JOURNAL OF ECONOMIC SURVEYS

doi: 10.1111/j.1467-6419.2012.00739.x

A CRITICAL REVIEW OF CONTAGION RISK IN BANKING

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Abstract. The recent financial crisis has focused the attention of scholars and policymakers on how to improve financial stability through better macro-prudential regulation and supervision. In this paper, we compare the existing theoretical and empirical literature on contagion through the banking system. It is argued that the structure of the interbank market, the size of banks, the linkages among them, the level of correlation of their investments and the transparency of the regulator are key factors in determining the possibility of contagion. We discuss the different findings and present avenues for future research.

Keywords. Banking crises; Bank runs; Contagion

1. Introduction

Banking crises are costly and quite frequent events which can spread to banks and regions all around the world. During the last 25 years, more than two-thirds of the International Monetary Fund (IMF) countries have suffered some kind of financial trouble, a fact which has drawn the attention of researchers (see Lindgren *et al*., 1996). However, the exact nature of the transmission mechanism and the best ways in which to diminish the impact of such crises are still unknown.

It has been estimated that the direct costs of bank bailouts in the recent Asian crises were more than 30% of the GDP of Thailand, Indonesia and South Korea (Beim and Calomiris, 2001), while the resolution cost for Japan was close to 20% of its GDP (Calomiris and Mason, 2003). These crises, together with those suffered in Scandinavia at the beginning of the nineties and in Latin America (Mexico, Argentina, Brazil and Venezuela) at the end of the twentieth century, as well as the recent banking crisis, stimulated vast amounts of literature on bank runs and contagion. However, as this work tries to show, there are still many gaps in this literature.

In this paper, the term 'contagion' refers to the transmission of an idiosyncratic shock that affects one bank, or possibly a group of banks, and how this shock is transmitted to other banks or economic sectors. This notion of contagion is part of the broader concept of systemic risk, which may result from contagion or a common shock affecting all banks simultaneously.

Banking crises have shed light on the fact that the financial system, and especially the banking sector, cannot only amplify and transfer problems that originate in one sector of the economy but also be a main driver of such crises. Another important fact is that banking problems are difficult to eradicate and so may survive even after the economies have recovered. These phenomena are stimulated by both high capital mobility and open financial systems. While emergent economies usually benefit from such inflows when the system is at rest, they tend to be more vulnerable during a crisis.

Prudential regulation, in the form of liquidity or capital requirements, is designed to enhance the resilience to shocks of the banking system by requiring institutions to maintain prudent levels of

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Journal of Economic Surveys (2013) Vol. 27, No. 5, pp. 978–995

liquidity and capital under a broad range of market conditions. However, at times of market turbulence, the remedial actions prescribed by these regulations may have perverse effects on systemic stability. Forced sales of assets may generate volatility feedback onto the market and produce a downward spiral in asset prices, which, in turn, may adversely affect other financial institutions (Cifuentes *et al*., 2005).

The recent financial crisis has renewed the debate on why the crisis occurred, the best strategies to escape from the crisis and the optimal regulation needed to prevent future collapses. It has been said that better regulation and supervision is needed to prevent future banking crashes. However, to make better policy recommendations, we need to know how theoretical predictions differ from the facts, the differences between different banking structures and the specificities in different countries. Moreover, the regulator has to establish a local framework for institutions operating internationally. This creates new conflicts of interest and calls for international harmonisation. In addition, institutions and markets tend to be highly interconnected, and new externalities appear. These elements all make a better understanding of contagion in banking extremely important.

While some studies focus retrospectively on financial crises (Tirole, 2002; Allen *et al*., 2012) and others analyse the implications of different financial networks for systemic risk (Allen and Babus, 2009), surprisingly, few papers try to reconcile the recent theoretical and empirical developments on contagion through the banking system. In this paper, we try to fill this gap by providing a critical revision of the existing literature (theoretical and empirical) and analysing the main causes and channels for contagion in the banking system. We show that the structure of the interbank market, the size of banks, the linkages among them, the level of correlation of their investments and the transparency of the regulator are key factors in determining the possibility of contagion. We provide recent evidence, discuss the findings and present possible avenues for future research.

The paper is organised as follows. Section 2 analyses the genesis of banking crises. Section 3 presents the transmission of banking crises through contagion from a theoretical perspective, and Section 4 analyses the new findings of network theory. Section 5 contains the empirical relevance, and Section 6 discusses banking regulations. Finally, Section 7 presents the concluding remarks.

2. Banking Crises

We should not start analysing contagion before discussing the existing literature on banking panics. Given the historical importance of banking crises, highlighted by the recent episodes around the world, a huge amount of literature has emerged which tries to analyse the causes of these crises and the best policies to prevent and remove their effects.

Although controversy exists concerning the causes of global banking crises, there now exists some consensus concerning the main source of fragility for individual banks: the fractional reserve system, under which long-term, illiquid, loans are financed by deposits on demand.[1]

2.1 *The Reasons for Banking Failure and Crises*

There are two main views in financial literature concerning banking failure and crises: one is the pure panic view pioneered by Diamond and Dybvig (1983). The other is the information-based view, in which bank failures are triggered by information asymmetries and uncertain returns.

Diamond and Dybvig (1983) formalise the idea of demand for liquidity, previously introduced by Bryant (1980), and analyse bank runs as a coordination problem among depositors, even in the presence of safe assets. The service that allows better risk sharing among people with different consumption horizons (and provides the rationale for the existence of banks) makes banks vulnerable to runs.

Whenever a large fraction of depositors decides to withdraw, it is individually rational for others to do the same, thus provoking an inefficient bank run. This will happen when the bank under attack is forced

to prematurely liquidate its assets. In the absence of aggregate uncertainty, suspension of convertibility can impede the bank run equilibrium while, under other circumstances,[2] deposit insurance would prevent the attack.[3]

The alternative view stresses problems of uncertainty and asymmetric information about banks' financial conditions as the source of the bank runs. The chain reaction involves bad information about a bank, agents withdrawing their deposits, liquidity problems for banks, bankruptcies and contagion. This view can be divided into two groups of reasons for the failure of banks. The first group is centred on bad banking management. Here, the main reasons include poor governance (Kirkpatrick, 2009), excessive risk taking (Demsetz *et al*., 1997), focus on size rather than performance (Boyd and Runkle, 1993), soft lending controls (Nakamura and Roszbach, 2010) and liquidity mismatches (Bird and Rajan, 2001). These inadequate incentives are accentuated by limited liability clauses and low capital requirements, and call for better regulation and supervision to foster market discipline.

However, the fact that banks are becoming more complex and interconnected makes supervision more complicated and bailout more likely. Santomero and Hoffman (1998) recognise that many banking systems are insolvent and, because governments struggle to recognise the banking weaknesses, they prefer to offer scapegoats rather than restructure the whole financial system.

In a recent review of historical financial crises, Allen *et al*. (2009) suggest that when big and interconnected financial institutions, such as Lehman Brothers, fail, investors become more cautious when evaluating risk. This in turn might affect other institutions, not necessarily connected to the first institution. Gorton and Metrick (2009) explain how investors might become more sensitive to information after bad news and how this spreads liquidity problems. In the same line of research, Caballero and Simsek (2009) present a model in which the complexity of financial linkages brings uncertainty to banks during downturns. This complex environment makes relatively healthy banks, and hence potential asset buyers, reluctant to buy, since they now fear becoming embroiled in a cascade they do not control or understand. These papers contribute to the idea that contagion in banking is not only a problem of direct linkages, but also of being part of a complex network.

The second group of reasons for the failure of banks recognises that macroeconomic risk might transform into banking problems. For example, Levy-Yeyati *et al*. (2010) find that, during macroeconomic crises, depositors respond more often to macroeconomics factors than to bank-specific factors, transforming a macroeconomic shock into a bank run. Similarly, Morris and Shin (2010) suggest that when the economy is healthy, with strong fundamentals, information asymmetries are likely to be neglected, but when a shock affects the economy, those asymmetries might destroy confidence and, potentially, markets.

In addition, since debt is riskier during a recession (Myers, 1977), equity holders face moral hazard problems. Leveraged firms will not invest optimally because they might not receive any payment during downturns. Moreover, they might invest in technologies that become volatile during a downturn (Fostel and Geanakoplos, 2010). Adrian and Shin (2010) find evidence that leverage is pro-cyclical when it is marked-to-market. During booms, banks have excess capacity and, consequently, the quality of their basket of loans decreases (as in the recent financial crisis). This behaviour increases risk during downturns and might intensify liquidity problems (this is also documented in Bohachova, 2008).

The literature on banking crises and bank runs is vast and cannot be fully covered here. We refer the interested reader to an excellent survey by Gorton and Winton (2003) and the books by Freixas and Rochet (1997) and Allen and Gale (2007).

3. Contagion through the Banking System—Theoretical Literature

Linkages among agents in financial markets are a concern because of the risk of financial contagion, that is, the risk that a small shock to one agent will propagate to other agents in a domino effect. This

effect occurs if the failure of one financial institution to settle payment obligations triggers a chain reaction that threatens the stability of the whole financial system.[4] Banks represent a very important source of finance for most companies and households, and their regulation and supervision is both unique and differentiated from any other type of firm. The possibility of contagion in the banking system is one of the main arguments to justify government provision of liquidity in case of possible bank failures (Sollow, 1982; Goodhart, 1987; Summers, 1991; Allen and Carletti, 2010). This potential intervention is one of the main drivers for regulation in banking to limit the adverse selection and moral hazard effects of such behaviour. This line of research seeks to analyse the implication of the failure of a bank (or group of banks) on the stability of the entire banking system, as well as the possible effects on other sectors of the economy and on the rest of the world.

3.1 *The Origins*

An interesting antecedent of this literature can be found in Bhattacharya and Gale (1987). They consider many intermediaries, each one having only private information about the proportion of the population that will withdraw their investment from that intermediary at the intermediate date. They show that there are welfare gains from setting up institutions, such as a central bank or a market for intermediaries, to trade in the interim period.

An additional concern of the interbank market is its role in settlement of payments. The maintenance of deposit balances with other banks facilitates the clearing of payments across the banking system. Rochet and Tirole (1996) analyse the effects of interbank lending in generating systemic risk, since banks do not collateralise their exposure to other banks' risk in the interbank market. Banks estimate their monthly liquidity needs and can loan their excess reserves to other banks with liquidity shortages in the interbank market (credit risk). However, what facilitates liquidity savings during normal periods (banks can lend those funds that are not kept as reserves to other companies and households for better spreads), exposes them to the failure of their counterparty in the interbank market. A natural consequence is the spillover of a crisis in one bank to the whole banking system (domino effect). Interbank credit lines reduce the costs of maintaining reserves, although at the expense of exposing the system to coordination failures, even if all banks are solvent (Freixas *et al*., 2000). Consequently, payoff and information externalities might be important in causing inefficient bank runs and contagion.

Big depositors, those not completely covered by deposit insurance, have incentives to respond to different sources of information before the value of the bank's assets is revealed, which can accelerate the failure. During the recent financial crisis, after some banks started to face liquidity problems, the whole interbank market dried up, since it was impossible for banks to assess the quality of other bank's assets. Chen (1999) proposes an incentive-compatible reform of the Federal Deposit Insurance Corporation (FDIC) that can make bank runs an efficient mechanism with which to discipline banks.

3.2 *Recent Developments on Contagion through the Banking System*

There exist at least two explanations for the rationality of contagion. The first explanation is informational. Here, the adverse information that precipitates a crisis in one institution also implies adverse information about other institutions. This view emphasises correlations in the underlying values across institutions and Bayesian learning by rational agents (Chen, 1999).

Banks are opaque institutions, so information about one institution might be used to infer information about others. In addition, a crisis in one market leads investors to reassess the risks associated with investments in other markets, regardless of whether or not there are any real linkages between the respective markets or institutions. These changes in asset prices might negatively affect the balance

sheet of banks and the stability of the banking system. In this case, the basic mechanism that propagates shocks across banks is the shift in investor sentiment through changes in perceptions.

Chang and Velasco (2000a, 2000b, 2001) present a model in which the combination of a fractional reserve banking system and external credit rationing can generate devastating effects. When creditors lose confidence and demand immediate payment on existing loans, banks might be forced to liquidate their investments prematurely. This financial panic feeds on itself, and depositors also try to withdraw their money, exacerbating the original effect. In Gianetti (2003), incomplete information about the quality of projects financed by banks might spread contagion. The failure of a truly insolvent bank may propagate to other banks, which are temporarily illiquid but otherwise solvent, owing to a uniform increase in interest rates, as creditors are not able to distinguish solvent from insolvent banks.

Vaugirard (2007) considers that external creditors have imperfect information about the costs incurred when liquidating the assets of banks. Consequently, a banking panic in one country might affect creditors' perceptions of risk in other countries. Higher costs of rollover debt can spread crises internationally. Similarly, in Moheeput (2008), banks are perceived to be connected through unobserved macroeconomic fundamentals. Depositors noisily observe the idiosyncratic risk of their own bank, and might respond to the failure of another bank, irrespective of the reason for that failure. Acharya and Yorulmazer (2007) analyse the inconsistency of the 'too many to fail' policy. The regulator might find it *ex post* optimal to bail out banks when many of them are in danger, but might promote bailouts of surviving banks when just some of them are in danger. Consequently, banks have incentives to invest *ex ante* in correlated technologies to maximise their joint survival. Thus, banks that are perceived to be linked also have a high degree of asset correlation. This argument justifies why depositors and other creditors respond to failures of other banks not directly connected to their own banks. Morrison and White (2010) argue that the existence of a common regulator may increase the likelihood of contagion, since the failure of one bank can undermine the confidence in the regulator.

In summary, the first explanation for contagion in the banking system is informational in nature. International creditors and depositors respond to signals that do not necessarily reflect the real condition of banks, forcing the early liquidation of projects. They assign an important role to depositors, but in practice, deposit insurance should reduce such effects. In addition, the behaviour of the central bank, as a lender of last resort, and funds provided in the interbank market should also reduce the effect of external creditors.

The second explanation for contagion reflects the fact that financial institutions are often directly linked to each other via portfolio or balance sheet connections. Although such linkages may be desirable *ex ante*, during a crisis, such balance sheet connections may cause the failure of one institution to spill over to others by contagion.

Concentrating upon the direct effects of increased risk of default, Allen and Gale (2000) introduce contagion as an equilibrium phenomenon. Banks maintain interbank deposits to insure against imperfectly correlated liquidity shocks, but these same deposits leave them vulnerable to an 'improbable' liquidity preference shock. In such a context, the structure of the interbank claims will determine the possibility of contagion.

Interbank market claims are said to be 'complete' when banks are allowed to interact directly with all other banks in every region.[5] However, these are extreme cases, and there are many other possibilities in which banks are, in some way, restricted in how much they can interact with other banks. Intuitively, banks may specialise in particular areas of business or have closer connections with banks that operate in the same geographical or political unit.

Allen and Gale's analysis assumes a pecking order for asset liquidation. Here, short-term assets are sold before interbank deposits, and interbank deposits are sold before long-term assets. In a paper that changes the pecking order condition, Saez and Shi (2004) show that, when a bank becomes bankrupt and the liquidity gap is small, banks holding deposits on the disturbed bank may liquidate their own long-term assets before liquidating their deposits with the failed bank. In this way, the safe bank can

transfer liquidity to the illiquid bank in an attempt to ensure late consumers their deposits, and so hopefully impede systemic illiquidity and contagion. They also introduce the concept of a liquidity pool, a claim structure in which banks are indirectly connected. This again guarantees liquidity even when one bank is insolvent and so impedes contagion. This paper introduces the idea of an interbank market, not only as a coinsurance instrument in the case of an anticipated liquidity problem, but also in the case of unanticipated shocks. The interbank market can resolve the problems it creates and restore financial stability.

In a model in which different regions are subject to different levels of moral hazards and have negatively correlated liquidity needs, Brusco and Castiglionesi (2007) show that integrated financial markets increase expected social welfare, but only at the cost of greater financial instability. Consequently, and contrary to the findings of Allen and Gale, contagion is greater when banks are more interconnected. Hasman and Samartín (2008) found similar results when banks use the interbank market to protect themselves against real shocks, and not only for liquidity reasons. The thought behind this idea is that in an incomplete structure, contagion is going to be limited to the closest banks, while in a complete structure, contagion will spill over to all regions. However, the loss in each region in a complete structure is smaller. The results of Babus (2006) coincide with those of Allen and Gale (2000). Her focus is on the optimal network design. Again, the problem is that there is a trade-off between high losses for a small number of banks (Brusco and Castiglionesi) and small losses when many banks are involved (Babus). According to Babus (2006), contagion only occurs when a bank fails before its projects mature. A drawback of her research is that she does not consider the direction of the linkages. Consequently, banks should be interested in bailing out creditors and debtors. In addition, even though the number of links is endogenous, the structure of the interbank market is exogenous and fixed.

From a policy perspective, Castiglionesi (2007) and Hasman and Samartín (2008) show that some kind of coordination might be needed to facilitate the use of the interbank market under incomplete markets. Usually, the central bank assumes this coordination role. In Castiglionesi (2007), the problem faced by the central bank is to choose the optimal level of reserves that will ensure enough liquidity during downturns to minimise the impact on profitable activities. The problem with this model is that it assumes differently informed agents, where banks and individuals share their 'ignorance', and the central bank has more information about changes in individual preferences. This problem is resolved in Hasman and Samartin (2008). In their model, a central bank can prevent contagion without assuming that it has superior information (using a contingent credit line procedure). Similarly, Aghion *et al.* (2000) consider the case of a private clearinghouse arrangement as a way to reduce insolvency of individual banks. They conclude that, in such an environment, a private banking system may not be immune to contagious bank runs, since there is a trade-off between reducing the potential insolvency of individual banks and keeping contagious runs away.

In summary, existing theory predicts two opposite results. One line of research suggests that a more complete banking structure (banks are more connected) implies a higher contagious effect (Brusco and Castiglionesi, 2007; Hasman and Samartin, 2008). The second group predicts the opposite result. Here, a less complete banking structure implies a higher probability of contagion (Allen and Gale, 2000; Babus, 2006). One aspect shared by all research considered here is that the banking structure is exogenous. In other words, the structure is not the result of an optimisation process. In the following sections, we will try to establish whether contagion exists, and, whether any interbank market structures facilitate contagion.

4. Networks in Banking

Research in banking has turned to network theory to analyse the implication of a given market structure for financial stability. The reasons for network formation, the type of network, the number of participants

and the implication for the network of different types of participants are all subjects of research. In a seminal paper, Leitner (2005) recognises the risk of contagion as a driving force behind network design. Consequently, once a crisis appears, banks should be willing to bail out those banks in trouble. This paper presents a conceptual framework for a theory of mergers and acquisitions in banking, in which banks would be eager to rescue other banks as a way to impede contagious effects. The paper by Babus (2009) revises this idea by introducing the liquidity–stability trade-off. Banks establish links to save on liquidity holdings, but since they know that this might create contagious effects, they increase the size of the network to distribute the losses among participants and, consequently, decrease the risk of contagion. According to Babus, a more complete network (one with many participants and much more connectivity) will reduce the risk of contagion. A question that emerges from these papers is what would happen if the bank experiencing financial difficulties is larger than the rest, or when banks do not know the real quality of other banks' assets, as happened in the recent crisis.

Similarly, Castiglionesi and Navarro (2008) study under what conditions banks would be interested in participating in a fragile financial network. They assume that banks' returns are an increasing function of their linkages to other banks and, consequently, the network has incentives to increase in size (as in Babus, 2009). On the flip side, networks are fragile because some banks might be more risky than others. They find that, as long as banks are weakly capitalised and the probability of a collapse in the network is small, the decentralised solution tends toward that of the social planner. Here, contagion does not disappear. Their results predict a banking network which is composed of a core-periphery structure. This line of argument might explain why, after the crisis of 2007, the interbank market dried up and banks tended to become isolated.

Allen *et al*. (2012) suggest that the maturity of debt is also crucial for contagion to occur. They find that, for short-term loans, more complete market structures are less likely to suffer contagion (as in Babus, 2009). They compare a clustered (two groups of three banks) to an unclustered structure (the six banks are connected), but a question that arises is what might happen with other types of structures, for example, when five banks are connected and one is not, or banks are connected in pairs. Or, what might happen if we include one bank that was not originally part of the network, or when banks are differently capitalised.

Nier *et al*. (2008) analyse the resiliency of different banking market structures to systemic risk. They consider changes in the level of capitalisation, the degree and extent of interbank connections, and the level of market concentration. They find that systems with better capitalised banks are more resilient to shocks. However, the effect of connectivity is non-monotonic. For low levels of connectivity, increasing connectivity also increases the risk of contagion, but after reaching a threshold, higher connectivity increases resiliency. Finally, higher levels of interbank liabilities and more concentrated systems are also more prone to systemic risk.

Drehmann and Tarashev (2011) analyse contribution of an individual bank to systemic risk. They recognise that banks can contribute to systemic risk, not only by transferring a shock that affects them to the real economy but also by being part of the channel: (1) transferring shocks from other banks to the real sector; (2) transferring a shock from the real to the financial sector; or (3) simply propagating a shock in the financial sector (receiving a shock from one bank and transferring it to another bank). They find that the role of the bank in the network is extremely important, whether it is located in the core or in the periphery of the network.

The effect of different banking structures on systemic risk was also measured by Sachs (2010), who found that, for complete market structures, a more stable financial system results from symmetrical connections. In contrast, for incomplete structures, they arrive at opposite results to those of Allen and Gale (2000). A complete network with unequal distribution of claims is less stable than an incomplete network with equal distribution of claims. They also find that a system of money centres is less stable than one in which assets are more dispersed.

Using numerical simulations, Ladley (2011) tries to resolve the apparent paradox of whether higher interconnections promote risk sharing or dampen financial stability. He finds that, for a large economic shock, higher interconnections worsen the impact of the initial event. However, in the case of small shocks, higher interbank connections promote risk sharing. He concludes that there is no optimal inter-bank market structure that reduces contagion under every possible scenario.

A source of contagion not considered by these papers is the existence of a 'multibanking channel'. The failure of one bank might create liquidity problems for those companies that use multibanking (get loans from different banks) if the bank that fails is the one responsible for refinancing projects. This might affect the future cash flow of the borrower and, indirectly, repayments to other financial institutions. Other important points that have been neglected by current literature are why banks might be interested in creating unbalanced networks, the trade-off between competition and cooperation that creates the network, the expansion of the network, and the dynamics of how to return to equilibrium after a collapse.

5. Applied Literature

The applied literature has followed a number of different avenues to measure contagion and the risk of contagion. We can separate these into two approaches. A first approach tries to distinguish 'pure' from 'information-induced' contagion using event studies. 'Pure' contagion is defined as significant withdrawals from institutions that turned out to be healthy, while in 'information-induced' contagion, depositors withdraw funds from those institutions that appeared to be unhealthy before the crisis. A second stream of literature analyses interbank connections with a simultaneous study of the overall risk exposure of the banking system (network theory).

In the first approach, we find the paper by Aharony and Swary (1983), who use capital market data to measure the abnormal performance of solvent bank groups in periods surrounding bankruptcy episodes for three big bank failures in the USA. They do not find evidence to support the hypothesis of pure contagion and conclude that the failure of a dishonestly run banking institution need not cause panic and loss of confidence in the integrity of the banking system as a whole. However, their results might underestimate the real effects of a bank failure, since the Federal Reserve System was working actively during the period they analysed. In 1996, the same authors (Aharony and Swary, 1996) tested the information-induced hypothesis for contagion and found that the distance of the solvent banks' headquarters from the headquarters of each failed bank, and the capital ratio as a proxy for their solvency are negatively related to the magnitude of the contagion effect. In contrast, size is positively related.

There also exists some evidence that contagion effects can be detected in the market prices of bank debt instruments. For example, Carron (1982) shows that the failure of the Franklin National Bank in New York in the seventies, lead to an increase in the spread between the US 'Jumbo' certificates of deposits (CDs) and the 3-month treasury bills (T-Bills) by a factor of at least six. Saunders (1987) also acknowledges that the average spread between 3-month euro-dollar deposits and T-Bills doubled during the Continental Illinois problem. In the case of equity returns, Jayanti and White (1996) also find evidence of international contagion to UK and Canada after the failure of the Continental Illinois.

Other examples of informational contagion are presented in Saunders and Wilson (1996). They analyse deposit flows during the great depression and find evidence of both, pure contagion and information-induced contagion. Calomiris and Mason (1997) analyse contagious failures during the Chicago Bank panic of 1932. They find that only those already weak banks failed, consistent with the hypothesis of information-induced contagion. More recently, Levy-Yeyati *et al*. (2010) found evidence that depositors respond to macroeconomic factors during crises and to bank-specific characteristics outside of crisis periods. This can explain why, in 2012, we are observing depositors withdrawing their

deposits from most of the banks in Greece, while only from some banks in Spain. Slovin *et al*. (1992) found evidence that supports the theory of asymmetric information as a source of contagion, where adverse individual bank announcements generate external information effects on other banks (see De Bandt and Hartmann, 2000, for a survey of this literature).

Recently, there has been a substantial body of work that has examined balance sheet interlinkages as a possible source of contagious failures in financial institutions. Most of these papers calibrate their models using actual cross-exposures in real banking systems and simulate the effects of a shock to the system resulting from the failure of one or more institutions. This literature finds that, although the possibility of contagion is not absent, it is not as important as suggested by the theory.

Elsinger *et al*. (2003) use a systemic analysis of the impact of a set of macroeconomic risk factors on banks in combination with a network model of mutual credit relations. In the Austrian case, they find that the correlation in exposures (fundamentals) is far more important than financial linkages (domino effects) in generating systemic risk. They conclude that reserves, to be maintained by the lender of last resort, need to be about 0.0003% of the total assets in the banking system to impede contagious default, while in the case of fundamentals defaults, the necessary reserves rise to 0.16% of total assets for the same confidence level. These results are more consistent with what the information-based theory of contagion predicts.

In the case of Germany, Upper and Worms (2004) find that domino effects as a result of interbank credit exposure are possible. They conclude that a bank failure can trigger contagion in a sizable part of the German banking system, especially if the failed bank is big, although safety nets considerably reduce such risk. Similarly, for the UK, Wells (2002) concludes that the insolvency of a big UK-owned bank can trigger multiple bank failures. However, they conclude that this fact is unlikely since those banks have usually very high credit ratings. In the case of the USA, Furfine (2003) finds that the failure of the most significant bank typically affects just a few other banks, which accounts for less than 1% of total banking system. These papers can answer the first question we posed, namely whether contagion exists. Therefore, contagion in the banking system is possible, but unlikely.

We now focus on the second point: what market structure promotes contagion? The results are mixed. For example, in the case of Chile, Cifuentes (2004) finds that, in a more concentrated banking system, the risk that an idiosyncratic shock spreads through the banking system is higher than in a decentralised system. In contrast, Degryse and Nguyen (2004) analysed the Belgian banking system, and find that a change from a complete structure towards a multiple money centre, as well as a more concentrated banking market, has decreased the risk and impact of contagion.

Lehar (2003) uses stock market and balance sheet data to conduct an international comparison of systemic risk. He also uses this information to measure how an individual bank contributes to the overall risk of the banking system. In the same line of research, Mueller (2003) applies a network and a simulation approach to measure the risk of contagion in Switzerland. She considers mutual interbank exposures and credit lines as the two sources of contagion. The first identifies the potential contagion paths and the banks that are more likely to be affected because of their exposure to the interbank market. The second, the simulation approach, focuses on the interbank's inherent instability. She concludes that the structure of interbank linkages has a considerable impact on systemic instability.

Gropp and Vesala (2003) use the distance to default to measure contagion across banks. They identify contagion in the negative extreme movements in bank default risk for European banks (using equity market and balance sheet data). They find that domestic contagion is more prevalent and quantitatively more significant than cross-border contagion. However, they find an increased relevance of cross-border contagion after the introduction of the euro. Using data for European banks, Galos and Soramaki (2005) test the effect of individual bank failures under different payment systems. Their results indicate that systemic consequences of one bank's failure on the solvency of other banks can be rather low. The drawback of this paper is that it does not consider the health of the counterparty or the state of the economy at the moment of the failure.

Using Italian data, Mistrulli (2011) shows that increased interconnections among banks has increased the risk of contagion. Nevertheless, he suggests that it is unlikely to trigger a crisis. The reason is that, as the theory predicts, banks establish links to distribute negative shocks.

Craig and von Peter (2010) analyse whether the network of bank connections is dispersed (where all banks are connected to other banks) or centred (there are money centres). Using German data, they find that the interbank market resembles centralised money centres (as predicted by Castiglionesi and Navarro, 2008). Big banks, mediate between a set of small banks. Another finding of the paper is that, by analysing the balance sheet of a given bank, they can determine whether that bank would be in the core or in the periphery. Consequently, the balance sheet of a bank gives information of its position in the network. They suggest that this might be the result of fixed costs or economies of scale (however, this supposition was not tested).

A parallel literature analyses the interbank market structures that emerge from analysing interbank transactions. For example, Furfine (1999) shows that large banks tend to be net borrowers, while small banks tend to be net lenders in the federal funds market. Bech and Atalay (2010) find that the federal funds market consists of a large number of small banks which are net lenders to a few large banks. They also observe that the size and position of a bank in the federal funds market affects their borrowing and lending interest rates.

Using data from the Norwegian interbank market, Akram and Christophersen (2010) find that interest rates depend not only on the overall liquidity in the interbank market, but also on its distribution among banks, suggesting the existence of market power. For example, banks considered 'too big to fail' or 'too connected to fail' are able to borrow at lower levels than other banks. Guggenheim *et al*. (2011), using data from the Swiss interbank market, find that the freeze of the interbank market and the decrease in daily turnovers after the collapse of Lehman Brothers, was due to an increase in risk perception and not to lower returns from a low interest rate. All these papers find that loan rates in the interbank market vary with market conditions, the size of the loan, and the type of the lender and borrower. Their results also suggest that the structure of the interbank market is far from being complete.

Nevertheless, the structure of the interbank market is not necessarily equal across countries and time, or before and after a crisis. For example, Imakubo and Soejima (2010) show that, in Japan, the structure of the interbank market has decentralised during the last few years. A study, analysing more countries, could give better insights into this issue.

One step in that direction is presented by Garratt *et al*. (2011). They analyse how contagious effects might spread internationally. They consider, as the source of contagion, the funding and the lending channels. The funding channel results when a bank refuses to rollover a loan, while the lending channel occurs when the bank defaults on a loan. They use clustering techniques to analyse how the transition from a structure of independent big clusters to another of smaller, but interconnected clusters can increase the risk of international contagion. Similar analyses to test for domino effects were carried out by Chan-Lau (2010) and Espinosa-Vega and Sole (2010). Again, the weakness of these papers is that they need to assume a given structure inside the cluster (they assume symmetry), which is not necessarily true.

Iyer and Peydró (2011) is the first paper to combine data on mutual exposure and a real bank failure. Using balance sheet data from Indian banks, they find that contagion is not a purely random phenomenon. Depositors' runs on banks depend on the level of exposure of their particular bank with respect to the failed bank, and that contagion has real effects. They recommend that capital requirements should consider the level of exposure of banks to single sources.

In summary, those papers testing for the information-induced hypothesis find that contagion is mainly information-induced and that depositors and creditors can distinguish good from bad banks. Even though financial innovation by creating informational asymmetries might have increased the likelihood of pure contagion, the activity of the central bank as a lender of last resort has made it difficult to analyse contagion effects with event studies. In the case of network theory, most papers

find that contagion is possible, although unlikely, and that the size of the failing bank, as well as the direction and type of linkages are key factors in determining the probability of contagion. This, contrasts with the theoretical literature previously analysed, in which banks were *ex ante* identical and consequently have incentives to form the same type of links. In practice, banks differ in many aspects (size, market power, location, etc.), even before joining a network. One very important difference between both methodologies is that one (information-induced models) use real failures, while the other (network theory) uses simulations. One limitation in carrying out empirical studies is the lack of evidence (there are not many bank failures). Another limitation of most of these studies is that, owing to the lack of information on a bank's mutual exposure (with the exception of Iyer and Peydró, 2011; Mistrulli, 2011), they have to assume a given distribution of interbank linkages and that the structure of exposure is also constant along the business cycle. In addition, none of these papers can anticipate whether a more contagious bank is more or less likely to fail, they consider the failure as an exogenous event, and they do not analyse whether a given structure promotes exposure to certain risks. In contrast, network theory allows us to better understand the possible effects of a given bank failure, under different market structures, on financial stability and therefore to derive policy implications.

Network theory allows us to better understand how a shock is going to spread once it appears. The level of exposure (loss given default, or LGD) that might determine whether a bank is going to fail once its neighbour fails, or what conditions determine whether other members of the network are going to bailout a bank in trouble. Network theory can also explain why some banking systems tend to a particular structure. Some drawbacks of network theory include the lack of disaggregate data to analyse the real level of exposure to other banks, or that the out-of-balance exposure cannot be easily estimated. Most of the analyses present a one-shot picture, and so it is difficult to analyse the evolution of the network (except with simulations), although they can compare networks across countries. It is also difficult to disentangle whether the network is fragile because of weak banks or whether banks are weak because of an unstable network.

6. The Present/Future of Banking Regulation

The recent financial turmoil has renewed the debate on banking regulation and supervision. In a highly interconnected system, when analysing the risk of a bank, the regulator should consider both its intrinsic risk and how its failure affects systemic stability. The role of banks for economic growth is well documented (Levine, 2005) but recent episodes have shown that financial fragility was underestimated. The result was that governments had to recapitalise banks in most developed countries and had to increase the deposit insurance guarantee to prevent panic behaviour. In addition, the real quality of banks' assets are still not clear, nor is it clear how resilient the system is to future shocks.

One of the main roles of financial intermediaries is to provide liquidity. A natural question is whether decentralised markets can achieve efficient outcomes. Allen and Gale (2004) show that, when banks are constrained to offer non-contingent contracts to their clients, a bankruptcy procedure would help them to alleviate such a friction and no government action can improve that result. In Castiglionesi *et al*. (2010), the incompleteness comes from partial financial integration. They find that extreme events, and consequently crises, might be optimal in the case of imperfect integration. Nevertheless, Fahri, Golosov and Tsyvinski demonstrate that, when agents are allowed to trade privately, the contracts offered by banks are no longer going to be efficient. Consequently, there is a role for regulation, called liquidity requirements, since in the absence of regulation there is not enough liquidity in the economy. Other papers that analyse liquidity in the interbank market include Wagner (2008), who finds that financial integration by facilitating risk sharing makes banks more homogenous and less liquid; and Acharya *et al*. (2012), who analyse the case in which banks have different market power. They show that, when funding options are scarce, needy banks might be obliged to inefficiently sell specific assets.

The provision of liquidity is therefore the rationale for a central bank. Similarly, in Allen *et al*. (2009), markets cannot provide the optimal level of hedging against aggregate and idiosyncratic liquidity shocks. Consequently, the central bank can implement the constrained efficient allocation using open market operations (see Rochet, 2008, for a discussion on the regulation on banks' liquidity).

In a recent paper, Farhi and Tirole (2012) suggested that banks may follow similar strategies anticipating government bailouts. Consequently, to be bailed out, many banks would invest in more risky and correlated investments, making crises more likely. In such an environment, they suggest that the optimal regulation should include minimum liquidity requirements and the supervision of the quality of those liquid assets. Similarly, both Acharya *et al*. (2010) and Hanson *et al*. (2010) show that this fierce intervention might move most intermediaries to a shadow banking system. An additional concern of the regulator is how to prevent moral hazard by banks.

Capital requirements were designed to control the risk of financial institutions. Basel I introduced fixed minimum capital requirements. The main criticism was that they could create a credit crunch due to a reduction in lending, which could also reduce banking in favour of other types of intermediation (see Jackson *et al*., 1999, for an empirical examination of Basel I). To reduce these effects, Basel II introduced the idea of risk-based capital requirements. Banks were offered the opportunity to choose between a simplified approach, with fixed weights, an approach based on credit ratings, and an internal rating-based approach (IRB) for sophisticated banks. The IRB approach required banks to estimate the probability of default (PD) for each individual credit, the loss given default (LGD), and the expected exposure at default. Gordy (2003) presents the main risks that Basel II faced, namely, *portfolio invariance* (requirements were based on the risk of a loan, not on its contribution to a portfolio), *single global risk factors* (which forget the idiosyncrasy of local risks), *pro-cyclicality* (judgements tend to underestimate risk in good times and overestimate them in bad times). Both formulations for capital requirements failed in preventing the recent financial crisis and we are still suffering its effects. (See Blundell-Wignall and Atkinson (2010) for an extended discussion of the criticism of Basel II.)

Microprudential regulation (Basel I and II) was designed to control the risk of each institution in isolation, but, apparently, made the system more fragile to large macroeconomic shocks. Zawadowski (2011) shows that the reason for the existence of high counterparty risk is that banks do not take into accounts the effects of their own failure on other banks. Basel III tries to resolve this problem by considering the effects on systemic risk of globally interconnected financial institutions (see Drumond, 2009). The real concern is whether governments are prepared to reorganise the banking system, or if they would prefer to take *ad hoc* measures.

The new focus of the debate is on macro-prudential regulation, showing that what is good for one institution might not be good for financial stability. Recent papers (Tarashev *et al*., 2010; Drehmann and Tarashev, 2011) have introduced the concept of systemic importance to analyse the effect of a given bank failure on systemic risk, and find that its role as a lender or as a borrower might have very different implications for financial stability. Acharya *et al*. (2010) suggest that a financial institution's contribution to systemic risk can be measured by its propensity to be undercapitalised when the system is undercapitalised. They propose a tax that can realign the interest of financial institutions with those of the regulator. An additional measure of risk is presented in Adrian and Brunnermeier (2008). Using characteristics such as size, leverage and maturity mismatch, they create a forward-looking risk measure to be used for macro-prudential regulation. Nevertheless, this procedure fails to consider that risk is endogenous and that once capital requirements change, risk exposure and correlation in the banking system also change. This problem is analysed by Gauthier *et al*. (2010), who follow an iterative procedure. With their correction, they find that systemic capital requirements can reduce individual and systemic risk by about 25% (see Aglietta and Scialom, 2010, for a discussion on macro-prudential regulation).

However, considering the fact that many banks are also connected internationally, more research in that direction is needed. In addition, the fact that central banks operate locally creates further concerns

for harmonisation. Not every country follows the same policy of bailouts, not only as a strategic option but also as a result of the lack of resources, which might deepen financial fragility. The question is whether or not an international central bank can be settled.

7. Concluding Remarks

Several papers (Levine and Zervos, 1996; Benhabib and Spiegel, 2000; Gaytán Gonzalez and Ranciere, 2004) find that banking intermediation promotes growth. It is generally believed that the failure of some banks may be catastrophic for the stability of the real economy and this explains why, in most banking crises, there has been some form of government intervention (Laeven and Valencia, 2008). Consequently, it is often argued that banking regulation has been developed to reduce the problems of asset substitution and risk shifting that this intervention can promote.

However, some economists (e.g. Kaufman, 1994) argue that regulation is the reason why the banking system is unstable or, at least, suggest that the need for regulation arises from the existence of deposit insurance (White, 1989; Berlin *et al*., 1991; Diamond and Rajan, 2011). What is clear is that both banking crises and the policies oriented to prevent them are costly. In this paper, we critically analyse the existing literature on contagion through the banking system with a special emphasis on network theory in banking.

The new literature on networks tries to find whether there exist optimal financial networks that promote financial stability. From a theoretical point of view, the results are not conclusive: some authors find that greater interconnection increases the vulnerability of the system, while others find exactly the opposite. What seems more plausible is that financial linkages promote stability for small shocks, but increase instability for big shocks and during downturns. Evidently, this is one avenue for future research. It would also be important to determine whether that optimality, if it exists, depends on other institutional features. From an empirical point of view, results are less controversial. Most papers find that contagion is not a purely random phenomenon; it depends on the structure of the banking system. Contagion is more likely for those banks working in the same area of business and in the same country. The size of the failing bank is also an important indicator of the risk of contagion. Nevertheless, this literature is still in its infancy, due to the reluctance of banks and central banks to provide information on interbank linkages. Extensions of the empirical literature might include analyses of the efficacy of different policy instruments used during the recent crisis to prevent contagion, to restore confidence, and to allocate credit. Other extensions should include the interaction of competition and cooperation between banks for financial stability, and also whether bank specialisation increases the risk of contagion.

Acknowledgments

The author would like to thank Margarita Samartín, Sandro Brusco, the editor, and two anonymous referees for their helpful comments. This research is partly funded by the Spanish Ministry of Science and Innovation, project, ECO2010-17158.

Notes

1. Bank runs are a common feature of banking crises, with 62% of crises experiencing sharp reductions in total deposits. For example, Argentina experienced system-wide runs in the crisis of 2001. Banking panics were a common occurrence in the United States in the late nineteenth and early twentieth centuries, as well as in the Great Depression, and have occurred in several developing countries, including Brazil

(1990), Russia (1995), Malaysia (1999), Ecuador (1999) and Uruguay (2002), among others (see Laeven and Valencia, 2008).
2. Demirguc-Kunt and Kane (2001) discuss the conditions under which deposit insurance would work and provide empirical evidence on how different features affect market discipline, market stability, and financial development.
3. Gorton (1988) provides several criticisms of this model, namely, that bank runs are not 'purely random'.
4. For a deeper analysis of the different channels for financial contagion, see Kaminsky *et al*. (2003) and Pritsker (2000).
5. A region is a spatial metaphor that can be interpreted in several ways. It can correspond to a single bank, a geographical region within a country, a country, or a specialised sector within the banking industry.

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