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Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns

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ABSTRACT

Interbank markets allow banks to cope with specific liquidity shocks. At the same time, they may represent a channel for contagion as a bank default may spread to other banks through interbank linkages. This paper analyses how contagion propagates within the Italian interbank market using a unique data set including actual bilateral exposures. Based on the availability of information on actual bilateral exposures for all Italian banks, the results obtained by assuming the maximum entropy are compared with those reflecting the observed structure of interbank claims. The comparison indicates that, under certain circumstances, depending on the structure of the interbank linkages, the recovery rates of interbank exposures and banks' capitalisation, the maximum entropy approach overrates the scope for contagion.

1. Introduction

Systemic risk has always played a prominent role in the economic policy debate. A widely shared view is that the banking system is an important chain in the propagation of shocks to the entire economy.[1] Early theoretical works concerning systemic risk in the banking sector have focused on depositor runs triggered by self-fulfilling expectations (Diamond and Dybvig, 1983) or by signals regarding bank solvency (Chari and Jagannathan, 1988; Jacklin and Bhattacharya, 1988). More recently, attention has been paid to financial contagion in the interbank market (Rochet and Tirole, 1996). While the interbank market may allow banks to cope with specific liquidity shocks (Bhattacharya and Gale, 1987), interbank relationships may represent a channel for contagion: the economic distress of an insolvent bank may propagate to other banks through interbank linkages.[2] Theoretical works (Allen and Gale, 2000; Freixas et al., 2000) have also highlighted that the propagation of shocks within the interbank market is dependent on the exact pattern of banks' financial linkages.

Many contributions have sought to measure the vulnerability of the interbank market to financial contagion.[3] However, these works suffer from two main data limitations. First, detailed data on banks' bilateral exposures are generally not available. In order to circumvent this problem, two approaches have been adopted: (a) the severity of financial contagion in the interbank market has been measured by focusing on a specific segment of the market for which actual bilateral exposures were available; in particular, Furfine (2003) has investigated contagion in the Federal Reserve's large-value transfer system (Fedwire) which, however, represents a small fraction of US total interbank exposures (according to Furfine himself, approximately 14%); (b) other contributions have taken into account the whole interbank market. However, since detailed information on banks' bilateral exposures is not available, these works have had to assume a specific pattern for them. In particular, it is possible to distinguish between two different cases: (i) interbank bilateral exposures are obtained on the basis of aggregated interbank assets and liabilities by maximising the entropy[4] of the matrix of bilateral claims (e.g. Upper and Worms, 2004) or (ii) when information about large bilateral exposures is available, the entropy maximisation method is applied only to those elements of the matrix of bilateral exposures that are not known (Blavarg and Nimander, 2002; Wells,

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[1] De Bandt and Hartmann (2000) and Kaufman (1994) provide a detailed discussion on the definition of systemic risk.

[2] A different channel for contagion through the interbank market could be related to signals or self-fulfilling expectations triggering interbank deposits withdrawals.

[3] See Upper (2007) and Appendix A for details of the literature on financial contagion.

[4] See Appendix B for details.

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2004; Degryse and Nguyen, 2007; van Lelyveld and Liedorp, 2006). The main limitation of this approach is that it assumes a market structure which might be quite different from the actual one. Indeed, the maximisation of the entropy rules out lending relationships in the interbank market[5] since it assumes that each bank lends to all the other banks in the market.

A second data limitation concerns the structure of the banking system. The existing literature has typically overlooked the fact that banks are often affiliated with a conglomerate, even if this may, quite obviously, affect the resilience of the banking system to systemic shocks.

In this paper, we investigate financial contagion in the interbank market by using a unique data set including detailed information on each actual bilateral exposure for all the Italian banks. Thus, the analysis deals with all kinds of interbank financial linkages, besides derivatives and shares, for every Italian bank and for each bank-to-bank relationship. According to the previous literature, we use simulation techniques to measure the severity of financial contagion.

The paper contributes to the literature in two main respects. First, it provides a measure of the vulnerability to financial contagion of the Italian interbank market,[6] thus enriching the evidence so far available for most of the industrialised countries. However, the analysis differs from those made for other countries as it is based on actual bilateral exposures instead of maximum entropy exposures. Furthermore, by taking into account the affiliation of banks with a conglomerate, it provides evidence on the link between financial conglomeration and banking system stability. The paper shows that even if the Italian interbank market is conducive to financial contagion it hardly triggers a systemic crisis. It also shows that the failure of a foreign bank is less conducive to contagion compared to a domestic bank default. We support this view by looking at both a pre-crisis period (2003) and at two different dates, one before (June 2008) and the other (November 2008) after the default of Lehman Brothers. Furthermore, banks conglomeration tends to improve the resilience of the banking system to shocks. However, in some cases, since conglomeration induces a strong interdependency among affiliated banks, the extent of contagion may be even wider if banks' affiliation is taken into account than when it is ignored.

Second, it shows that the measure of financial contagion depends on the pattern of interbank linkages.[7] To this end, the paper applies the maximum entropy method, it reruns the simulation exercises and then compares them with the results based on actual bilateral exposures. The comparison indicates that, in line with the thesis prevailing in the literature, the maximum entropy method leads to an undervaluation of the extent of contagion. However, this does not hold in general. Under certain circumstances, depending on the structure of the interbank linkages, the recovery rates of interbank exposures and banks' capitalisation, the maximum entropy approach implies an overvaluation of the scope for contagion.

These results have two consequences. On the empirical level, it indicates that in some circumstances, depending on the structure of the interbank market, the maximum entropy approach may not be very reliable in assessing the severity of financial contagion. Furthermore, since it does not provide a lower bound to contagion vulnerability, it may not be reliable either for assessing whether the interbank market is conducive to contagion or not. On the theoretical level, following Allen and Gale's (2000) taxonomy, the comparison between maximum entropy and observed exposures may be interpreted as a comparison between complete and incomplete markets. In this respect, the results obtained in this paper show that complete markets are not always less conducive to contagion than other markets, as Allen and Gale (2000) stated. On the contrary, this paper is in line with the theoretical model by Brusco and Castiglionesi (2007) and Hasman and Samartin (2008) showing that incompletely connected markets are more resilient to contagion.

The remainder of the paper is organised as follows. Section 2 describes the methodology and data. Section 3 deals with the vulnerability to financial contagion of the Italian interbank market. Section 4 investigates how the maximum entropy method affects the severity of financial contagion by comparing, for the Italian case, the results obtained on the basis of the maximum entropy matrix of bilateral exposures with those obtained using the observed matrix. Section 5 concludes and summarises the main findings.

2. Data and methodology

2.1. Data

We obtain data on gross bilateral interbank exposures from the Bank of Italy supervisory reports database. Since January 1989 all Italian banks, including their foreign branches, submit to the Bank Italy their end-of-month bilateral exposures to all other banks, foreign intermediaries included. Data refer to all kinds of interbank assets except shares. The database allows for a distinction between different claims (CDs, current accounts, repos, other loans, subordinated and unsubordinated bonds) classified according to their maturity (up to 18 months, over 18 months), currency of denomination and counterpart nationality (Italy vs. rest of the world).

2.2. The contagion mechanism

All banks raising funds in the interbank market are allowed to fail one at a time. The losses suffered by banks lending to the failed bank are then computed. If the amount of the losses is greater than lenders' tier-1 capital (i.e. capital and reserves) then lenders default. The simulation is then iterated by verifying if banks that fail after the first iteration make other banks fail as well. At each iteration banks that failed in the previous one are dropped from the set of banks which may be affected by contagion. The simulation continues until at least one bank default occurs.[8]

More formally, let B be the set of banks and x_{ij} denote the funds that bank $j \in B$ borrows from bank $i \in B$, where $x_{ij} \geqslant 0 \; \forall (i,j) \in B \times B$ and $x_{ii} = 0 \; \forall i \in B$, by $c_i > 0$ the initial capital endowment of bank i, and by $\alpha \in [0, 1]$ the rate of loss (i.e. the incidence of losses due to contagion out of the interbank exposure). Finally, let $z \in B$ denote the first bank that defaults because of some idiosyncratic shock, and define $D_z^n \subseteq B$ and $S_z^n \subseteq B$ as the set of banks, respectively, defaulted and surviving at the nth step of the contagion path initiated by bank z, as follows:

$$D_z^n = \left\{ \mathcal{k} \in B : c_{\mathcal{k},z}^n \leqslant 0 | c_{\mathcal{k},z}^{n-1} > 0 \right\}$$
$$S_z^n = \left\{ \mathcal{k} \in B : c_{\mathcal{k},z}^n > 0 \right\}, \quad \forall \; n \geqslant 1 \tag{1}$$

where $c_{\mathcal{k},z}^n$, which is the capital of bank $\mathcal{k}$ at the nth step of contagion initiated by bank z, is equal to:

$$c_{\mathcal{k},z}^n = c_{\mathcal{k},z}^{n-1} - \alpha \sum_{j \in D_z^{n-1}} x_{\mathcal{k}j}, \quad \forall \; n \geqslant 1 \text{ and } \forall \; \mathcal{k} \neq z \tag{2}$$

[5] Cocco et al. (2009) find evidence supporting the existence of lending relationships in the interbank market for overnight funds.

[6] The paper by Angelini et al. (1996) has also analysed the risk of contagion in the Italian interbank market, although the work takes into account only the netting system segment.

[7] On the need to run stress tests on the banking system as whole, that is taking into account interlikages among banks see, among others, Goodhart (2006).

[8] Simulations do not allow for a role of the central bank in providing liquidity to the banking system. For a model of the role of the central bank in avoiding financial contagion see Castiglionesi (2007).