mistrulli, 2011). By adopting a more realistic setting, e.g. taking into account correlated market shocks and short-term 100% losses for creditors, quite different results have been obtained (Cont et al., 2012). Notwithstanding this uncertainty, central banks are becoming more and more interested in network analysis, supporting network-related research and dissemination, although most empirical work in this direction still looks merely descriptive (Castrén and Kavonius, 2009; European Central Bank, 2010). In order to develop more realistic models, the modeling framework should be grounded in the empirical evidence both qualitatively and quantitatively.

In recent years there has been a growing literature on the validation and calibration of agent-based models with real data (just to give some examples: Bianchi et al., 2007; Brenner and Werker, 2007; Fagiolo et al., 2007). Validation represents

[1] For a survey see Upper (2011).