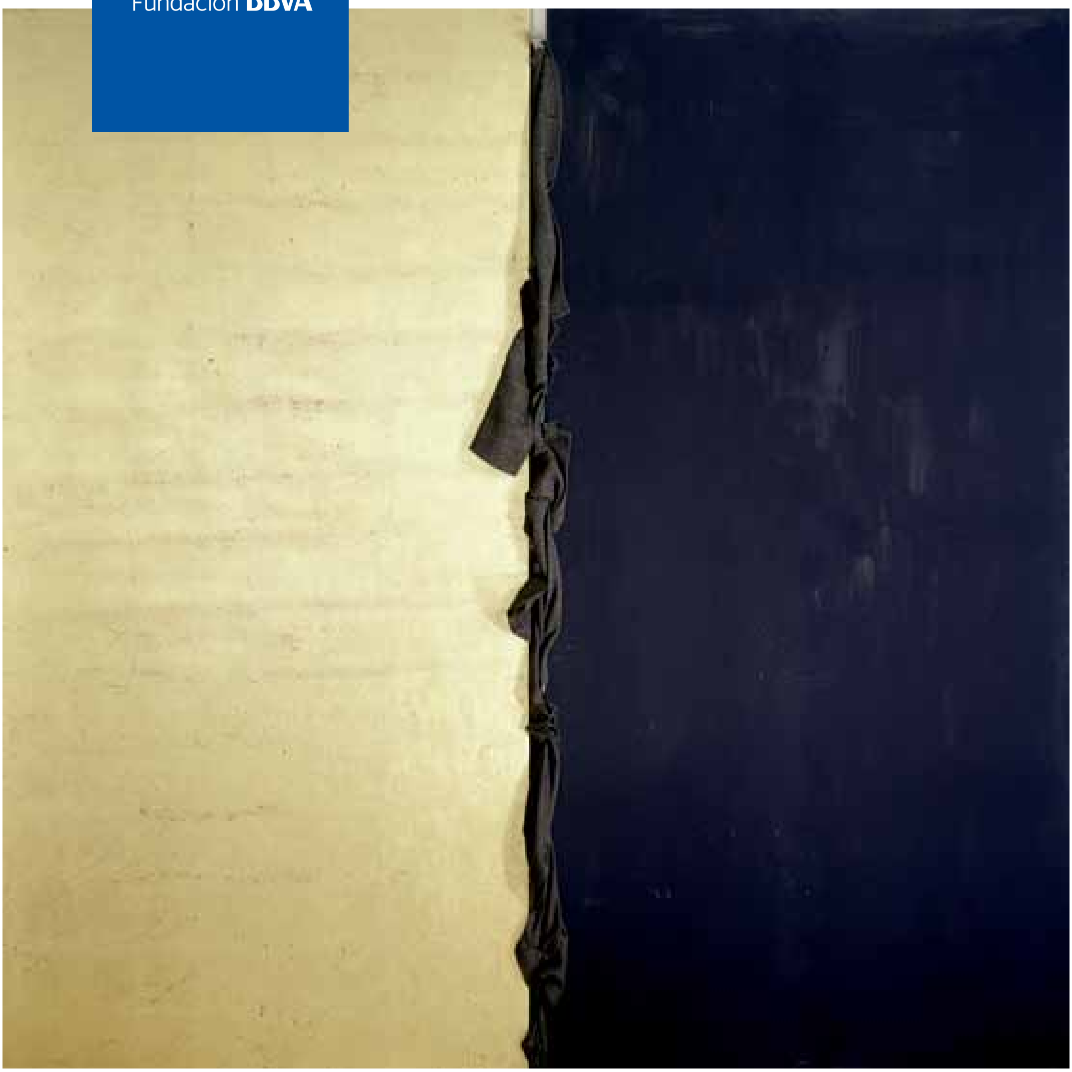
BANKING INTEGRATION AND FINANCIAL CRISIS

Some Recent Developments

Iván Arribas Fernández
Emili Tortosa Ausina (Eds.)

Fundación BBVA



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Some Recent Developments

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CATALOGUING-IN-PUBLICATION DATA

Banking Integration and Financial Crisis: Some Recent Developments/ editado por Iván Arribas Fernández y Emili Tortosa Ausina; Santiago Carbó Valverde… [et al.] – 1.ª ed. - Bilbao : Fundación BBVA, 2015.
207 p. ; 24 cm
ISBN: 978-84-92937-60-8
1. Sistema bancario. 2. Crisis financiera. I. Arribas Fernández, Iván, ed. II. Tortosa Ausina, Emili, ed. III. Carbó Valverde, Santiago. IV. Fundación BBVA, ed.
336.71
336.71.027

First published in September 2015

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© Fundación BBVA, 2015
Plaza de San Nicolás, 4. 48005 Bilbao

COVER ILUSTRATION: © Rafael CANOGAR, VEGAP, Madrid, 2015
Frontera, 2003
Técnica mixta, 244 × 247,5 cm

ISBN: 978-84-92937-60-8

LEGAL DEPOSIT NO.: BI-1.127-2015

EDITION AND PRODUCTION: Editorial Biblioteca Nueva, S. L.

PRINTED BY: Lável Industria Gráfica, S. A.

This book is produced with 100% recycled paper made from recovered fibres, in conformity with the environmental standards required by the current European legislation.

CONTENTS

Introduction

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FINANCIAL integration, in general, and banking integration, in particular, have received a great deal of attention from several points of view, not only from academics but also from practitioners and policy-makers, over more than 30 years now. The attention has run in parallel to its upward tendency, which did not experience relatively marked reversals until the recent 2007-2008 financial crisis. Although the causes boosting financial integration are diverse, there has been some consensus among both academia and policy-makers on its overall benefits, which were supposed to be substantial, and diverse.

1. Financial development, financial integration, and economic growth

The debate as to the benefits of enhanced financial globalization stems indirectly from the long-lasting debate on the links between finance and economic performance. This debate emerged as far back as the beginning of the last century, and some of the most prominent advocates, such as Schumpeter (1911), argued that financial intermediaries provide essential services for technological innovation and economic development, which enable to grow faster. Holding a rather different—almost opposite—view, authors such as Robinson (1952) considered that the effects of finance on economic growth were much more dubious, arguing that it is actually the economy which leads while finance follows.

By the end of the last century, the most widespread view was that financial development exerted a significantly positive effect. This was supported by relevant compelling evidence, including not only specific investigations but also several survey studies, such as Levine (2005), Papaioannou (2008), Aghion (2008), Ang (2008), or Demirgüç-Kunt (2010), to cite a few. Although this literature was generally interested in the broad question of the impact of financial development on growth, some studies such as Edison et al. (2002) explicitly analyzed the links between international financial integration and economic growth,[1] concluding that it was not possible to reject the null hypothesis that international financial integration did not accelerate growth.

However, while acknowledging the general benefits of financial development (and financial integration), some studies also stressed that the prospects might be not entirely positive. For instance, Ang (2008) reviewed the empirical literature focusing on either testing the role of financial development in stimulating economic growth or examining the direction of causality between the two variables. In the conclusions, he acknowledged that, although the positive role of finance on growth had become a stylized fact, some methodological reservations about the results from the empirical literature also existed.

2. Other benefits of international financial and banking integration: indirect channels

Regardless of its implications for growth, international financial integration has received a great deal of attention over the last thirty years, due to its undeniable links to the broader issue of international economic integration, and, more generally, globalization. In these two cases, particularly the latter, the interest has been extended to many related issues to these two topics, and in many cases the interest was not necessarily related to growth, although,

[1] Some relevant contributions have also focused explicitly on the effect of financial integration on financial development; see, for instance, Guiso et al. (2004).

especially in the case of international economic integration, the ultimate reason explaining its importance was the implications for growth.

These additional positive impacts would actually be higher, and more varied. As indicated by Kose et al. (2009), the effects on financial sector development, institutions, governance, and macroeconomic stability might be substantial. Therefore, the main benefits could be catalytic, rather than direct.

For instance, one of the alleged benefits of the integration of global financial markets is its *supposed* positive effect on financial stability, as risks would be spread around the world. Under this view, the relative failure of research based on cross-country growth regressions to find the *expected* positive effects of financial globalization could have an explanation.

The particular issue of increased financial and banking integration has been specifically sought in certain areas. In the specific case of Europe, several initiatives such as the Financial Services Action Plan (FSAP) have explicitly pursued the goal of greater financial integration. However, although indirect, the ultimate goal was to promote economic growth and convergence, based on the idea that the integration and development of financial markets would ease the removal of frictions and barriers to exchange, contributing to a more efficient allocation of capital.

3. The dangers of international financial and banking integration

The broad consensus, with few—yet notable—exceptions, regarding the positive effects of enhanced financial integration came to a relatively abrupt halt with the start of the financial crisis in 2007. Some years later, the view that financial globalization might have largely contributed to the beginning of the crisis is very extended. This point has been made, among others, by Lane (2012), who argued that financial globalization enabled the scaling-up of the US securitization boom that "was the proximate trigger for the crisis," and that "it is difficult to imagine that the growth in these credit markets would have been of similar magnitude without the participation of foreign investors." Despite this consensus as to the influence of financial globalization on the crisis, it is also important to research the mechanisms by which cross-border financial integration might either have provided a buffer to mitigate crisis shocks or, on the contrary, led to an increase in the magnitude of the effect.

However, even before the start of the 2007-2008 international financial crisis, some voices had been warning about the limited benefits of deeper financial integration on growth. For instance, Gourinchas and Jeanne (2006) indicated that, despite standard theoretical arguments as to the positive effects of financial integration on convergence, the welfare gains for the typical emerging market might be limited. Some of the most critical views even considered that it was a stylized fact that there is actually *no* correlation between long-run economic growth and financial globalization (Rodrik and Subramanian 2009). When mentioning the paper on financial globalization and the crisis by Lane (2012), Dani Rodrik argued that some of the original arguments for financial globalization were that it would equalize marginal returns to capital around the world, transfer savings from rich to poor countries, contributing to enhancing growth and convergence. It would also contribute to enhanced risk sharing and consumption smoothing across countries. According to this author, "these arguments have receded to the background, in large part because the accumulating evidence has not been kind to them" (Rodrik 2012, p. 33).

4. International financial integration and the crisis

Once the subprime financial crisis took place, many voices claimed that the benefits of financial globalization were even harder to find. Assuming that financial engineering was able to generate large gains (especially in terms of economic growth), this might sound less plausible than ever before. On this point, Rodrik and Subramanian have been particularly critical, arguing that the crisis has demonstrated that more is not necessarily better, and that "if you want to make an evidence-based case for financial globalization today, you are forced to resort to fairly indirect, speculative, and, in our view, ultimately unpersuasive arguments" (Rodrik and Subramanian 2009, p. 136).

In his most relatively recent contributions, Stiglitz (2010a, 2010b) also indicated that, although integration of global financial markets "was supposed to lead to greater financial stability, as risks were spread around the world" (Stiglitz 2010b, p. 388), "the financial crisis has thrown doubt on this conclusion." He makes a comparison with the design of electric networks, where a failure in one part of the system can lead to a system-wide failure; similarly, in the international financial network, a failure in one part of the global economic system might cause a global *meltdown*. Whereas in the case of an electric network this can be avoided using circuit breakers, a *well-designed* financial network should also have its own circuit breakers, such as, for instance, the temporary imposition of capital controls. Actually, Stiglitz had already warned about some of the dangers of globalization in his best-selling book *Globalization and Its Discontents* (Stiglitz 2002), in which he considered that the opening up of financial markets in emerging market economies to foreign capital might lead to economic collapse.

Yet authors such as Mishkin have also argued why, despite the vulnerabilities shown by the financial crisis, after explaining the benefits of financial integration in previous contributions (Mishkin 2007), "we shouldn't turn our backs on financial globalization" (Mishkin 2009). Specifically, he admits that getting financial globalization to work is not an easy task, since it requires both policies that promote property rights, and also good-quality financial information in order to encourage effective prudential supervision and a stable macroeconomic environment. However, despite the dismal views on financial globalization offered by several relevant economists—among whom we find not only Dani Rodrik or Joseph Stigltz, but also Jagdish Bhagwati (2004a, 2004b) or even financiers such as George Soros (2002)—Mishkin still considers that (financial) globalization is more an opportunity than a danger. Although "the globalization of trade and information during the past century has lifted vast numbers of the world's people out of extreme poverty," it is also true that "without financial globalization, developing countries will not be able to realize their potential, and their continued poverty will engender further instability and breakdowns in political relations with other nations" (Mishkin 2009, p. 140). The available instruments for accomplishing such a task are powerful, consisting not only of home-grown policies, but also others promoted by international financial institutions like the International Monetary Fund and the World Bank, as well as the support offered by citizens in advanced countries by opening their markets to goods and services from relatively poorer countries.

Other *gentle* views on financial globalization, in spite of the crisis, are offered by Kose et al. (2009). They consider that the failure of those research initiatives to find the expected positive effects of international financial integration on growth (based on cross-country regressions) is not a failure but an opportunity, since it points to newer approaches that are potentially more useful and convincing. Among them, one should look for the gains not in enhanced access to finance for domestic investment, but rather in indirect benefits which are generally harder to detect with macroeconomic data and techniques.

In sum, the passionate debate as to the merits of financial globalization and the usual disparate views on it, indicate that this can still be judged as a very *hot* topic and, therefore, new contributions in the field are welcome. This book poses that exactly. Specifically, given how the recent international financial crisis has contributed to relaunch the debate as to the potential benefits or dangers of financial globalization, this monograph features five contributions which deal with several aspects related to it. The different chapters, apart from analyzing various problems related to financial integration (either directly or indirectly), also constitute an enriching kaleidoscope on this issue, due to the range of perspectives adopted by the different authors.

5. Measuring international financial and banking integration

The diversity of issues covered by the literature on financial integration is now remarkable. Some of them have been explicitly concerned about its measurement, either directly or by different aspects related to it. On this particular issue, the influential papers by Lane and Milesi-Ferretti (2001, 2007) provide compelling evidence on the specific question of the integration of world capital markets. In their influential papers, they provide information on the construction of a database on the stocks of foreign assets and liabilities held by various countries—especially in the developing world. Other measures have been proposed by Baele et al. (2004) or Schindler (2009), among many others.

The measure by Chinn and Ito (2006, 2008) has also been widely used, partly due to its relative simplicity compared to others. Its most updated version provides information until 2011, although the initial year varies across countries. Their index measures the degree of capital account openness, and is based on cross-border financial transactions reported in the IMF's *Annual Report on Exchange Rate Agreements and Exchange Restrictions.*

Some studies do actually acknowledge the variety of methodologies to measure financial integration. As indicated above, the literature linking economic growth and financial integration has usually leaned towards analyzing the causality with financial development, rather than financial integration. However, the paper cited above by Edison et al. (2002) does actually deal with the issue as to how different measures of financial integration might impact on growth. Specifically, after explicitly acknowledging how difficult it is to measure international financial integration, they do it using an extensive array of indicators, such as the IMF-restriction measure and Quinn's (1997) measure of capital account restrictions, several measures of capital flows (FDI, portfolio, and total capital flows), measures of both capital inflows and outflows, or the measure of accumulated stock of foreign assets by Lane and Milesi-Ferretti (2001, 2007) referred to above.

Some other authors have considered broader measures of financial integration. This would include the KOF index by Axel Dreher (2006), who proposes a more encompassing index to measure different aspects of globalization, not only financial globalization. In contrast, other measures of financial integration are actually more specific, focusing on particular types of integration such as banking globalization. However, the number of contributions in this case is much more deficient. Goldberg (2009) has emphasized the importance of this type of financial globalization, which might be particularly relevant in some economies where the role of banks is predominant. However, in this particular case, data are hard to reach, which partly explains the relatively low number of studies.

Even so, several research initiatives have been conducted in the specific field of banking integration. Some of them have been explicitly concerned with its measurement (Cabral, Dierik and Vesala 2002; Manna 2004; Pérez Cid, Salas and Saurina 2005; Gropp and Kashyap 2010; Arribas, Pérez García and Tortosa 2011a, 2011b), although in other cases, the interests have been broader (Buch 2005; Sander, Kleimeier and Heuchemer 2013a, 2013b). However, the different contributions have generally disregarded the effects of banking integration on economic growth.

6. The book's plan

The book's chapters move from the analysis of real cases to more theoretical ones; from an analysis of the causes of financial crises, its effect in the banking system and the shortcomings in the regulation of financial markets, to the identification of stable and resilient models of banking systems. In short, chapters 1 and 2 analyze the *Spanish case*. The first analyzes the effect of a bank market expansion when it entails a risk exposure and a liquidity imbalance. The second explores the role played by securitization before and during crises. Afterwards, chapter 3 introduces new measures of integration of the banking system and discusses the relationship between the level of integration and the effect of crises. Chapters 4 and 5 use theoretical models to explain sources of contagion and systemic risk, and study the effect and the propagation of a bank's default in a banking system. Now, let us look in more detail at the content of each chapter.

In chapter 1, Alfredo Martín Oliver analyzes some aspects of the Spanish banking system, alerting about the social cost that financial integration could bring when bank market expansion increases its exposure to foreign capital markets, the quality of regulatory capital deteriorates, and the performance measures hide the generation of imbalances. The *Spanish case* has been widely analyzed by several researchers, thus the majority of the arguments by Martín Oliver are well known. However, he makes a clear and orderly exposition and, above all, using data from Dealogic and the Bank of Spain.

After Spain joined the European Monetary Union, the banking system found an unlimited amount of resources, as debts and securitization displaced the traditional banks' deposits. Those resources were available for all banks, regardless of their size, on a non-competitive market. Therefore, Spanish banks could lend money to the real-state sector to a near-zero real interest rate, most likely without keeping the credit standards. This process resulted in an increment of productivity measures that were incorrectly interpreted as a technical progress instead of related with the financial integration, a route less demanding in labor and capital inputs. Simultaneously, to preserve the risk weighted assets above the regulatory minimum, the Spanish bank market decided to increase the volume of the regulatory capital, but changing the composition to give more weight to debt-like instruments, therefore spoiling the quality of regulatory capital. As a result, prior to the crisis, a strong liquidity problem appeared because international markets stopped lending to the Spanish bank system, heavily indebted and unresponsive already.

Martín Oliver summarizes and concludes providing four lessons for the future.

Chapter 2, by Santiago Carbó Valverde and Francisco Rodríguez Fernández, explores the role played by securitization before and during the crisis. They summarize the main findings in the literature and compare them with their own recent research. After a brief analysis of the mortgage market in Spain, they ask and answer three crucial questions: (i) how are mortgage quality and securitization related?; (ii) are covered bonds an alternative to mortgage-backed securities?; and (iii) did securitization have a say in lending to small and medium enterprises?

The mortgage market in Spain is one of the largest in the world, even when considering that in the last years both its number and value have sharply fallen. There are two main types of mortgage securities issued in Europe, mortgage-backed securities (MBS) and covered bonds (CBs). Interestingly, both are highly being issued in Spain, whereas only one of them is mainly used in other European countries. In addition, Spain is the second largest mortgage securitization market in Europe (2011 data).

There is a consensus analyzing the relationship between mortgage securitization and mortgage quality. Before the crisis, securitization allowed banks to reduce their regulatory pressure on capital requirements and increase their resources and funds. Some analysts found positive effects in this securization process: diversification of the credit risks across the finance system with an increment of its resilience, lower solvency risk of the banks and a better performance (some of them mentioned by Martín Oliver in chapter 1). Other authors argue that, unfortunately, costs were an increase in the risk exposure of banks along with a reduction of credit standards. As a result, the crisis in Spain brought several periods of financial instability and bank restructuring plans. This process worsens when, as Carbó Valverde and Rodríguez Fernández agree, there is a considerable lag between banks' performance and their assessments by rating agencies.

In the Spanish case, where both MBS and CBs are equally issued, the authors wonder if they are seen as substitutes. However, as there are some real and regulatory differences, they observe that CBs issuance is mostly used when banks need liquidity, whereas MBS issuance is preferred when banks want to reduce their risk level.

In the last part of chapter 2 the impact of securitization in the lending to SMEs is analyzed. As a general fact, banks that are more exposed to securitization are more likely to face liquidity constraints during the crisis and, therefore, reduce their willingness to provide loans. A long relationship between a firm (the borrower) and a bank (the lender) could mitigate this fact and allow firms a better access to credit, but not necessarily. Additionally, firms that deal with banks with high use of MBS issuances have more credit rationing in crisis periods.

In chapter 3, Arribas and Tortosa see the banking system as a network where countries are the nodes and the financial flows are the ties among them. Then, they propose a new measure of integration that is tuned to control by distance and also includes indirect relationships among countries. The authors analyze the evolution of the degree of integration of the banking system during the 1999-2011 period, for a group of 22 economies, focusing the discussion in the role played by both the crisis and the distance.

The authors' concept of integration, the Standard of Perfect Banking Integration, is derived not only from network analysis approaches, but also from the *geographic neutrality* concept introduced separately by Krugman (1996), Kunimoto (1977) and Iapadre (2006). According to this notion, the highest level of integration is reached when bank flows are not geographically biased, and cross-border asset trade is not affected by home bias. More precisely, they considered that the flow between two banking markets is not only proportional to the related size of the banking markets, but it inversely depends on the distance between those economies as well.

Under this framework, the authors measure the gap between the actual openness of the banking system and the regularity of bilateral bank flows regarding the theoretical ones, under the Standard of Perfect Banking Integration. They name these measures as *degree of openness* and *degree of banking connectedness,* and their combination defines the *degree of integration.*

The empirical application to the banking systems of 23 countries (which implies more than 90% of the total bank assets) over the 1999-2011 period enables the authors to conclude that, after a period of increment in the degree of integration, this has sharply fallen with the present crisis due to both a decrement in the degree of openness and connectedness. Despite the general tendency, there are remarkable discrepancies among countries.

Controlling the geographical distance implies the increase of the degrees of openness. However, in the case of the degree of bank connectedness, the effect is quite the opposite.

Chapter 4, by Chinazzi and Fagiolo, surveys recent literature that explains sources of contagion and systemic-risk, but from a theoretical point of view. The consulted papers understand the bank system as a network, as in chapter 3, where the nodes are banks and the links are financial flows, and focus their attention in the role played by the level of connectivity between financial actors.

In the words of the authors, the key question is: *Does a more connected banking network imply a more stable and resilient financial sector?* They conclude, as stylized fact, that connectivity has a severe impact on systemic resilience but in a non-monotonic way. A minimum level of connectivity is needed for stability, but above a certain threshold the connection can serve as amplifier of the shocks. Of course, this conclusion strongly depends on underlying assumptions of the theoretical model used.

Theoretical and analytical models also allow improving the answer to the key question by introducing the interaction of connectivity with different characteristics of the bank system, such as bank heterogeneity, moral hazard, imperfect information or capital and liquidity requirements. Concerning bank heterogeneity, the non-monotonic result between connectivity and stability grows when banks' size is highly heterogeneous; moreover, the heterogeneity in banks' degree (number of connections) also decreases the resilience of the network. In the presence of moral hazard problems the more stable structures are core-periphery, where a set of banks, the core, are highly connected between them, whereas peripheral banks are poorly connected with the ones in the core. The effect of the connectivity is uncertain under imperfect information on the quality of banks. Finally, regardless the level of capital requirements, the non-monotonic relationship between connectivity and stability remains, while a high level of liquidity requirements guarantees a direct monotonic relationship.

At the end of the chapter the authors point out that more research should be done to obtain a deep understanding on the relationship between the topology of the network that is the bank system and its systemic risk in contagion process. More specifically, how local and global network statistics can provide an insight into contagion and systemic risk.

In chapter 5, Montagna and Lux offer an important contribution to the literature analyzed in the previous chapter. They generate simulated interbank markets, characterized by the same features founded in real markets, and then they study the effect and propagation of the biggest bank default on the whole network.

The empirical literature reveals that real financial markets share three common features: *disassortativity,* highly connected banks attached to poorly connected ones; *scale-free degree distribution,* there are a small number of hubs (banks highly connected); and the size of banks follows a lognormal distribution with fat tail, that is, there are a large number of small banks. Thus, Montagna and Lux generate a simulated interbank market that verifies the above three properties, parameterized by bank capitalization, interbank exposure and the size of the biggest bank. Later, they analyze the relationship between these parameters and the total number of defaults when the biggest bank fails. In their analysis the single source of a shock comes from external assets.

With respect to the bank capitalization, they find a monotonic relationship: the higher the capitalization, the lower the bank defaults. However, there is a proportion of capitalization—with respect to total assets—above the threshold that is able to confine the contagion process. Interbank exposure, again as a percentage of total assets, shows a non-monotonic behavior. Both a null interbank exposure and a complete interbank exposure prevent the spread of any shock. The first, because there are no channels for the propagation of the shock; the second, because it means a complete isolation from external markets, that is the source of shocks. Around a threshold value, the contagion process reaches its maximum value.

The effect that the size of the biggest bank has in the number of defaults, depends on the capitalization of the biggest bank. When the biggest banks have a high level of capitalization, it turns out that the larger their sizes, the higher the number of defaults. However, under a low level of capitalization, the relationship reverses and, as the size of the biggest bank increases, the number of defaults decreases.

References

AGÉNOR, Pierre-Richard. "Benefits and Costs of International Financial Integration: Theory and Facts." *The World Economy* 26, no. 8 (2003): 1089-1118.

AGHION, Philippe. "Interaction Effects in the Relationship Between Growth and Finance." In X. Freixas, P. Hartmann and C. Mayer, eds. *Handbook of European*

Financial Markets and Institutions. New York: Oxford University Press, chapter 3 (2008): 99-117.

ANG, James B. "A Survey of Recent Developments in the Literature of Finance and Growth." *Journal of Economic Surveys* 22, no. 3 (2008): 536-576.

ARRIBAS, Iván, Francisco PÉREZ GARCÍA and Emili TORTOSA AUSINA. "The determinants of international financial integration revisited: The role of networks and geographic neutrality." *Studies in Nonlinear Dynamics and Econometrics* 15, no. 1 (2011a): article 4.

—. "A Network Perspective on International Banking Integration." *Journal of Policy Modeling* 33, no. 6 (2011b): 831-851.

BAELE, Lieven, Annalisa FERRANDO, Peter HÖRDAHL, Elisaveta KRYLOVA, and Cyril MONNET. "Measuring European financial integration." *Oxford Review of Economic Policy* 20, no. 4 (2004): 509-530.

BHAGWATI, Jagdish. "Anti-globalization: why?" *Journal of Policy Modeling* 26 (2004a): 439-463.

—. *In Defense of Globalization.* Oxford: Oxford University Press, 2004b.

BUCH, Claudia M. "Distance and international banking." *Review of International Economics* 13, no. 4 (2005): 787-804.

CABRAL, Inês, Frank DIERICK, and Jukka VESALA. "Banking integration in the Euro area." ECB Occasional Paper Series no. 6, Frankfurt: European Central Bank, 2002.

CHINN, Menzie D., and Hiro ITO. "What Matters for Financial Development? Capital Controls, Institutions, and Interactions." *Journal of Development Economics* 81, no. 1 (2006): 163-192.

—. "A new measure of financial openness." *Journal of Comparative Policy Analysis* 10, no. 3 (2008): 309-322.

DEMIRGÜÇ-KUNT, Asli. "Finance and economic development: The role of government." In A.N. Berger, P. Molyneux and J.O.S. Wilson, eds. *The Oxford Handbook of Banking.* New York: Oxford University Press, chapter 29 (2010): 729-755.

DREHER, Axel. "Does globalization affect growth? Evidence from a new index of globalization." *Applied Economics* 38, no. 10 (2006): 1091-1110.

EDISON, Hali J., Ross LEVINE, Luca RICCI, and Torsten SLØK. "International financial integration and economic growth." *Journal of International Money and Finance* 21, no. 6 (2002): 749-776.

GOLDBERG, Linda S. "Understanding banking sector globalization." *IMF Staff Papers* 56, no. 1 (2009): 171-197.

GOURINCHAS, Pierre-Olivier, and Olivier JEANNE. "The elusive gains from international financial integration." *Review of Economic Studies* 73, no. 3 (2006): 715-741.

GROPP, Reint, and Anil K. KASHYAP. "A new metric for banking integration in Europe." In A. Alesina and F. Giavazzi, eds. *Europe and the Euro.* National Bureau of Economic Research Conference Report, Chicago (IL): University of Chicago Press, chapter 6 (2010): 219-246.

GUISO, Luigi, Tullio JAPPELLI, Mario PADULA, and Marco PAGANO. "Financial market integration and economic growth in the EU." *Economic Policy* 19, no. 40 (2004): 523-577.

IAPADRE, Lelio. "Regional integration agreements and the geography of world trade: measurement problems and empirical evidence." In P. De Lombaerde, ed. *Assessment and Measurement of Regional Integration.* London: Routledge (2006): 65-85.

Jayaratne, Jith, and Philip E. Strahan. "The finance-growth nexus: Evidence from bank branch deregulation." *The Quarterly Journal of Economics* 111, no. 3 (1996): 639- 670.

Kose, M. Ayhan, Eswar Prasad, Kenneth Rogoff, and Shang-Jin Wei. "Financial globalization: A reappraisal." *IMF Staff Papers* 56, no. 1 (2009): 8-62.

Krugman, Paul R. "Regionalism versus multilateralism: analytical notes." In J. de Melo and A. Panagariya, eds. *New Dimensions in Regional Integration.* Chapter 3, Cambridge: Cambridge University Press (1996): 58-89.

Kunimoto, Kazutaka. "Typology of trade intensity indices." *Hitotsubashi Journal of Economics* 17, no. 2 (1977): 15-32.

Lane, Philip R. "Financial Globalisation and the Crisis." BIS Working Paper no. 397, Basel: Bank for International Settlements, 2012.

Lane, Philip R., and Gian Maria Milesi-ferretti. "The external wealth of nations: measures of foreign assets and liabilities for industrial and developing countries." *Journal of International Economics* 55, no. 2 (2001): 263-294.

—. "The external wealth of nations Mark II: Revised and extended estimates of foreign assets and liabilities, 1970-2004." *Journal of International Economics* 73, no. 2 (2007): 223-250.

Levine, Ross. "Finance and growth: theory and evidence." In P. Aghion, and S. Durlauf, eds. *The Handbook of Economic Growth.* Volume 1A of Handbooks in Economics, Amsterdam: Elsevier, chapter 12,(2005): 865-934.

Manna, Michele. "Developing statistical indicators of the integration of the Euro area banking system." Working Paper no. 300, Frankfurt a. M.: European Central Bank, 2004.

Mishkin, Frederic S. "Is financial globalization beneficial?" *Journal of Money, Credit and Banking* 39, nos. 2-3 (2007): 259-294.

—. "Why we shouldn't turn our backs on financial globalization." *IMF Staff Papers* 56, no. 1 (2009): 139-170.

Papaioannou, Elias. "Finance and growth. A macroeconomic assessment of the evidence from a European angle." In X. Freixas, P. Hartmann and C. Mayer, eds. *Handbook of European Financial Markets and Institutions.* New York: Oxford University Press, chapter 2 (2008): 68-98.

Pérez Cid, Daniel, Vicente Salas Fumás, and Jesús Saurina. "Banking integration in Europe." *Moneda y Crédito* 220 (2005): 105-144.

Quinn, Dennis. "The correlates of change in international financial regulation." *American Political Science Review* 93 (1997): 531-551.

Robinson, Joan. *The Rate of Interest and Other Essays.* London: Macmillan, 1952.

Rodrik, Dani. "Comments on "Financial Globalisation and the Crisis". BIS Working Paper no. 397, Bank for International Settlements, Basel (2012).

Rodrik, Dani, and Arvind Subramanian. "Why did financial globalization disappoint?" *IMF Staff Papers* 56, no. 1 (2009): 112-138.

Sander, Harald, Stefanie Kleimeier, and Sylvia Heuchemer. "E(m)u effects in global cross border banking." *Economics Letters* 118, no. 1 (2013a): 91-93.

—. "Financial crises and cross border banking: New evidence." *Journal of International Money and Finance* 32 (2013b): 884-915.

Schindler, Martin. "Measuring financial integration: a new data set." *IMF Staff Papers* 56, no. 1 (2009): 222-238.

SCHUMPETER, Joseph A. *The Theory of Economic Development.* Cambridge, MA: Harvard University Press, 1911.

SOROS, George. *On Globalization.* New York: Public Affairs, Ltd., 2002.

STIGLITZ, Joseph E. *Globalization and Its Discontents.* Penguin, 2002.

—. "Contagion, liberalization, and the optimal structure of globalization." *Journal of Globalization and Development* 1, no. 2 (2010a): article 2.

—. "Risk and global economic architecture: Why full financial integration may be undesirable." *American Economic Review* 100, no. 2 (2010b): 388-392.

WORLD BANK. *World Development Indicators.* Washington, D.C., accessed 8 October 2013 in http://data.worldbank.org/data-catalog/world-development-indicators.

1. How Did Financial Integration Impact on the Activity, Productivity and Solvency of Spanish Banks Prior to the Crisis?

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1.1. Motivation

Financial integration allows banks and firms of different countries to invest in projects or to raise funds from outside their country of origin, contributing to achieve an efficient allocation of capital within the integrated zone. The entrance of Spain into the European Monetary Union (EMU) granted the access of Spanish banks to European and international financial markets and, during the years prior to the crisis, they benefited from access to wholesale financing at low cost. This chapter presents evidence that financial integration not only contributed to the growth of banks' balance sheets and of the Spanish economy in general, but it also contributed to the generation of imbalances within banks that arose with the outbreak of the crisis, which were difficult to detect due to the high profits and productivity growth of banks during those years. More concretely, this chapter shows how the strength of bank capital was eroded within EMU and how the expansion of the international demand for securities and subordinated debt was a key component of this erosion. The growth of business and reliance on hybrid instruments issued in international markets created a mirage in the robustness of the systems. By checking how productivity measures were distorted by securitization, and by providing a decomposition of capital according to the source, these weaknesses are revealed.

Financial markets around the globe underwent an impressive development during the years preceding the financial crisis: the volume of assets traded in financial markets increased exponentially, enhanced by a surge of financial innovations in the form of new products, whose functions were not only restricted to raising funds, but to transfering risks, hedge risks and arbitrage capital. Dependencies and interconnections among financial markets rose as a natural consequence of their development, increasing the degree of financial integration among financial markets around the world. In this context, the European Union (EU) has targeted economic and political integration and, particularly, the financial and banking integration of EU members. Indeed, the European Central Bank (ECB) follows closely this process in its Annual Report on Financial Integration, which analyzes a long list of indicators of the degree of financial integration among EU members. In the 2012 report, the ECB argues that banking and financial integration in the EU is desirable because (i) it strengthens the mechanism of transmission of the monetary policy, (ii) it contributes to achieve a higher efficiency in the allocation of resources and capital, (iii) it contributes to productivity gains that increase competition within national markets of member states and (iv) it reduces the financial barriers among member states and facilitates access to financial markets, instruments and services.

In this chapter, we provide some evidence that financial integration could have also entailed other consequences, in terms of liquidity imbalances and risk exposure, not as desirable as those listed above and that Diamond and Rajan (2009) have pointed out as the proximate causes of the crisis. More concretely, we explore how the reduction of financial barriers between markets, which is in the ECB's list of the positive contributions of financial integration, has turned into large growth rates of productivity due to the change of the banks' business model, rather than efficiency gains and a lower level of solvency ratios for Spanish banks.[1] The reasons that

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[1] Martín Oliver, Ruano and Salas (2013) analyze the impact of financial integration on the productivity of Spanish banks. They show that around two-thirds of the productivity gains were attributed to change of the business model of Spanish banks during the pre-crisis period.

we identify in this chapter are basically four. First, international markets have financed a large part of the high growth of banks focused on real-estate activities. The entry of Spain into the EMU granted Spanish banks the access to cheap and almost unlimited financing from Euro and foreign markets, which absorbed more than 70% of the debt instruments that they issued from 1998 to 2007. The destination of these funds to finance real-estate loans contributed to enhance the housing bubble in Spain, whose worst effects could have been less devastating (evictions, credit crunch, losses of billions of euros...), if banks had rationed their growth policy and the recourse to international wholesale financing.

Second, the good figures of banks' performance measures during those years hindered to detect and forecast the risks that were being generated. Apparently, performance measures showed an intensive growth that was attributed to the capacity of banks to manage their risk and business activity with the tools generated by financial engineering. Banking research has a long and fructiferous tradition in the measurement of the productive efficiency and the technical progress of financial intermediaries. From a macro perspective, the conclusions drawn from banking research suggested that, during the years before 2008, the financial intermediation industry around the world experienced unprecedented levels of productivity growth and profitability (Haldane, Brennan and Madouros 2010). The severe financial crises that followed immediately after the historically high levels of productivity triggered a debate centered on the measurement of banks' output and also on the influence of banks' characteristics and environmental conditions in explaining the observed differences of their individual performance. These unprecedented growth rates of the productivity attributed to banks during the years before the crisis have raised new concerns on what is really behind the productivity of banks.

Third, banks ended up with a large dependence on wholesale financing while the importance of traditional, more stable sources of funds (i.e., deposits) dwindled in the banks' balance sheets. As a consequence, Spanish banks became directly exposed to the shutdown of international financial markets with the outburst of the financial crisis and they underwent serious liquidity problems, due to difficulties to refinance debt instruments reaching maturity.

Fourth, Spanish banks' risk-weighted assets (RWA) increased as a result of the lending expansion, and they were obliged to raise fresh regulatory capital in order to comply with Basel regulation. It happened that banks chose hybrid capital instruments to cover the main bulk of their regulatory capital needs and, hence, the quality of regulatory capital became worse: the core capital (equity and reserves) lost weight in favor of debt-like instruments and, thus, the capacity of regulatory capital to absorb loan losses dwindled. This result was more evident when holders of subordinated debt and preferred stock had to share the burden of losses, claiming that they bought those securities misguided by banks themselves. The experience alerted on the limitations of hybrid regulatory capital instruments as a true loss absorbing regulatory capital and it justifies the new core capital standards set by Basel III.

The rest of the chapter is organized as follows. Section 1.2 describes the data that is used in the chapter; section 1.3 explores the consequences of financial integration on banks' balance sheets in terms of assets and liabilities; section 1.4 presents the impact of the change of banks' business model on productivity; section 1.5 analyzes the change in the composition of regulatory capital during the period under study. Section 1.6 presents the conclusions and summarizes the main findings of the chapter.

1.2. Database

The database of issuances of financial instruments has been constructed from Dealogic and it gathers information of all the issuances of Spanish banks in financial markets during the period 1998 to 2007. We do not consider later years as in 2008 financial markets stopped operating normally for Spanish banks. Issuances are classified in two groups, debt issuances and regulatory capital issuances, following the criteria of whether the corresponding instrument can absorb losses without risking the viability of the bank. Under this notion of capital, ordinary shares, convertible debt, preferred shares and subordinated debt have the capacity of absorbing losses because it is the ultimate stakeholder the one assuming the loss of value. On the other hand, we group issuances of senior debt, covered bonds and securitization as debt issuances according to their value and proceeds do absorb losses of the bank only in the event of severe instability and bankruptcy. This is one of the two notions of capital in Acharya et al. (2011) that coincides with the list of eligible capital of Basel I and II.

The section that analyzes the evolution of the asset side of banks is based on aggregate data of assets and the balance of credit by categories, published in the Statistical Bulletin of the Bank of Spain during the period 1998 to 2011. Here we extend the sample period to the latest year available to analyze the change in the composition of assets as a result of the crisis. Further, the analysis of regulatory capital uses data from the Annual Report on Supervision by the Bank of Spain for the variables RWA, total regulatory capital and core regulatory capital of all Spanish banks, also during the period 1998-2011.

1.3. Financial integration and business model of banks

The traditional activity of a bank is the intermediation between investors and savers, that is, collection of funds from the savers of an economy, with short- and medium-term inter-temporal consumption preferences, and the transformation into loans of different maturity that match investors' needs of that economy. In traditional banking, deposits constitute the basic source of banks' lending activity funding. This is the business model of the Spanish banking industry until the end of the 1990s: table 1.1 shows that, during those years, the average composition of the liability side is made up of 84% deposits and around 11% own funds (capital, reserves and accumulated loans loss provisions). Only a marginal 3-5% of banks' balance sheets is financed with debt instruments, thus, banks do not consider debt as a close substitute of deposits prior to 2000. However, during the next years the traditional intermediation model begins to fade. Table 1.1 shows that the weight of deposits decreases from 84.28% in 1998 to 59.11% in 2006 in favor of debt (from 3.67% in 1998 to

TABLE 1.1: Evolution of the composition of assets and liabilities of Spanish banks, 1988-2006
(percentage with respect to total assets)

	Assets				Liabilities			
	Loans	Interbank	Government bonds	Rest	Deposits	Debt	Own funds	Securitization
1988	64.87	4.43	20.77	9.93	84.17	5.06	10.77	0.00
1989	64.47	5.79	21.49	8.25	85.74	3.97	10.30	0.00
1990	64.67	–0.99	21.70	14.62	85.63	3.50	10.87	0.00
1991	67.05	0.86	16.07	16.03	84.29	3.84	11.87	0.00
1992	67.80	–0.56	15.55	17.22	84.12	2.06	12.41	1.41
1993	63.99	2.63	15.47	17.91	83.35	2.25	12.63	1.77
1994	63.63	–0.29	19.27	17.39	83.89	2.50	11.96	1.65
1995	61.61	3.21	19.85	15.33	84.85	2.37	11.14	1.64
1996	63.56	1.76	20.07	14.62	84.52	2.90	11.02	1.56
1997	68.08	0.25	17.00	14.67	84.23	3.55	10.76	1.47
1998	74.12	–5.30	15.97	15.20	84.28	3.67	10.51	1.54
1999	74.30	–5.32	14.22	16.81	81.18	7.03	9.92	1.88
2000	76.80	–2.25	11.64	13.80	82.68	3.80	9.45	4.07
2001	74.84	–0.48	11.49	14.15	81.73	4.23	9.53	4.51
2002	76.91	–0.61	10.92	12.77	79.39	4.07	9.57	6.96
2003	79.04	–2.87	10.67	13.16	74.40	5.79	9.31	10.49
2004	80.49	–1.00	7.72	12.79	67.27	8.96	10.09	13.68
2005	82.65	–2.33	6.25	13.43	62.69	11.25	9.30	16.76
2006	84.58	0.99	4.11	10.32	59.11	12.34	8.71	19.84

Source: Almazán, Martín Oliver and Saurina (2013).

12.34% in 2006) and, specially, securitization[2] (from 1.54% in 1998 to 19.84% in 2006). Banks no longer base their growth and financing on deposits only, because they can access to alternative sources to finance their banking activity.

1.3.1. Domestic and foreign wholesale funding on banks' balance sheets

The explanation of this breaking point, from which debt and securitization become a real alternative to banks' deposits, can be located around the introduction of Spain in the EMU and the consequent access of banks to the European and international capital markets. The access to new sources of funding is accompanied with a loss of funds' cost, partly due to the translation of the lowering Spanish sovereign risk premium to the funding cost of Spanish firms. Additionally, the huge increase in the volume of assets traded in global markets, enhanced by financial engineering, also contributes to explain the exponential raise of wholesale financing of Spanish banks.

Table 1.2 provides evidence of the importance of international markets on the issuances of debt of Spanish banks during the period 1998-2007: Euro and foreign markets concentrated more than 60% of the total issuances (versus less than 40% from domestic market), except in 2006 when the volume amounted to 53.15%. Adding up the volumes of all the years under study, the issuances in Euro and foreign markets amount to 71.12%. In absolute values, table 1.2 shows that the issuances of debt-like instruments increases exponentially during the 2000s, consistent with the increasing weight of debt and securitization observed in table 1.1. Comparing the beginning and the end of the period analyzed, the volume of total debt-like instruments issued in 2007 is multiplied by a factor of 13 compared to 1998; the highest contributor to this growth is securitization.

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[2] Almazán, Martín Oliver and Saurina (2013) include covered bonds in their definition of securitization and so do we in the comments of figure 1.1, following the source of reference. A more precise definition of securitization instruments can be found in chapter 2.

TABLE 1.2: Issuance of debt instruments of Spanish banks, by market type, 1998-2007
(millions of euros)

	Domestic market						Non-domestic markets*						
	Covered bonds	Securitization	Senior debt	Preferred shares	Subordinated debt	Total domestic (A)	Covered bonds	Securitization	Senior debt	Preferred shares	Subordinated debt	Total international (B)	$\frac{B}{A+B}$
1998	0	3,395	824	0	483	4,703	0	0	17,310	2,825	1,665	21,800	82.26%
1999	0	3,396	3,814	250	94	7,554	4,500	3,465	13,530	4,331	4,055	29,881	79.82%
2000	0	7,299	2,851	0	550	10,700	2,000	23,740	17,730	2,003	5,687	51,160	82.70%
2001	0	1,081	1,803	176	65	3,125	3,500	31,150	28,010	3,039	4,291	69,990	95.73%
2002	0	6,278	5,775	396	80	12,529	11,500	28,930	27,250	517	3,513	71,710	85.13%
2003	0	9,491	458	55	848	10,851	24,650	41,200	40,220	100	3,146	109,316	90.97%
2004	150	7,517	7,893	0	507	16,067	24,990	61,320	44,790	1,673	5,600	138,373	89.60%
2005	8,500	25,920	30,490	0	2,669	67,579	38,890	57,970	50,900	1,715	5,735	155,210	69.67%
2006	46,350	53,210	40,300	558	8,071	148,489	26,500	74,260	59,490	1,948	6,262	168,460	53.15%
2007	23,160	76,440	17,160	150	4,451	121,361	11,680	144,900	45,620	2,675	12,510	217,385	64.17%

* Euro markets, foreign and non-euro markets included.

Source: Dealogic (2010) and author's calculations. Instruments have been classified applying the following filters to DCM Dealogic issuances: *Covered Bonds*: Issue structure equals "CV"; Deal Type not any of "ABS" or "MBS". *Securitization*: Deal Type is one of "ABS" or "MBS" and issue structure is not equal to "CV". *Senior Debt*: Subordinated Debt equals "N"; Deal Type not any of "PREF or ABS or MBS or ST" and Issue Structure not equal to "CV". *Preferred Shares:* Deal Type equals "PREF". *Subordinated debt:* Subordinated Debt equals "Y"; Deal Type not any of "PREF or ABS or MBS or ST" and Issue Structure not equal to "CV". Securitization of covered bonds (the so-called *cédulas singulares)* have been included under *Covered Bonds,* even when they have structure of *Securitization* according to Dealogic.

The high surge of securitization in Spain, especially from 2005 to 2007, responds to the high demand from financial markets towards this type of products. During these years, financial engineering generates a wide range of financial products related to securitization, risk transfer and tranching, and markets are eager to absorb large volumes of these instruments issued by banks around the globe. Part of this interest is justified by the low-risk perception that investors have towards securitization bonds because they are backed by an *a priori* diversified loan portfolio, and credit agencies rate the main part of issuance with top grades. During the period analyzed, Spanish banks realized that securitization represents an opportunity to obtain funds at costs at least as low as other alternatives, since some tranches could even have better ratings than the senior debt of the issuer.

Compared to traditional deposits, securitization has the advantage that banks do not have to compete with other banks to collect funds in branches because there is a large demand willing to buy both the issuances of a particular bank and those from the competitors'. As well as this, securitization represents a gate to enter international financial markets for small- and medium-size banks. These banks did not have the opportunity to issue securities in wholesale markets due to asymmetric information problems (Almazán, Martín Oliver and Saurina 2013), but thanks to financial innovation they could issue asset-backed securities (ABS), bonds that markets were eager to buy at a similar cost to that of big, well-known banks. The strategy is that a group of banks, usually from different regions of Spain, put in common mortgages and real-estate loans from their balance sheet and issue securitized bonds backed by this common portfolio. Thus, markets understand that the geographical risk of loans granted by a single regional bank is diversified with the rest of loans backing the issuance. Thereby, small and medium banks could also become less dependent of traditional deposits to fund their lending activity.

As said, the increasing recourse to securitization and debt is translated into a higher weight of wholesale funding in banks' balance sheets, whereas deposits become less important to finance banks' activities. A positive consequence is that Spanish banks no longer depend on the collection of deposits to finance loans and projects with positive net present value. The drawback is that Spanish banks become more dependent on wholesale funding to refinance debt issuances reaching maturity and to foreign markets' conditions, given that 71.12% of the total volume has been issued in non-domestic markets. Deposits might limit the capacity to growth, but they constitute a sounder and more stable source of funds, not so dependent on external factors of the bank. With the outburst of the crisis in 2008, international markets shut down and banks around the globe had difficulties to refinance debt. For Spanish banks, the situation became even worse because the Euro sovereign crisis hindered the access to foreign refinancing even more, aggravating their liquidity problems. Besides Government's guarantees, the only exit for Spanish banks during these years has been the ECB appeal that has provided the liquidity that financial markets do not grant.

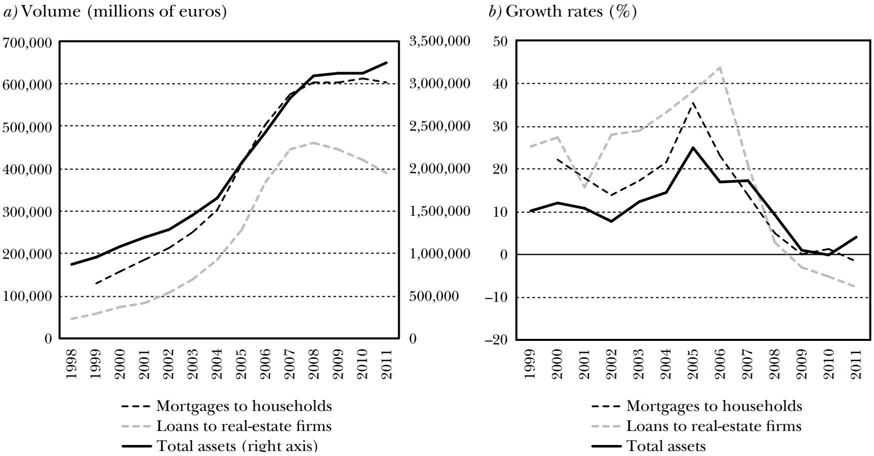
Summing up, financial integration has reduced the dependence of Spanish banks on traditional deposits to finance their activity. However, they have become structurally dependent on the conditions affecting international wholesale markets. The outburst of the crisis has entailed liquidity problems for Spanish banks due to difficulties to refinance past debt issuances. A more limited recourse to foreign wholesale funding during the pre-crisis period could have limited liquidity problems faced by Spanish banks during the crisis.

1.3.2. The use of the financial resources on the asset side

In this section we argue that the real-estate bubble that burst during the economic crisis is in part a consequence of financial integration. The access to international financial markets allows Spanish banks to finance the high credit growth rates in their balance sheets, concentrated on the lending to the real-estate sector, something recurrent in the idiosyncrasy of Spanish crises over time.

Figure 1.1 shows the evolution of assets and total loans of Spanish banks during the period 1998-2011. We observe that the exponential increase of total assets in panel *a* of figure 1.1 responds to the same trend as mortgages and real-estate loans. The slope of

FIGURE 1.1: Evolution of assets and credit, 1998-2011

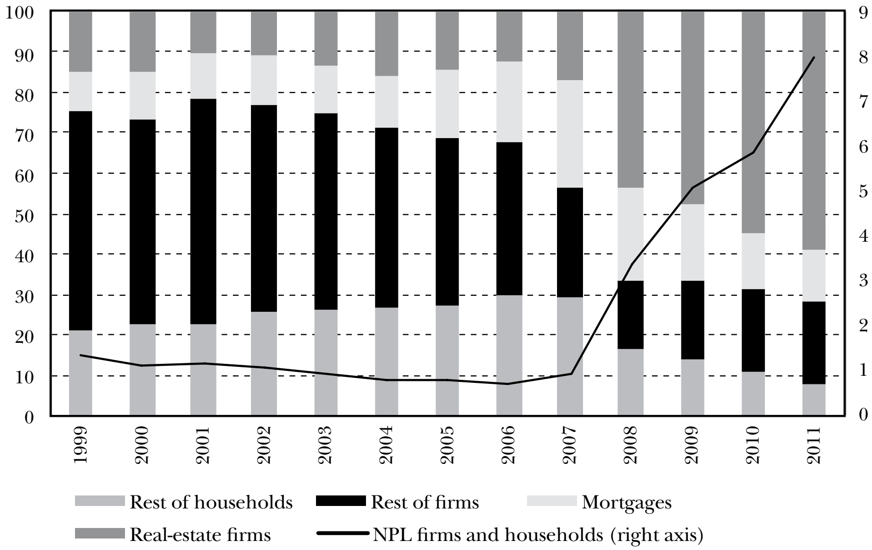


Source: Statistical Bulletin (Bank of Spain 1998-2011) and author's calculations.

total assets becomes steeper especially from 2003 on, coinciding with the largest debt issuances in international markets. During this period, the average growth rates (see panel *b* of figure 1.1) amount to 13.84%, peaking in 2005 with a growth rate of 24.9%. The high increase of assets can be explained to a large extent by the evolution of the lending activity. Mortgages and loans to real-estate present the same exponential trend as banks' assets and their growth rates soar during the years of higher increase of wholesale financing; from 2003 to 2007, the yearly average growth rate of mortgages amounts to 20.87% and that of loans to real-estate firms is 29.15%.

During the expansion years preceding the crisis, the Bank of Spain repeatedly warned banks of the potential risks embedded in their strategy of excessive loan growth and concentration on the real-estate sector (i.e., reduction of lending standards, enhancement of housing bubble, etc.), despite the existing deterring mechanisms to loan growth, such as the dynamic provisioning. This happens while banks' credit indicators give a very different and more positive view of the situation: Non-performing loans (NPL) ratios are around 1% (figure 1.2), one of the lowest ratios in these series. It is the outbreak of the global crisis and the deterioration of the Spanish economy which uncover the

FIGURE 1.2: Contribution to NPL ratio, by components. Spanish banks, 1999-2011 (percentage)



Source: Statistical Bulletin (Bank of Spain 1999-2011) and author's calculations.

imbalances of the previous period: loans begin to default and NPL ratios start an increasing trend that beat previous historic peaks of the series and reach 7.97% in 2011. The main contributor to this growth is loans to the real-estate sector, which explain 59.09% of the NPL in 2007. The deterioration of the loan portfolio has resulted in billions of losses, public capital injections, bailouts and restructuring the whole Spanish banking sector, still underway in 2013.

To a large extent, the nearly inelastic demand of international markets for bonds issued by Spanish banks has enhanced the growing housing bubble financed by Spanish banks. Back to table 1.2, we have shown that the resources obtained from domestic markets covered only 28.88% of the total volume issued during the years 2000-2007. This does not mean that raising funds from foreign markets are negative and/or should be controlled. Rather, we claim that the fact of banks not having a limited amount of resources that obliged them to screen and select across potential borrowers probably resulted in incentives to lower credit standards, and expanded their business granting risky loans.

1.4. Productivity growth and performance measures

One of the reasons why it is difficult to detect the imbalances that are being generated during the period under study is because Spanish banks and, more generally, financial intermediation industry around the world experience unprecedented levels of productivity growth and profitability. Haldane, Brennan and Madouros (2010) refer to estimates of productivity growth provided by the Bank of England using the harmonized KLEMS[3] database for OECD (Organisation for Economic Co-operation and Development) countries (O'Mahony and Timmer 2009). For the Spanish financial intermediation industry, the estimates of the growth rate of total factor productivity (TFP) amount to 9 percentage points above the growth rate of TFP of the whole economy. Therefore, the Spanish banking industry, now under severe restructuring, is one example of the apparent paradox of a period of high productivity growth followed by a period of deleveraging and restructuring. Martín Oliver, Ruano and Salas (2013) study the reasons that can explain the high productivity growth observed in the performance measures, and they find that the excess of growth above the historical trend basically responds to a change of the business model of banks, which is related to the effects of financial integration mentioned above. More concretely, the access to international financial markets, substitution of deposits by securitization and growth based on the real-estate sector resulted in an increase of productivity figures that were wrongly interpreted as technical progress.

In their paper, Martín Oliver, Ruano and Salas (2013) obtain their productivity estimates[4] using a production-function approach, assuming a Leontief technology and introducing IT (information technology) capital services as inputs. Then, they estimate the production function applying the methodology posited

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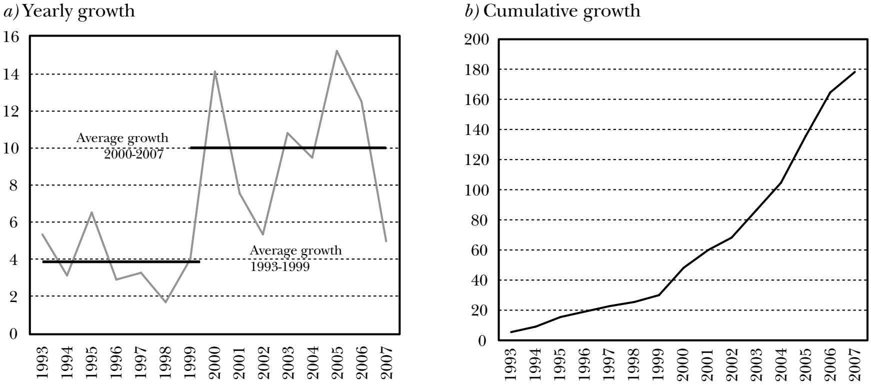
[3] Kapital Labour Energy Material Services.

[4] There are several papers published on measurement and determinants of productivity and efficiency of Spanish banks (i.e., Grifell and Lovell 1997; Maudos et al. 2002; Illueca, Pastor and Tortosa 2009).

by Levinsohn and Petrin (2003), and they explain productivity estimates of each bank as a function of banks' characteristics and a time trend in industry technical progress. Figure 1.3 presents the estimates of productivity of Spanish banks found in Martín Oliver, Ruano and Salas (2013). Panel *a* of figure 1.3 shows the annual growth rate of the banking industry productivity and panel *b* shows the cumulative growth rates. The weighted average productivity in 2007 is 2.8 times the value of 1993, what implies an increase of 180% during the 15 years period (see panel *b* of figure 1.3). Most of the increase in the ratio occurs during the Euro period (2000-2007), when the average growth rate is 10.01%, compared to the 3.85% average annual rate during the 1993-1999 period (see panel *a* of figure 1.3). These high figures are consistent with previous papers that find high growth rates in performance measures of Spanish banks (O'Mahony and Timmer 2009). However, the explanation of high growth cannot only be attributed to technical progress. Martín Oliver, Ruano and Salas (2013) regress the estimates of bank productivity with respect to a list of potential determinants, and they find that a large part of the productivity growth during the Euro period can be explained because of the change of Spanish banks' business model.

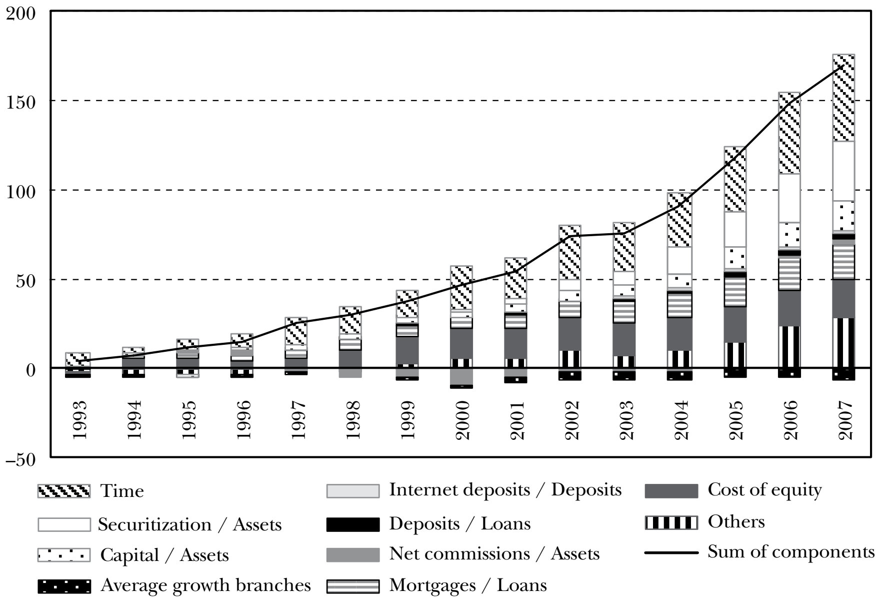
Figure 1.4 presents the decomposition of productivity growth into its determinants. We observe that technical efficiency can

FIGURE 1.3: Productivity growth of Spanish banks, 1993-2007
(percentage)



Source: Statistical Bulletin (Bank of Spain 1993-2007) and author's calculations.

FIGURE 1.4: Decomposition of productivity of Spanish banks, 1993-2007
(percentage)



Source: Martín Oliver, Ruano and Salas (2013).

explain only one third of the increase in productivity during the Euro period. The rest of the variation responds mainly to factors related to financial integration, that is, the lower cost of capital for Spanish banks, the increasing specialization of the banks on the mortgage and real-estate segment and the increase of securitization and leverage. As commented in the previous section, this increase in the leverage comes mainly from funds obtained in the external market (i.e., debt and, especially, securitization). The reason why leverage can be related to productivity might be that securitization enables banks to obtain external finance without having to consume labor and capital inputs (as opposed to the collection of deposits), and banks can grant more loans with the same inputs (which explains the estimated higher productivity). When all the determinants are taken into account from the productivity differences, we observe that the technical progress (growth of the time trend) of the banking industry remains relatively constant, compared to the pre-euro period, with a sustained yearly growth rate of 3-4% a year.

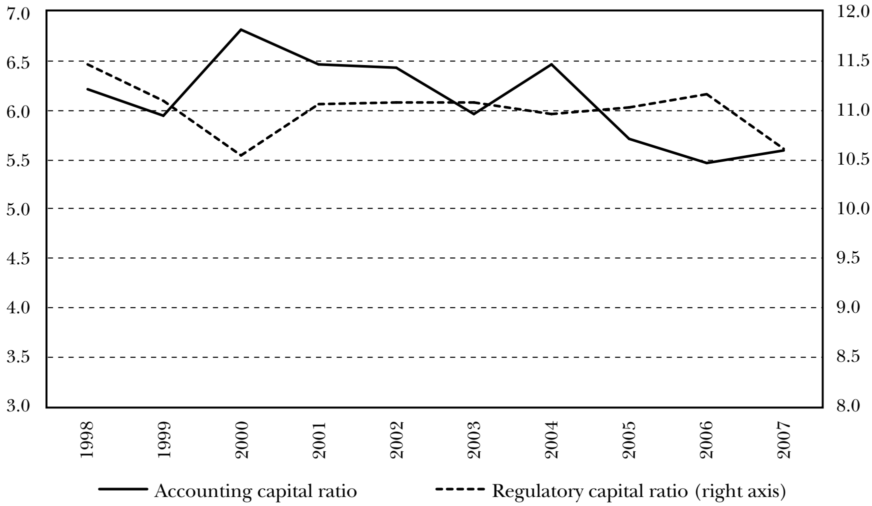
Wrapping up, the productivity of Spanish banks grows above the pre-euro trend during the period 1998-2007 and this growth responds mainly to determinants related to financial integration rather than efficiency gains. More concretely, around 55% of total productivity growth is determined by the lower cost of capital, the increase of banks' leverage, securitization, and the growth of mortgages financed with new funds. Only one-third of productivity growth responds to technical efficiency.

1.5. Financial integration and solvency of banks

This section studies the impact of securitization and credit growth on the quantity and quality of banks' capital. During the period under study, Spanish banks have to fulfill the regulatory capital requirements set by the Basel Accord in 8% of the RWA. The growth in volume of assets is parallel to a higher risk embedded in the granted loans and, thus, RWA level increases during the period under study. Banks could have responded either by absorbing the higher RWA with the buffer of regulatory capital accumulated during previous years (with a reduction of the Basel capital ratio), or they could have offset the rise in RWA by increasing the volume of regulatory capital (numerator of the regulatory capital ratio). Figure 1.5 shows that Spanish banks choose the second option. The level of regulatory capital remains constant over time around values quite above the regulatory minimum. Therefore, the coefficient of regulatory capital does not decrease due to the growth of its denominator; It rather remains well above the level of the regulatory minimum obliged by Basel I and, thus, solvency has not been affected by banks' growth. Now we turn our attention to the composition of regulatory capital during this time period and study. Recent papers provide descriptive evidence of bank capital worsening in US banks prior to and during the crisis that reduces the capacity of capital to act as a corporate governance mechanism, since the participation of owners in potential losses has become smaller (Acharya et al. 2009; Mehran, Morrison and Shapiro 2011). According-

FIGURE 1.5: Accounting capital ratio and regulatory capital ratio. Spanish banks, 1998-2007

(percentage)



Source: Bank of Spain (2001, 2002. 2004, 2007, 2011a).

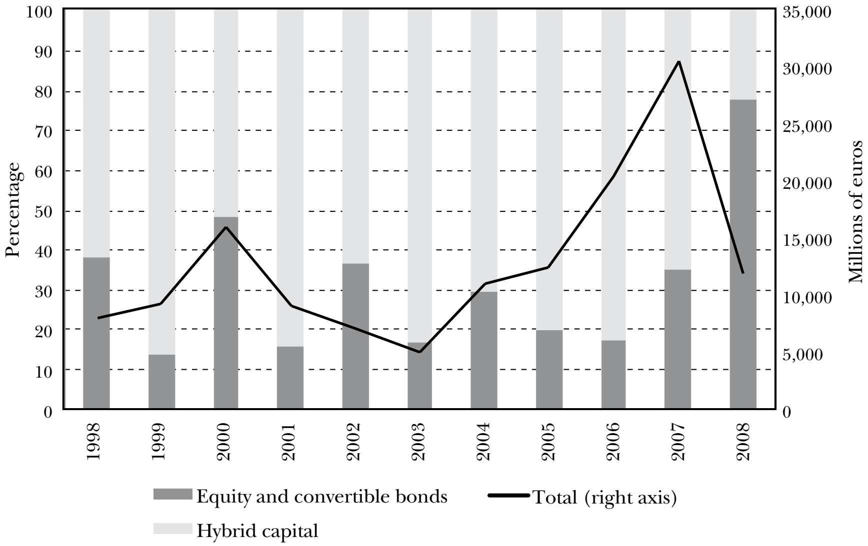
ing to Acharya et al. (2011), this dwindling weight of equity capital could also explain the difficulties of banks to raise new funds, since creditors will only lend if common shareholders are bearing a significant part of risk. We study whether this has been the case for Spanish banks and whether the high ratio of the Basel coefficient is hiding a deterioration of the quality of regulatory capital.

First, we study the evolution of equity capital, defined as the sum of capital and reserves (core capital), which is the capital of highest quality to absorb losses. Figure 1.5 shows that the capital ratio of the banking system has decreased from its peak of 6.81% in 2000 to 5.59% in 2007, implying a reduction of 1.22 percentage points of the weight of core capital with respect to total assets. Although the accounting capital ratio does not adjust by risk measures, we appreciate a fall of top-quality capital weight in the balance sheet of Spanish banks, compared with the more constant evolution of the regulatory capital in the same graph. We find that the main cause of the decreasing trend of equity capital ratio is that the issuances of regulatory capital are mainly in form of hybrid capital, that is, preferred shares and subordinated debt.

Basel I and II consider preferred shares as a component of Tier 1 capital, within certain limits, and Spanish banks use them to fulfill regulation taking advantage of their benefits as a debt-like instrument (i.e., tax-deductible interest rates, lower cost of capital). Nonetheless, the recent financial crisis has shown, especially in the Spanish case, that preferred shares are not as good as equity to absorb losses. To analyze capital deterioration, we take the current criterion of Basel III that does not include preferred shares in the list of capital instruments that compute as core Tier 1 capital, and we consider them as hybrid instruments in the same terms as subordinated debt.

Figure 1.6 shows the composition of the capital issuances of Spanish banks during the sample period, distinguishing between hybrid capital and equity and convertible bonds. For all years, hybrid capital represents more than 50% of the total issuances of regulatory capital and, for the whole period, the average proportion amounts to 71.5%. That is, banks manage their regulatory capital ratios to maintain the levels above the regulatory minimum, but the strategy consists on issuing only 3 units of core capital out of 10 units issued of regulatory capi-

FIGURE 1.6: Issuances of hybrid capital and core capital instruments, 1998-2008



Source: DCM Analytics and ECM Analytics (Eastland Capital), Dealogic and author's calculations.

tal instruments. By doing so, banks are taking advantage, on one hand, of the high demand of international markets during the pre-crisis years and, on the other hand, of the advantages of debt-like capital instruments that compute as regulatory capital, both Tier 1 (preferred shares) and Tier 2 (subordinated debt). As a result, the quality of capital deteriorates and loses capacity to absorb losses.

Decomposition of the regulatory capital

So far, we have seen that banks issue hybrid capital to maintain the regulatory capital ratio constant and this action results in a decreasing trend of the accounting capital ratio. Now, we decompose the regulatory capital ratio into three components to understand how this ratio was kept constant at the same time that equity capital ratio decreased:

$$\frac{Regulatory\ Capital}{RWA} = \frac{Regulatory\ Capital}{Core\ Capital} \times \frac{Core\ Capital}{Assets} \times \frac{Assets}{RWA}$$

The first ratio, *Regulatory Capital/Core Capital,* is the inverse of the core capital weight within the regulatory capital. The definition of core capital has been constructed with data of the regulatory statements drawn from the Annual Report of Supervision (Bank of Spain) and, thus, it does not coincide with the accounting concepts of capital and reserves used in figure 1.5. Here, we define core capital as the Tier 1 capital once we remove the preferred shares[5] and the part of the deductions from Tier 1 and Tier 2 funds that corresponds to original own funds.[6] The second ratio, *Core Capital/Assets,*

[5] Regulation establishes that the volume of preferred shares that can compute as Tier 1 cannot exceed 30% of total Tier 1 capital. According to the Annual Report of Supervision data, preferred shares are below this limit during the period under study and, thus, we assume that there is no deduction in Tier 1 for exceeding the 30%.

[6] From 2008 onwards, deductions of regulatory capital are divided in deductions corresponding to Tier 1 capital and deductions corresponding to Tier 2 capital, each of them representing around 50% of total deductions during the period 2008-2011. For the previous years, the information of capital deductions is aggregated and we cannot obtain the exact figure that corresponds to Tier 1 capital. As an approximation, we take the weight of deductions of Tier 1 capital during the period 2008-2011, that is, 50%.

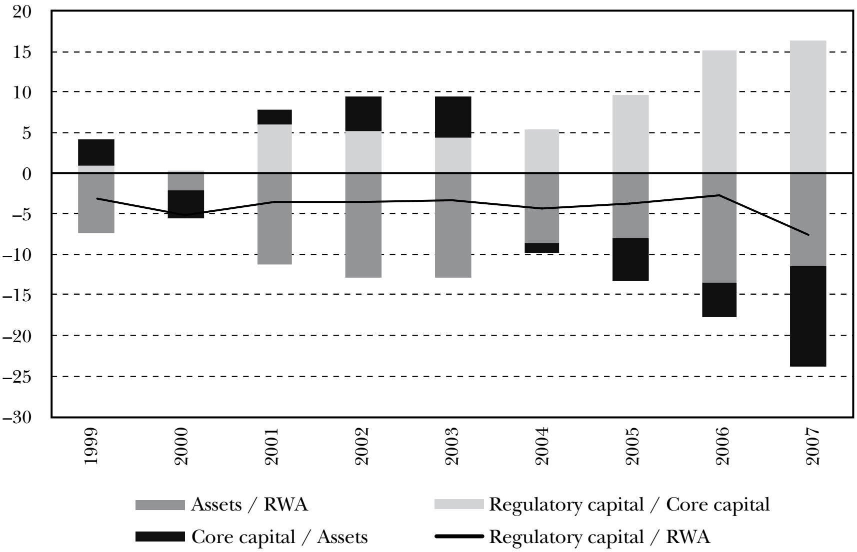
informs of the weight of the core capital computed with regulatory statements with respect to accounting assets. As said, this ratio is not the same as the ratio presented in figure 1.5, because there we only used accounting data. Next, the third ratio, *Assets/RWA,* is equal to the total accounting assets divided by the RWA of Spanish banks and it informs of the evolution of banks 'assets risks. With the previous equation, we can write the growth rate of the regulatory capital ratio as a sum of the growth of its components:

$$\Delta\, ln\left(\frac{Regulatory\ Capital}{RWA}\right) = \Delta\, ln\left(\frac{Regulatory\ Capital}{Core\ Capital}\right) + \Delta\, ln\left(\frac{Core\ Capital}{Assets}\right) + \Delta\, ln\left(\frac{Assets}{RWA}\right)$$

Figure 1.7 shows that the cumulative growth rate of the regulatory capital ratio is relatively constant, except for the negative growth in 1999 and 2000, in line with the flat trend of the ratio observed in figure 1.5. However, we also observe that the constant trend of the ratio occurs at the same time that there are time variations of different sign in each of its components that compensate each other. The negative contribution of *Core Capital/Assets,* from 2004 onwards confirms the negative trend of the core capital with respect to assets observed in figure 1.5 from accounting data. More importantly, we observe that the weight of core capital also decreases in terms of total regulatory capital (positive contribution of *Regulatory Capital/Core Capital,* since 2007), and by 2007 it has fallen to 85% of its value in 1998. These figures confirm that regulatory capital in Spanish banks has deteriorated as in US banks (Acharya et al. 2009, 2011; Mehran et al. 2011). Thus, the higher proportion of hybrid capital in banks' capital is not compensated with retained earnings or other sources of equity capital. On the contrary, banks are substituting core capital with hybrid capital, probably because it has a lower cost and, thus, profits increase.

Further, the weight of core capital dwindles at the same time that the risk of the banks' assets increases, since *Assets/RWA* shows a negative contribution for all the years in figure 1.7. In 2007, the average risk per unit of asset has increased in 12.85% with respect that of 1998, according to the Basel I methodology to

FIGURE 1.7: **Contribution to the growth rate of regulatory capital ratio, by components** (percentage)



Source: Bank of Spain (2001, 2002. 2004, 2007, 2011a).

compute RWA. This implies that the regulatory capital quality to absorb losses is worsening at the same time that the assets of the banks become riskier.

Summing up, during the years before the crisis, the quality of regulatory capital of Spanish banks deteriorates as the weight of core capital decreases in favor of debt-like instruments, which are computed as Tier 2 and Tier 1 (up to a limit) under Basel I and II. The consequences have been the lower capacity of regulatory capital to absorb the loan losses arisen during the crisis and the higher difficulty of Spanish banks to obtain external funding in international markets since the beginning of the crisis.

1.6. Conclusion

The access of Spanish banks to international markets has provided an almost unlimited source of funds to Spanish banks. They are no longer constrained to deposit growth to finance new projects and the cost of capital of the new issuances benefits from the reduction of interest rates and risk premium of the Spanish economy. Adding up all the issuances of debt-like instruments, funds obtained from international markets represent the 71.12% of the total issuances of Spanish banks from 2000 to 2007. A great deal of the large volume of issuances responds to the enrollment of Spanish banks in the list of entities issuing tranched products related to securitization. At the same time, real-estate prices increase at exponential rates due to the combination of the higher economic value of generated rents, discounted at lower interest rates, and the unlimited supply of credit granted to firms and households.

There are sound arguments about the potential benefits of financial integration, but the recent experience of Spanish banks alerts about potential social costs that should be taken into account as lessons for the future: (i) international markets have financed a large proportion of the excessive growth of banks focused on real-estate activities; (ii) banks have ended up with a higher dependence on wholesale financing from international markets and a lower dependence on traditional, more stable sources of funds (i.e., deposits); (iii) high figures of performance measures that hide the generation of imbalances and that arise due to the change of the banks' business model; (iv) banks have increased their recourse to hybrid capital instruments to offset the increasing trend of their RWA: 72.14% of the issuances computing as regulatory capital during 2000-2007 are debt-like instruments. The lower weight of core capital within regulatory capital reduces its capacity to absorb losses. It also contributes to explain the difficulties of Spanish banks to refinance debt during the crisis, since creditors only lend if common shareholders bear a significant part of the risk (Acharya et al. 2011). The revealed importance of capital quality justifies the stricter definition of core Tier 1 capital included in Basel III.

The structural dependence on international wholesale markets, built during the period 2000-2007, has resulted in liquidity problems with the outburst of the crisis and in the stagnation of bank credit and economy activity. Though we are not blaming financial integration for this situation, the financial integration in the period of high growth was not backed up by crisis resolutions mechanisms in accordance with the potential liquidity and solvency crisis that was being built up. The end of the story about the banking crisis in Spain has not been written yet. Meanwhile the sector has entangled the reduction of the number of banks operating in Spain through mergers and acquisitions, the conversion of savings banks into commercial banks, the bailout of banks, the injection of public capital in banks, the revision of supervision mechanisms of the Bank of Spain, the creation of a *bad bank* to absorb toxic assets, and the drastic reduction of the number of branches and workers, among others.

Acknowledgements

The author acknowledges financial support from the Spanish Ministry of Education, Culture and Sports project, MCI-ECO2010-18567.

References

ACHARYA, Viral V., Jennifer N. CARPENTER, Xavier GABAIX, Kose JOHN, Matthew RICHARDSON, Marti SUBRAHMANYAM, Rangarajan SUNDARAM, and ELTAN ZEMEL. "Corporate governance in the modern financial sector." In V.V. Acharya and M. Richardson, eds. *Restoring Financial Stability: How to Repair a Failed System.* Chapter 7, Hoboken, NJ: John Wiley & Sons (2009): 185-196.

ACHARYA, Viral V., Irvind GUJRAL, Nirupama KULKARNI, and Hyun Song SHIN. "Dividends and bank capital in the financial crisis of 2007-2009." *NBER Working Paper* no. 16896, Cambridge, MA: National Bureau of Economic Research, 2011.

ALMAZÁN, Andrés, Alfredo MARTÍN OLIVER, and Jesús SAURINA. "Loan securitization, access to funds and banks' capital structures." *Mimeo*, 2013.

BANK OF SPAIN. *Memoria de la Supervisión Bancaria en España.* Madrid, 2001.

—. *Memoria de la Supervisión Bancaria en España.* Madrid, 2002.

—. *Memoria de la Supervisión Bancaria en España.* Madrid, 2004.

—. *Memoria de la Supervisión Bancaria en España.* Madrid, 2007.

—. *Memoria de la Supervisión Bancaria en España.* Madrid, 2011a.

—. *Statistical Bulletin.* Years 1993 to 2011. Madrid, 2011b.

DEALOGIC. London and New York, accessed December 2010 in http://www.dealogic.com.

DIAMOND, Douglas W., and Raghuram G. RAJAN. "The credit crisis; conjectures about causes and remedies." *American Economic Review Papers and Proceedings* 99, no. 2 (2009): 606-610.

GRIFELL TATJÉ, Emili, and C.A. Knox LOVELL. “The sources of productivity change in Spanish banking.” *European Journal Operational Research* 98 (1997): 365-381.

HALDANE, Andrew, Simon BRENNAN, and Vasileois MADOUROS. “What is the Contribution of the Financial Sector: Miracle or Mirage?” In A. Turner et al. *The Future of Finance: The LSE Report.* London: London School of Economics and Political Science (2010): 87-120.

ILLUECA, Manuel, José Manuel PASTOR, and Emili Tortosa AUSINA. “The effects of geographic expansion on the productivity of Spanish savings banks.” *Journal of Productivity Analysis* 32 (2009): 119-143.

LEVINSOHN, James, and Amil PETRIN. “Estimating Production Functions Using Inputs to Control for Unobservables.” *The Review of Economic Studies* 70, no. 2 (2003): 317-341.

MARTÍN OLIVER, Alfredo, Sonia RUANO, and Vicente SALAS FUMÁS. “Why high productivity growth of banks preceded the financial crisis.” *Journal of Financial Intermediation* 22, no. 4 (2013): 688-712.

MAUDOS, Joaquín, José Manuel PASTOR, Francisco PÉREZ, and Javier QUESADA. “Cost and profit efficiency in European banks.” *Journal of International Financial Markets, Institutions and Money* 12 (2002): 33-58.

MEHRAN, Hamid, Alan D. MORRISON, and Joel D. SHAPIRO. *Corporate governance and banks: What have we learned from the financial crisis?* Staff Report no. 502, Federal Reserve Bank of New York, 2011.

O’MAHONY, Mary, and Marcel P. TIMMER. “Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database.” *Economic Journal* 119 (2009): 374-403.

2. Securitization Before and During the Financial Crisis: The Case of Spain

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Mortgages are a key ingredient of the financial system in any advanced economy as in most cases they represent the main source of household debt and one of the main investments of retail banks. It is well-known that mortgage debt is frequently affected by episodes of asset price bubbles and financial crisis by increasing mortgage delinquencies and carrying foreclosures and evictions with obvious social implications. Not surprisingly, mortgages were at the core of the beginning of the financial crisis in the United States (US) with a huge increase in defaults in subprime lending. But this time the difference was that those subprime mortgages had become the main ingredient of a number of relatively opaque securities that were sold in many forms in international markets, causing uncertainty, distrust and almost the collapse of monetary markets.

Given the disruption caused by securitization, mortgage-backed securities (MBS) have been subject to a significant scrutiny in the last few years. However, this has not precluded banks from keeping on issuing different types of secondary mortgage securities, particularly in Europe. The main reason for such increases in securitization during the crisis years was the issuance for retention purposes. That is, to obtain liquidity from the European Central Bank (ECB) using those securities as collateral. Spain has been one of the main cases, and over the last two decades it has become one of the world's countries with the largest amount of mortgage-related securities, including both MBS and covered bonds (CBs). This issue poses important implications for the integration of the European financial system as securitized products have been considered one of the main sources of financial interactions among European banks in Europe and, therefore, they play a key role in potential risk and contagion effects, as well as on the stability of the whole EU financial sector.

In this chapter we analyze some important issues surrounding securitization before and during the crisis, taking Spain as a reference. Furthermore, we aim at putting some of the general trends and main policy implications together in a less technical way. The issues covered are significant and relevant for financial integration in Europe due to, at least, three reasons:

i. Securitization represents one of the main forms of financial activity across the borders of the different EU financial systems.
ii. The relationships between securitization and lending have important implications on the pricing of financial products, and, thereby on the access to these products within the EU.
iii. Market fragmentation (as opposed to financial integration) may have increased during the crisis years, and the way banks have securitized their loans has had an impact on reducing the effects of such fragmentation (by providing alternative ways to obtain liquidity and to finance households and small and medium-sized enterprises [SMEs]). Actually, some of the efforts of the ECB have been ultimately oriented to promote the use of SME-related securitizations in open-market liquidity operations by European banks.

The rest of the chapter is structured as follows. In section 2.1 we look into the main characteristics and evolution of the mortgage market in Spain in comparison with other countries. Section 2.2 explains how mortgage debt and securitization are related. The case of CBs as a possible alternative to MBS is explained in section 2.3. Section 2.4 deals with the implications of securitization for corporate loans, and, in particular, for lending to SMEs during the crisis. The chapter ends with a summary of conclusions and some policy implications.

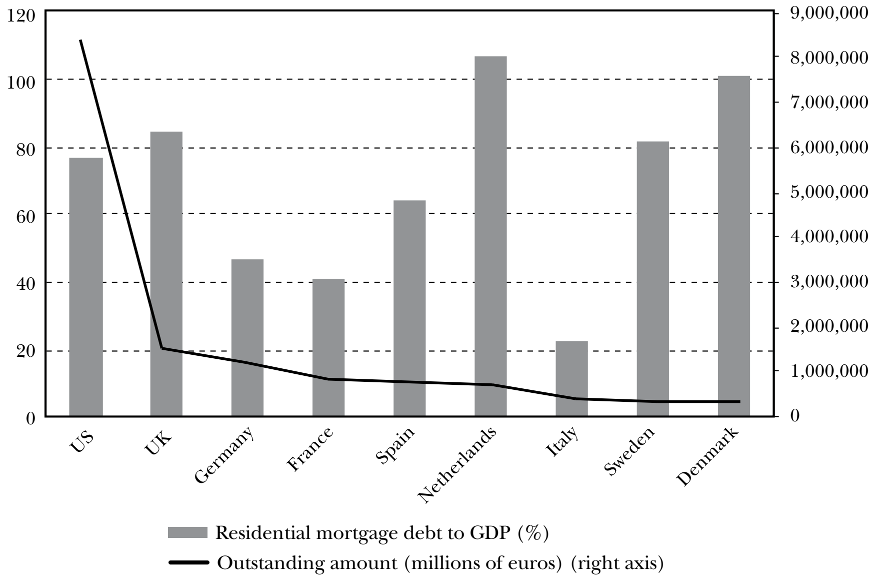
2.1. The mortgage market in Spain

The statistics of the European Mortgage Federation illustrate on the representativeness of Spain in international mortgage markets (see figure 2.1).

Spain is one of the largest mortgage markets in the world in absolute terms. Total outstanding mortgage debt held by residents as a percentage of gross domestic product (GDP) is 64% in Spain. This seems relatively high compared to other countries, such as Italy (22.7%), France (41.2%) and Germany (46.5%), but it is lower than the case of the US (76.5%), the United Kingdom —UK—(85%) or the Netherlands (107.5%).

As shown in table 2.1, examining the most recent data, the number of new mortgage contracts has been continuously falling since 2009. In that year, the mortgages signed decreased by 15.6%

FIGURE 2.1: Mortgage debt outstanding and annual growth, 2010



Source: European Mortgage Federation (2011) and authors' calculations.

TABLE 2.1: Annual change in mortgage contracts in Spain, 2009-2012

	Number of contracts	Value of the new mortgages	Average amount
2009	–15.6	–27.5	–14.1
2010	–11.2	–18.0	–7.6
2011	–32.2	–36.4	–6.2
2012	–29.5	–33.4	–5.6
Memo:			
Average mortgage value in 2009 (Euro)		150,647	
Average mortgage value in 2012 (Euro)		112,875	

Source: National Statistics Office (INE 2012).

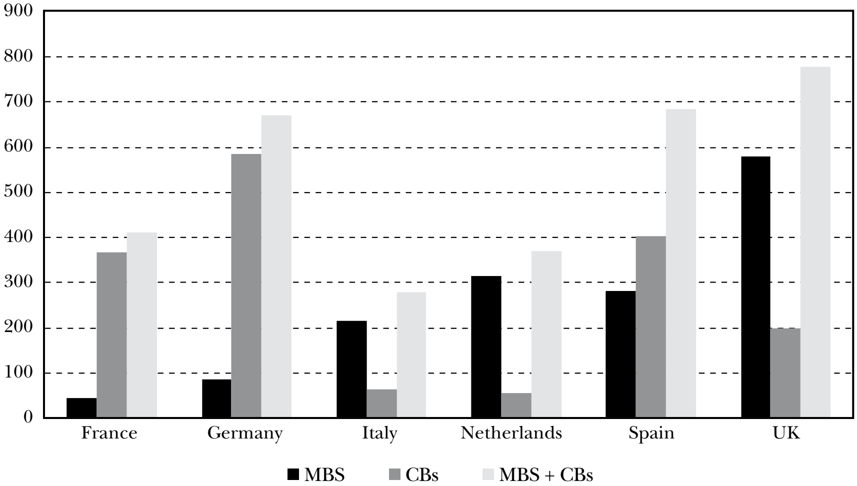
and in 2012 the fall was 29.5%. The value of the mortgages subscribed has declined even faster, from –27.5% in 2009 to –33.4% in 2012. As a consequence, the average amount of mortgages in Spain has decreased from 150,647 euros in 2009 to 112,875 euros in 2012.

The data shows that Spain is a prominent example of mortgage securitization. Current debates on the status and future evolution of Spanish financial stability are a key reference for mortgage markets. There are two main types of mortgage securities being issued in Europe: MBS and CBs. MBS are debt obligations that represent claims to the cash flows from pools of mortgage loans, most commonly on residential property. Mortgage loans are purchased from banks, mortgage companies, and other originators, and then assembled into pools by a specialized entity. The entity then issues securities that represent claims on the principal and interest payments made by borrowers on the loans in the pool. Covered bonds are similar to MBS but bondholders have a claim (full recourse) against the cover pool of financial assets in priority to the unsecured creditors of the issuer. Importantly, the issuer has the ongoing obligation to maintain sufficient assets in the cover pool to satisfy the claims of covered bondholders at all times.

As shown in figure 2.2, Spain represents the second largest mortgage securitization market in Europe, behind the UK. According to the Association of Financial Markets in Europe

FIGURE 2.2: Mortgage-backed securities and covered bonds in Europe. Total outstanding, 2011

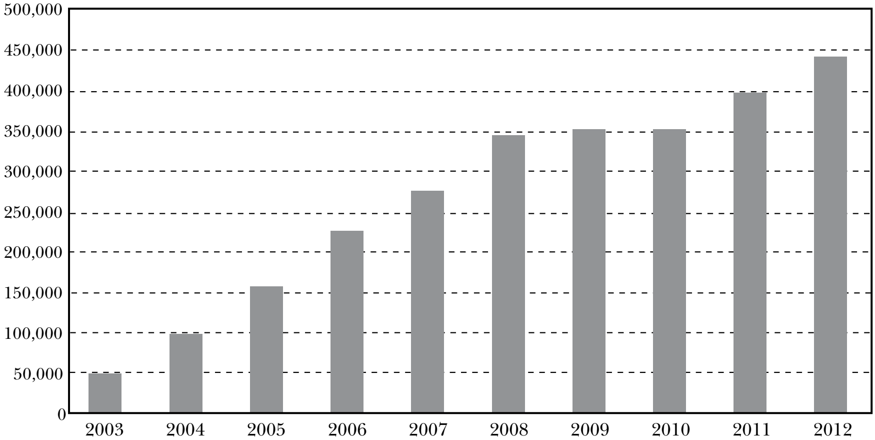
(billions of euros)



Source: AFME (2012), European Covered Bond Council (2011) and authors' calculations

(AFME) and the European Covered Bond Council, Spain and the UK are big issuers of both MBS and CBs, which is not the case for most other European Union (EU) countries, where either CBs (i.e., Germany) or MBS (i.e., Italy) dominate. There are many reasons for such differences, which mainly respond to legal and institutional features. These institutional differences have persisted despite of the number of EU regulations oriented to promote further integration in EU securitization practices. However, even if regulations are becoming more similar across EU countries, differences in preferences for CBs versus MBS persist because tradition and industry still experience significant weights in the choice of the securitization instruments by EU banks. The total CBs and MBS outstanding in the UK in 2011 were 777 billion euros and Spain is next with 683 billion euros. The third country in this ranking is Germany with 671 billion euros, while the volume in France is 410 billion euros. In the case of Spain, the most important mortgage-securitized assets are CBs. The outstanding value of these instruments has increased from 62 billion euros in 2003 to 410 billion euros in 2012 (see figure 2.3).

FIGURE 2.3: Covered bonds in Spain, 2003-2012
(outstanding amount, millions of euros)



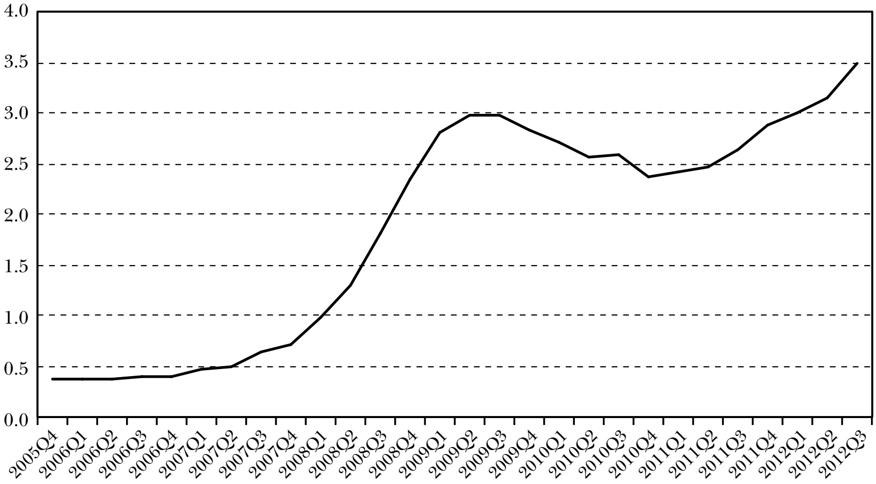
Source: Asociación de Intermediarios de Activos Financieros (AIAF) and authors' calculations.

2.2. How are mortgage quality and securitization related?

Given the importance of Spanish mortgages both domestically and internationally, it seems worthwhile to look at the evolution of non-performing mortgage loans (NPL) ratio. The idea is to show to what extent financial instability issues related to loan quality deterioration have affected this market during the crisis. This is shown in figure 2.4. In particular, the NPL ratio has increased from 0.37% in 2005Q4 to 3.49% in 2012Q3. Even if the increase is significant, the NPL ratio seems low compared to the 10.4% NPL of the entire loan portfolio in a country with a 26% unemployment rate.

How are the loan quality issues transmitted to securitization products? The Spanish case is a very interesting one in this context as both features—deterioration and loan quality, and a large volume of outstanding securities—take place. Carbó, Marqués and Rodríguez Fernández (2012; henceforth CMR) deal with these issues by analyzing the discussion surrounding securitization during the crisis. CMR discuss how securitization allowed banks to turn traditionally illiquid claims into marketable securities. The

FIGURE 2.4: Non-performing mortgage loans, 2005Q4-2012Q3
(percentage of total mortgage loans)



Source: Bank of Spain (2012) and authors' calculations.

development of securitization allowed banks to off-load part of their credit exposure to other investors, thereby lowering regulatory pressures on capital requirements, allowing them to raise new funds. The massive development of the private securitization market experienced in recent years coincided with a period of low risk aversion and scant defaults. This resulted in a number of shortcomings in fims' risk management tools and models, which often used default figures from this period and tended to underestimate default and liquidity risks. The most prominent example is the securitization of mortgage loans which diversifies idiosyncratic risks, but renders the underlying portfolio subject to macroeconomic risks including declines in housing prices.

As shown by CMR, a number of studies have analyzed the impact of securitization on financial stability from a broader perspective. The broad idea is that the availability of credit risk transfer mechanisms has changed banks' role dramatically from their traditional relationship based on lending to originators and distributors of loans. This change has implications on bank's incentives to take on new risks (Shin 2009). However, the overall view prior to the crisis was that, in addition to allowing lenders to keep costly capital, securitization improved financial stability by smoothing out the risks among many investors (Duffie 2008). Indeed, a widely held view prior to the recent global credit crisis, underlined the positive effect of securitization in diversifying credit risk across the financial system, strengthening its overall resilience (Greenspan 2005). From the perspective of individual banks, securitization was expected to be used for modifying their risk profile by allowing them to manage more effectively their credit risk portfolio geographically or by sector. Scant early empirical evidence from the pre-crisis period also goes in this direction. Jiangli and Pritsker (2008) argue that securitization increased bank profitability and leverage while reducing overall insolvency risk. Other studies also found a positive effect of securitization on bank performance. In particular, banks more active in the securitization market were found to have lower solvency risk and higher profitability levels (Duffie and Zhu 2011; Cebenoyan and Strahan 2004; Jiangli et al. 2007).

At the same time there were progressively more skeptical views on the impact of securitization on the financial system stability. Some argue that, by making illiquid loans, liquid securitization could increase, other things being equal, the risk appetite of banks (Calem and LaCour-Little 2003; Wagner 2007; and Brunnermeier and Sannikov 2013). Risk sharing within the financial sector through securitization can also amplify bank risks at the systemic risk level (Brunnermeier and Sannikov 2013). Wagner (2007) shows that liquidity of bank assets attained to securitization increases banking instability and externalities associated with banking failures, as banks have stronger incentives to take on new risk.

Given these findings, it is highly likely that, by augmenting the amount of funding available to banks, securitization activity had a significant and positive impact on credit growth during the years prior to the credit crisis (Loutskina and Strahan 2009; Altunbas, Gambacorta and Marqués 2010). In a number of countries experiencing a period credit growth, securitization activity probably strengthened the feedback effect between increases in housing prices and credit expansion. The growth in securitization issuance also led to laxer credit standards and looser screening of borrowers thereby supporting higher credit growth in the years prior to the crisis (Keys et al. 2010). CMR note that this is because securitization involves a longer informational distance than ordinary loans between the loan's originator and the ultimate bearer of the loan's default risk. Hence securitization can potentially reduce lenders' incentives to carefully screen and monitor borrowers, thereby affecting loan quality. Other factors contributing to laxer credit screening standards in the years prior to the crisis include the degree of competition in the banking system, external financial imbalances, the level of private sector debt, corporate governance in the banking sector, a relative tightness of monetary policy, intensity of banking supervision, and policy responses to the crisis also significantly differed across countries.

The Spanish case is an interesting reference to analyze these issues. As in many episodes of banking problems across the world, the spectacular upward swing in the Spanish credit cycle was buttressed by particularly loose lending practices and large increases in housing prices (see Tornell and Westermann 2002; and Reinhart and Rogoff 2009). Hence the recent Spanish episode of financial instability shares many common features with many early banking crises (i.e. large increases in loan growth coupled with housing bubbles). These features also emerged together with new factors, such as financial innovation in general and most significantly in securitization markets.

CMR also offer an empirical analysis of these issues by studying the Spanish credit cycle, which largely explains the financial crisis in this country and, particularly, the episodes of financial instability and uncertainty that the Spanish banking sector suffered during 2009 and 2010. These episodes gave, in turn, rise to the implementation of significant bank restructuring plans in 2010-2012. CMR characterize the sequential evolution of the credit cycle and claim that securitization and, in particular, mortgage-backed securitization, together with housing prices, may have had a large and lasting effect—through excessive lending—in triggering the banking crisis in Spain. They conduct our empirical analysis of the credit cycle by combining information at the individual security (mortgage-backed securities, MBS, and asset-backed securities, ABS), institution (i.e. bank), and geographical level (i.e. region in which each bank operates). The information is quarterly and the sample period runs from 2000Q1 to 2010Q1.

Importantly CMR approximate credit risk developments at the bank level by considering non-performing loans of each institution and rating changes at the individual security level. Essentially, our database allows us to identify not only the rating of these securities at the time of origination, but also their evolution over time. CMR also analyze to what extent housing prices, securitization activity and lending may have asymmetric effects across institutions and regions, by identifying the role of each of these factors. Their results suggest that credit developments in Spain (also prior to the crisis) were not that different from those experienced by other countries in previous banking crisis identified by earlier literature (see Reinhart and Rogoff 2009). They find that loan growth significantly affects loan performance with a lag of at least two years. Additionally, overall bank loan performance is also found to explain *ex-post* rating changes with a distance of four quarters, also suggesting that there is a considerable lag before rating agencies reassess their credit views. It is also remarkable that originating bank characteristics (in particular, observed solvency, cash flow generation and cost efficiency) also affect considerably the ratings of securities deals which are no longer on the balance-sheet. Additionally, these bank characteristics seem to have a higher weight in the rating changes of securities originated by savings banks, as compared to those originated by commercial banks.[1]

2.3. Given the problems that arose with CBs, are CBs an alternative to MBS?

Given the likely differences in their risk profile and the impact that MBS had in the financial crisis, some have argued that other types of securitization and, in particular, CBs, could serve as an alternative that solves some of the incentive and risk problems that may arise with MBS issuance. At this point, securitization in

[1] The distortion in the bank's characteristics caused by securitization has been explored in chapter 1.

countries like Spain, UK or Germany have been considered as comparative cases because in some of them (UK, Spain) CBs have been extensively used, while in some others (Germany) only CBs have been issued. This has implications for policy lessons derived from the recent financial crisis in Europe in what regulation can do to reduce the risk attached to securitization by promoting more homogenization of these practices in Europe. Carbó, Rosen and Rodríguez Fernández (2011; henceforth CRR) analyze these issues both theoretically and empirically, including a cross-country analysis in which Spain constitutes one of the baseline cases as in Spain both MBS and CBs are used to a large extent, while in other countries (i.e. Germany or the US) only one of them is mainly used.

As shown in CRR, the recent financial crisis has a number of causes, but many lay much of the blame on the movement of financing away from traditional bank lending to what is known as the *shadow banking system* (see, e.g., Adrian and Shin 2009; Brunnermeier 2009; Gorton and Metrick 2009). The shadow banking system includes many things, but a key issue among them are the mechanisms by which loans (and loan-like debt instruments) are financed by other than the originating bank. Securitization—the sale of bonds backed by the payments on a group of loans—plays a major role in the shadow banking system. The ability to securitize loans easily in the pre-crisis period abetted the rapid increase in the issuance of loans that were used as collateral for securitizations. However, the financial crisis exposed a lot of problems with the securitization process, especially for residential mortgages, the largest asset class used to back securitizations, leading to a rapid reduction in the issuance of new residential MBS. In the aftermath, there has been a search for alternatives to securitization (see the report by the Banking Supervision Committee [ECB 2011]).

An alternative to securitization for residential mortgages are CBs, which have been used in some European countries for over a century. In the early stages of the crisis, the critiques on the shortcomings and complexities of the securitization process highlighted the robustness of traditional covered bond products (such as German *Pfandbriefe).*

CRR compare the main characteristics of MBS and CBs. At a very basic level, MBS and CBs work similarly. A bank originates a group of mortgages that are then put into a ring-fenced pool. While the characteristics of the ring fencing and the pool can differ across type of securities and across countries, the common characteristics are that mortgages serve as specific collateral for bonds, be MBS or CBs. This means that, in effect, mortgages are financed by bondholders giving banks access to a broader set of investors than traditionally financed mortgages. The traditional model for mortgage financing is: the bank originating the loan would keep it on its balance sheet until the mortgage was repaid. The loan would be financed out of general liabilities, which are primarily composed of bank deposits, plus capital. MBS and CBs both allow banks to access bond investors as well as bank depositors to fund mortgages.

The similarities between MBS and CBs suggest that the covered bond market might serve as an alternative to the securitization market for financing mortgages. To see whether banks issued CBs for the same reasons that they issued MBS, we examine banks in Europe and the US. There are a number of possible reasons why a bank uses mortgages to back MBS or CBs. One possibility that a number of studies have focused on is the originate-to-distribute (OTD) model, where banks originate loans only to collect the fee income from selling them (see, e.g., Rosen 2011). Alternatively, a bank may want to bring forward the profit from mortgages because it needs short-run liquidity. Selling loans into an MBS pool or selling CBs accomplishes this. Related to this, a bank may also need to raise capital to satisfy regulatory (or market) requirements. Finally, banks may use MBS or CBs for risk management (as Packer, Stever and Upper [2007] suggest). We test whether banks systematically use MBS or CBs for these reasons.

As shown by CRR, it is important to bear in mind that banks might not view MBS and CBs as substitutes since there are some actual and some regulatory differences between them. As we describe in the next section, the transfer of risk from banks to bondholders is more complete with MBS than with CBs. In addition, regulatory capital relief can also be larger when loans are sold to a pool backing a MBS than when they are placed into a pool backing CBs. While these factors seem less important than the similarities between MBS and CBs, CRR find that banks use them for different reasons and that these reasons are related to their differences. In particular, CRR find CBs issuance, but not MBS issuance, to be consistent with banks issuing the bonds when they need liquidity. Our results suggest that low liquidity banks are more likely to issue CBs and that CBs issuance leads to increases in liquidity. As evidence of this, we find that a bank is more likely to issue CBs when it has relatively low return and a high loan-to-deposits ratio. After the issuance of CBs, return increases and the loan-to-deposit ratio decreases if we net out the paired CBs pool and CBs liabilities.

The results in CRR also indicate that MBS issuance is more likely to occur when banks are reducing risk, but there is little evidence that they are issued for liquidity reasons. There is no significant relationship between MBS issuance and changes in return. In addition, while banks with high loan-to-deposit ratios are more likely to issue MBS, the issuance of MBS does not predict lower loan-to-deposit ratios in the future. Also, MBS issuance has no effect on loan growth or capital ratios. But, consistent with risk management, banks are more likely to issue MBS when their loan provisions are high—indicating high risk—and having issued MBS is associated with lower loan provisions in the future. This is consistent with MBS, but not CBs, allowing banks to transfer significant risk to bondholders. CRR also examine whether agency problems can explain why banks issue MBS and CBs, and find evidence that MBS issue is associated with these problems. For example, there is evidence of herding behavior for MBS, but not for CBs. Faster growth in MBS issuance in a country was positively associated with future MBS issuance by banks in that country, but faster CBs growth in a country had no significant impact on future CBs issuance in the same country.

2.4. What about the real effects? Did securitization have a say in lending to SMEs?

The above results show that it is unclear whether a higher weight of CBs versus MBS may reduce overall loan risk, but some of the results point in the direction that CBs involve a safer packaging of the loans as they set limit on risk transferring. Finally, both types of securitization may affect bank lending differently and, therefore, they may improve or worsen the credit crunch during the crisis years. Carbó, Degryse and Rodríguez Fernández (2012; henceforth CDR) explore these relationships. CDR first study the role of securitization in normal times and crisis periods. As they show, securitization may stimulate loan supply by increasing the liquidity of bank's balance sheets (see, e.g., Wagner and Marsh 2006; or Duffie 2007) or improving a bank's risk absorption capacity. During stress periods however, banks relying on securitization may face additional liquidity or capital constraints reducing their willingness to provide loans.

The empirical work focuses on the causes for banks to participate in securitization markets and the consequences of securitization on bank's willingness to grant loans, and bank's incentives to screen and monitor are developing rapidly (see, e.g., Dell'Ariccia, Igan and Laeven 2009; Mian and Sufi 2009; Keys et al. 2010; or Panetta and Pozzolo 2010). Initial empirical work on how loan sales impacts the lending relationship finds that selling of loans does not hamper the bank-firm relationship (e.g., Drucker and Puri 2009). Hirtle (2007) studies the use of credit derivatives and finds that the use of these enhances a bank's loan supply. The paper of CDR is closer related to recent empirical work on the impact of securitization on bank lending (see, e.g., Goderis et al. 2007; Jiménez et al. 2010). Goderis et al. (2007), for example, investigate the impact of banks being active in securitization on aggregate loan growth of a bank's portfolio and find that those banks exhibit a larger loan growth than banks not being active in securitization. CDR improve upon their work as they employ bank-firm level lending relationship information and the main bank's activity in securitization to study how securitization affects credit constraints at the firm level. Jiménez et al. (2010) employ detailed bank-firm level data from the Spanish credit registry and develop a clever identification strategy to pin down the supply effect of securitization. They find that banks with more securitizable assets make more loans available to firms. However, there is a substantial crowding out effect taking place as this expansion crowds out bank loans from other banks within the same firm. They conclude that in general equilibrium, the impact of securitization is close to 0 due to the crowding out of existing bank credit. Their identification strategy relies on employing firm fixed effects to absorb credit demand shocks, allowing to compare the impact of bank credit supply shocks within a firm. This implies that they can only consider firms with two bank relationships. This may be a restriction as many firms have one bank only, and the single relationship firms may be the ones where shocks to the bank relationship are most cumbersome (see, e.g., Degryse, Masschelein and Mitchell [2010] for an analysis of shocks to the bank relationship stemming from bank mergers). The CDR approach is to estimate a disequilibrium model containing a loan demand, loan supply and transaction equation, allowing them to study how securitization activity of the firm's main bank impacts credit supply and credit rationing for all firms. Interestingly, CDR find that a greater intensity of securitization of a firm's main bank reduces credit constraints to a greater extent.

A second important issue in CDR is the question on how relationship banking affects credit availability in normal times and in crisis periods. Most studies find that relationship borrowers (longer duration, wider scope, fewer banks, geographically close banks) have better access to credit. Petersen and Rajan (1994), for example, find that firms with stronger relationships have a higher debt to assets ratio, and resort less often to trade credit. Cole (1998) reports that bank-firm relationships of more than three years have a large impact on credit availability already. Agarwal and Hauswald (2010) find that relationship banking enhances credit availability when bank and borrowers interact in person but not in case of e-loans. Other papers study the impacts of bank distress on borrowing firms and the role of relationships. The closest work are recent papers that look into the issue of whether the US financial crisis spurred a supply side effect. Puri, Rocholl and Steffen (2011), for example, employ loan application data at German savings banks in the period 2006-2008. They investigate whether savings banks which are exposed to shocks from *Landesbanken* (whom they own) stemming from the US, behave differently than non-exposed savings banks, i.e. who own *Landesbanken* without exposure to the US financial crisis. They find evidence for a supply side effect in that the affected banks reject substantially more loan applications than non-affected banks. Furthermore, bank relationships help in mitigating the supply side effects as firms with longer relationships are less likely to be rejected even when their savings bank is exposed to a financial shock. CDR contribute to this literature by investigating how a firm's main bank previous access to additional liquidity impacts credit supply when the securitization market dries up.

As for their results, CDR first establish that firms with a more intense lending relationship as measured through its length and lower number of banks they are dealing with, enjoy a greater credit supply and lower degree of credit rationing. Securitization activity of the firm's main bank helps reducing credit constraints. Indeed, firms having relationships with banks more involved in securitization activities enjoy lower credit constraints in normal periods; however, they also face increased credit rationing during crisis periods. This shows that securitization generates supply effects which differ in normal and crisis periods. Finally, we show that there is heterogeneity within securitization. We carry out this by investigating the impact of different types of securitization—CBs and MBS—on credit rationing. While both types of securitization reduce credit rationing in normal periods, the main bank issuance of MBS aggravates credit rationing in crisis periods.

2.5. Conclusions

In this chapter, different dimensions of securitization before and during the financial crisis are explained taking Spain as a reference.

The three main set of results in this chapter are as follows:

— Securitization activity and lending may have asymmetric effects across institutions and regions. These differences and asymmetric effects cannot be directly related to financial integration issues, although some of the results in this chapter suggest that promoting safer and more comparative securitization practices across Europe may reduce overall credit risk.

— Credit developments in Spain (also prior to the crisis) were not that different from those experienced by other countries in previous banking crisis identified by earlier literature. Loan growth significantly affects loan performance. Additionally, overall bank loan performance is also found to explain *ex-post* rating changes, suggesting that there is a considerable lag before rating agencies reassess their credit views. It is also remarkable that originating bank characteristics (in particular, observed solvency, cash flow generation and cost efficiency) also considerably affect the ratings of securities deals which are no longer on the balance-sheet. Therefore, in order to promote a safer and more integrated securitization market in Europe, the emphasis should not only be put on banks as the main issuers, but also on rating agencies.

— MBS and CBs may also have implications for the real economy. In particular, for lending before and during the crisis years. Specifically, firms having relationships with banks being more involved in securitization activities enjoy lower credit constraints in normal periods; however, they also face increased credit rationing during crisis periods. Additionally, while both MBS and CBs reduce credit rationing in normal periods, the main bank issuance of MBS aggravates credit rationing in crisis periods.

References

ADRIAN, Tobias, and Hyun Song SHIN. "Money, Liquidity, and Monetary Policy." *American Economic Review Papers and Proceedings* 99, no. 2 (2009): 600-605.

AFME (Association for Financial Markets in Europe). *Annual Review 2012. Navigating the world.* Brussels and London, 2012.

AIAF (Asociación de Intermediarios de Activos Financieros). Estadísticas AIAF. Período 2003-2012. Accessed December 2012 in http://www.aiaf.es/esp/aspx/Aiaf/EstadisAIAF.aspx.

AGARWAL, Sumit, and Robert HAUSWALD. "Distance and Private Information in Lending." *Review of Financial Studies* 23, no. 7 (2010): 2757-2788.

ALTUNBAS, Yener, Leonardo GAMBACORTA, and David MARQUÉS IBAÑEZ. "Securitization and the bank lending channel." *European Economic Review* 53, no. 8 (2010): 996-1009.

BANK OF SPAIN. Non-performing loans statistics. 2005-2012 period. Accessed December 2012 in http://www.bde.es/webbde/es/estadis/infoest/a0403.pdf.

BRUNNERMEIER, Markus K. "Deciphering the Liquidity and Credit Crunch 2007-08." *Journal of Economic Perspectives* 23, no. 1 (2009): 77-100.

BRUNNERMEIER, Markus K., and YULIY SANNIKOV. "A Macroeconomic Model with a Financial Sector." *American Economic Review,* forthcoming, 2013.

CALEM, Paul S., and Michael LACOUR-LITTLE. "Risk-based capital requirements for mortgage loans." *Journal of Banking and Finance* 28 (2003): 647-672.

CARBÓ VALVERDE, Santiago, Hans DEGRYSE, and Francisco RODRÍGUEZ FERNÁNDEZ. "Lending relationships and credit rationing: the impact of securitization." *Financial Economics Discussion Paper* no 9138, London: Center for Economic Policy Research, 2012.

CARBÓ VALVERDE, Santiago, David MARQUÉS IBÁÑEZ, and Francisco RODRÍGUEZ FERNÁNDEZ. "Securitization, risk transferring and financial stability: the case of Spain." *Journal of International Money and Finance* 31 (2012): 80-101.

CARBÓ VALVERDE, Santiago, Richard J. ROSEN, y Francisco RODRÍGUEZ FERNÁNDEZ. "Are Covered Bonds a Substitute for Mortgage-Backed Securities?" *Working Paper* no. 2011-14, Federal Reserve Bank of Chicago, 2011.

CEBENOYAN, A. Sinan, and Philip STRAHAN. "Risk management, capital structure and lending at banks." *Journal of Banking and Finance* 28 (2004): 19-43.

COLE, Rebel A. "The importance of relationships to the availability of credit." *Journal of Banking and Finance* 22, no. 6-8 (1998): 959-977.

DEGRYSE, Hans, Nancy MASSCHELEIN, and Janet MITCHELL. "Staying, Dropping or Switching: The impact of Bank Mergers on Small Firms." *Review of Financial Studies* 24 (2011): 1102-1140.

DELL'ARICCIA, Giovanni, Deniz IGAN, and Luc LAEVEN. "Credit Booms and Lending Standards: Evidence from the Subprime Mortgage Market." Center Discussion Paper Series no. 2009-46S, Tilburg: Tilburg University, European Banking Center Research, January 2009.

DRUCKER, Steven, and Manju FERNÁNDEZ. "On Loan Sales, Loan Contracting, and Lending Relationships." *Review of Financial Studies* 22, no. 7 (2009): 2835-2872.

DUFFIE, Darrell. "Innovations in Credit Risk Transfer: Implications for Financial Stability." Working Paper, Stanford University (CA), 2007.

—. "Innovations in Credit Risk Transfer: Implications for Financial Stability." BIS Working Paper no. 255, Basel: Bank of International Settlements, 2008.

DUFFIE, Darrell, and Haoxiang ZHU. "Does a Central Clearing Counterparty Reduce Counterparty Risk?" *Review of Asset Pricing Studies 1,* no. 1 (2011): 74-95.

ECB (European Central Bank). *Recent Developments in Securitisation.* Frankfurt, February 2011.

EUROPEAN COVERED BOND COUNCIL. *Cover Bond Data.* Brussels, 2011.

EUROPEAN MORTGAGE FEDERATION. *EMF Quarterly Review - Q3 2011.* Brussels, 2011.

GODERIS, Benedikt, Ian W. MARSH, Judit VALL CASTELLO, and WOLF WAGNER. "Bank behaviour with access to credit risk transfer markets." Research Discussion Paper no. 4/2007, Bank of Finland, 2007.

GORTON, Gary, and Andrew METRICK. "Securitized Banking and the Run on Repo." NBER Working Paper no. 15223, Cambridge (MA): National Bureau of Economic Research, 2009.

GREENSPAN, Alan. "Risk transfer and financial stability." *Remarks to the Federal Bank of Chicago's Forty-first Annual Conference on Bank Structure,* Chicago (IL), May 2005.

HIRTLE, Beverly. *Credit Derivatives and Bank Credit Supply*. Federal Reserve Bank of New York Staff Report no. 276, 2007.

INE (National Statistics Office). Estadísticas financieras y monetarias. Hipotecas. Accessed December 2012 in http://www.ine.es/jaxi/menu.do?L=0&type=pcaxis&path=%2Ft30%2Fp149&file=in ebase.

JIANGLI, Wenying, and Matt PRITSKER. "The Impacts of Securitization on US Bank Holding Companies." Working Paper available at SSRN http://ssrn.com/abstract=1102284, 2008.

JIANGLI, Wenying, Matthew PRITSKER, M., and Peter RAUPACH. "Banking and securitization." *Mimeo*, Board of Governors of the Federal Reserve System, 2007.

JIMÉNEZ, Gabril, Atif R. MIAN, José Luis PEYDRÓ, and Jesús SAURINA. "Local Versus Aggregate Lending Channels: The Effects of Securitization on Corporate Credit Supply in Spain." NBER Working Paper no. 16595, Cambridge (MA): National Bureau of Economic Research, 2010.

KEYS, Benjamin J., Tanmoy K. MUKHERJEE, Amit SERU, and Vikrant VIG. "Did securitization lead to lax screening? Evidence from subprime loans." *Quarterly Journal of Economics* 125, no. 1 (2010): 307-362.

LOUTSKINA, Elena, and Philip STRAHAN. "Securitization and the declining impact of bank financial condition on loan supply: Evidence from mortgage originations." *Journal of Finance* 64, no. 2 (2009): 861-922.

MIAN, Atif R., and Amir SUFI. "The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis." *Quarterly Journal of Economics* 124, no. 4 (2009): 1449-1496.

PACKER, Frank, Ryan STEVER, and Christian UPPER. "The covered bond market." *BIS Quarterly Review* (September 2007): 43-55.

PANETTA, Fabio, and Alberto F. POZZOLO. "Why Do Banks Securitize Their Assets? Bank- Level Evidence from Over One Hundred Countries." *Mimeo*, March 2010.

PETERSEN, Mitchell A., and Raghuram RAJAN. "The Benefits of Lending Relationships: Evidence from Small Business Data." *Journal of Finance* 49, no. 1 (1994): 3-37.

PURI, Manju, Jörg ROCHOLL, and Sascha STEFFEN. "Global Retail Lending in the Aftermath of the US Financial Crisis: Distinguishing between Demand and Supply Effects." *Journal of Financial Economics* 100, no. 3 (2011): 556-578.

REINHART, Carmen M., and Kenneth S. ROGOFF. *This Time It's Different: Eight Centuries of Financial Folly*. Princeton (NJ): Princeton University Press, 2009.

ROSEN, Richard J. "The impact of the originate-to-distribute model on banks before and during the financial crisis." Working Paper no. 2011-20, Federal Reserve Bank of Chicago, 2011.

SHIN, Hyun Song. "Securitization and financial stability." *The Economic Journal* 119 (2009): 309-332.

TORNELL, Aaron, and Frank WESTERMANN. "Boom-bust cycles in middle income countries: Facts and explanation." NBER Working Paper no. 9219, Cambridge (MA): National Bureau of Economic Research, 2002.

WAGNER, Wolf. "The liquidity of bank assets and banking stability." *Journal of Banking and Finance* 31, no. 1 (2007): 21-139.

WAGNER, Wolf, and Ian W. MARSH. "Credit Risk Transfer and Financial Sector Performance." *Journal of Financial Stability* 2, no. 2 (2006): 173-193.

3. Beyond the Law of One Price: International Banking Integration in Pre- and Crisis Years

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3.1. Introduction

On the eve of the financial crisis that began in 2007, the degree of international financial integration made rapid progress, especially for advanced economies. Several contributions (see, for instance, Lane and Milesi-Ferretti 2003; Kose et al. 2006; Rogoff et al. 2003; Lane and Milesi-Ferretti 2008) have acknowledged this trend. As indicated by Lane (2012), who stressed that the decade before the global financial crisis was actually distinguished by rapid growth in cross-border financial positions, despite of the threats that the Latin American and Asian crises had had on this process, the widespread attitude among policy-makers, financial authorities and even academics was to highlight the beneficial effects of financial globalization.

What now, looking in retrospect, might seem a bit of a reckless stance, considering what happened later, was quite reasonable by the end of the 1990s and first half of the 2000s due to the relative calm in global economy during the ten years that preceded the international financial crisis. In addition, the numerous contributions in the field of financial globalization[1] have actually paid a

[1] We will refer to international financial integration and financial globalization interchangeably.

great deal of attention to the risks it might bring about.[2] Although many studies have had a tighter focus on the effects of financial globalization on emerging economies, the current economic crisis that is strongly affecting several European economies may provide an important lesson for the rest of the world economies, considering the high levels of cross-border financial integration that exists today.

Within this global scenario, it is now possible to obtain a more complete evaluation of the financial globalization model, with a deeper understanding of the dangers associated to it for both developed and developing economies, due to the testing ground provided by the financial crisis. The research initiatives that have attempted to do so are blooming and, therefore, any effort to provide an updated review will be unsuccessful because the crisis seems far to be over yet, particularly in some countries. However, some recent contributions have made this attempt, and an updated list of quotations on the specific topic of financial globalization and the financial crisis is provided by Lane (2012).[3]

However, much of the related literature has not considered some of the complexities of the links between the different financial systems. Specifically, although many studies in this particular field have proposed measures of *de jure* financial openness (see, for instance, the recent proposal by Schindler [2009]), with less initiatives focusing on *de facto* indicators, it has been generally disregarded measuring the degree of *connectedness,* with few exceptions. However, this might be actually relevant in some particular contexts, as shown by Billio et al. (2012) in finance, in general, and in insurance sectors, in particular.

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[2] Some examples of this include, among others, Rodrik (1998, 2000), Obstfeld (2009), Prasad and Rajan (2008), Stiglitz (2010) and, with a more historical perspective, Eichengreen (1991) and Obstfeld and Taylor (2004).

[3] A branch of this literature has focused on the specific links between the financial crisis and cross-border banking. Confining the analysis to the case of bank activities is particularly relevant in the case of Europe and euro area countries, due to the euro effect on cross-border banking. In this specific case, the research initiatives conducted so far are comparatively minor, although the recent contributions by Kleimeier, Sander and Heuchemer (2013a, 2013b) provide some relevant empirical evidence on how the financial crisis is affecting cross-border banking in the case of Europe.

Related to this, some recent contributions such as Fagiolo (2006), Kali and Reyes (2007), Kali, Mendez and Reyes (2007), Fagiolo, Reyes and Schiavo (2010), among others, have proposed measuring integration considering network analysis approaches in which countries are nodes of the network and trade flows between them are the ties. Some of these authors consider they are modeling what could be referred to as the World Trade Web (see Fagiolo, Reyes and Schiavo 2009). A variant of these approaches focuses on the particular case of financial integration, and this would include McGuire and Tarashev (2006), von Peter (2007), Kali and Reyes (2010), Schiavo, Reyes, and Fagiolo (2010), as well as the most recent papers by Minoiu and Reyes (2013) or Chinazzi et al. (2013). These types of approaches are implicitly measuring *de facto* financial, or banking, integration. Other authors such as Alfarano and Milaković (2009) have considered similar methods yet without the explicit attempt of measuring financial or banking integration. Chapters 4 and 5 of this book also apply tools borrowed from network theory to explain how robustness can emerge in banking systems (chapter 4) and the determinants of systemic risk in simulated banking systems (chapter 5).

Arribas, Pérez and Tortosa have proposed a related approach to measure the degree of trade integration (Arribas, Pérez and Tortosa 2009), as well as banking integration (Arribas, Pérez and Tortosa 2011a, 2011b). Although their proposals share some of the underpinnings of other approaches based on network analysis, they also have a strong focus on providing a formal framework for the so-called *global village*. For this, they considered ideas borrowed not only from network analysis approaches (similar to those considered by the papers cited in the previous paragraph), but also from the *geographic neutrality* concept introduced separately by Krugman (1996) and Kunimoto (1977)—see also Iapadre (2006). According to this notion, each country's trade flows (or financial flows, depending of the type of economic integration under analysis) would be proportionate to each country's share in the World economy—and, therefore, this would be also related to home bias literature in finance. In other words, the alternative they propose enables to measure *how far* the financial integration might be from its full potential (Stiglitz 2010).

Some of the advantages of the methods proposed by Arribas, Pérez and Tortosa consist of how easily they can be tuned to control for relevant issues in the international trade or finance literatures. For instance, in international economics the role of distance has been subject to thorough scrutiny, generating a high number of contributions. In Arribas, Pérez and Tortosa (2011c), their initial proposals (Arribas, Pérez and Tortosa 2009) are tuned to control for this distance parameter. In this study, we consider that the role of distance may also be important in finance (as shown by the home bias literature) and, therefore, we present indicators of *banking* integration which go beyond those proposed in Arribas, Pérez and Tortosa (2011a, 2011b) in two main ways, namely, by including explicitly a distance parameter, and also by extending the period of analysis to the most recent years, which includes both pre-crisis and crisis years.

3.2. Defining banking integration indicators

Quantities-based indicators of financial, or banking, integration focus on the volume of cross-border banking assets—foreign assets and liabilities—as opposed to price-based indicators, which are usually based on the Law of One Price (LOOP). However, we argue this is only one component of banking integration. Thinking of banking system as a network in which nodes are the countries (or their banking markets as a whole) and ties are the financial flows among them, we construct a second component derived from the structure of current relations between banking markets.

Relevant aspects of this structure include the number of trading partners (in terms of trade in assets), and whether the relationships are direct or indirect—i.e. whether cross-border bank flows cross third economies. Moreover, although flows between banking markets reflect only first-order relations, higher-orders might be relevant as well. The sub-prime crisis starting in 2007 constitutes an example of how important this issue could be (although, simultaneously, difficult to model).

The set of relations established between banking markets operates like roads between cities. First, they allow markets to be connected even when there is no direct relation between them. Second, flows can reach their final destination in different ways, depending on the intermediating banking markets they cross. Capital may move from one market to another several times before arriving at their final destination. This possibility enables the interconnectedness of the world banking or financial systems to increase, facilitating their integration. In addition, the volume of cross-border banking activity between them is also important, as well as the proportionality of this activity to the size of the banking markets, and the indirect relationships across intermediating banking markets.

If we consider banking globalization as synonymous of the highest possible level of financial integration, which might not always be desirable, as suggested by Stiglitz (2010) or might lead to undesired effects as other chapters in this book warn, the flow from one country to another would only depend on their relative size because barriers to cross-border flows are lifted and there is no home bias effect. As suggested by literature on home equity bias, investors should be able to exploit the benefits of international asset diversification, and not concentrate their investments on the assets of their home country. Considering this global scenario, we will define the Standard of Full Banking Integration (SFBI) as an extension of the concept of *geographic neutrality* (Krugman 1996)—see also Kunimoto (1977), and as a hypothetical benchmark that will not necessarily be reached if trade in assets' frictions exist. Therefore, geographic neutrality implies that the proportion of home and foreign assets held by domestic investors should be proportional to the relative sizes of each banking system. The absence of geographic neutrality would be equivalent to the equity home bias effect (Lewis 1999), where individuals hold too little of their wealth in foreign assets. Thus, under the above neutrality assumption *home neutrality (as opposed to home bias)* and *foreign neutrality (as opposed to foreign bias)* properties must be verified:

— *Home neutrality:* An economy that balances its total cross-border assets trade proportionally to its size with respect to the rest of the world will have a higher level of integration.

— *Foreign neutrality:* An economy that balances its direct relations with another individual economy, proportionally to economies' sizes, will have a higher level of integration.

Two additional concepts should be considered to complete our notion of SFBI. First, higher-order relationships between economies should be included because economies reinforce their relations with other economies through indirect relationships across intermediate economies. The neutrality assumption implies that these indirect flows also should be proportional to economies' sizes. Second, we extend the SFBI, similar to that introduced by Arribas, Pérez and Tortosa (2011a, 2011b), by considering Samuelson's (1954) standard iceberg assumptions, since we considered that the flow between two banking markets is not only proportional to the banking markets' relative size, but also inversely depends on the distance between those economies. The inclusion of these two concepts, indirect flows and distance, into SFBI makes the modification of the *foreign neutrality* property necessary in the following terms:

— *Foreign neutrality (extension):* An economy that balances its direct and indirect relations with another individual economy, in proportion to economies' sizes and inversely to economies' distance, will have a higher level of integration.

The above properties will allow us to define a country-specific index to measure how far an individual banking system is from our benchmark, the SFBI. Given that we are interested in defining a global integration index, we summarize the individual indexes. However, in this global index larger economies should weigh more than smaller ones. This leads us to the last property,

— *Size:* the larger the country's banking system, the more relevant its integration will be for international banking integration.

To analyze the extent to which economies meet the three properties, we define an integration index and measure the gap between the current level of banking integration and the SFBI.

3.2.1. Controlling for distance

Let N be our sample of countries (represented by each country's banking markets), and let i and j be typical members of this set. Let X_i be the size of the banking markets of country $i \in N$ (for example, in terms of total assets), d_{ij} the geographic distance between countries i and j, and d_{ii}, country i's internal distance—which will be used for reasons explained below.

In order to compare economies that are not contiguous we considered Samuelson's (1954) iceberg type transportation costs idea, in the sense that if the banking markets of country j (whose size is X_j) get as close to the banking markets of country i as possible, then j's size will be reduced to X_j / d_{ij}^{θ} or, as Samuelson (1954) stated, "only a fraction of ice exported reaches its destination as unmelted ice," where θ is a non-negative parameter that measures the impact of distance (the farther away markets are, the greater the reduction, with an intensity that depends on the θ parameter). In the extreme cases, if $\theta = 0$, the *iceberg* effect fades away; therefore for $\theta = \infty$, only the domestic market is relevant.

We defined a_i as banking markets in country i's share of total world banking market, that is, $a_i = X_i / \sum_{j \in N} X_j$. We define r_i^{θ} as the analogous to a_i when distance enters the analysis—that is, $r_i^{\theta} = (X_i / d_{ii}^{\theta}) / \sum_{j \in N} (X_j / d_{ij}^{\theta})$. Note that: (i) we also considered that there is an iceberg effect on the domestic economy (because of countries' different geographic sizes), or, equivalently, that distance-related financial costs exist for both inter- and intranational flows; (ii) the foregoing definition does not depend on the units of measurement for the distance between economies, given that r_i^{θ} can be written as $r_i^{\theta} = X_i \Big/ \sum_{j \in N} \left(X_j / (d_{ij} / d_{ii})^{\theta} \right)$, where this expression allows the effect of the geographic distance to be reinterpreted as the one given by a normalized distance matrix between economies, where every internal distance of the economies is 1 and the distance from economy i to economy j, d_{ij} / d_{ii}, is the times the geographic distance between these economies is bigger than economy i's internal distance; and (iii) the impact of the distance depends on the θ parameter. In a world in which distance is irrelevant, $\theta = 0$ (geographic neutrality) and $r_i^\theta = a_i$.

3.2.2. Definitions

Our approach to measuring banking integration proceeds in four stages, defining indicators of financial distance-corrected counterparts to those presented in Arribas, Pérez and Tortosa (2009). First, we define a *de facto* degree of integration based on how open banking systems are—degree of bank openness—; second, we characterize how connected different banking systems are defining a degree of bank connectedness; third, we also factor in indirect connections, defining the degree of total bank connectedness; finally, we combine both the degree of bank openness and the degree of total bank connectedness in order to construct a single degree of banking integration for each country in our sample.

Therefore, we are contributing in a different way the set of tools offered by economic geography to unearth some of the complex interactions between globalization and spatial inequalities (Combes 2008). One of the most relevant features of our indicators is that they are country specific and, consequently, we can temper Leamer's statement that "physically, culturally, and economically, the world is not flat" (Leamer 2007). According to the indicators that we present later, this statement does not apply equally to all countries.

Given a measurable relationship between banking markets in different countries, we define the flow X_{ij} as the intensity of this relationship between banking markets in country i and banking markets in country j. In our framework, banking flows can be evaluated through foreign claims (i.e., assets held abroad by banks of country i). In general, flow will be asymmetrical so that X_{ij} will not necessarily be equal to X_{ji}, for all $i, j \in N$.

Degree of banking openness

In the first stage of our metric we characterize the *degree of banking openness*. We will take into account that investors hold a proportion of domestic assets, and that its volume will vary depending on the size of each particular banking system.[4] In order to control for this home bias effect, we define $\hat{X}_i$ as the foreign claims of country i taking into account the weight in the distance-corrected world banking system of the country under analysis, namely, $\hat{X}_i^\theta = (1 - r_i^\theta) X_i$. We then define the relative flow (cross-border banking assets or liabilities) or degree of banking openness between countries i and j as $DBO_{ij}^\theta = X_{ij} \big/ \hat{X}_i^\theta$. Then the *degree of banking openness* for a country $i \in N$ can be defined as,

$$DBO_i^\theta = \sum_{j \in N \backslash i} DBO_{ij}^\theta = \frac{\sum_{j \in N \backslash i} X_{ij}}{\hat{X}_i^\theta} \tag{3.1}$$

By definition the degree of banking openness takes the value of 1 if and only if domestic neutrality is verified. The degree of openness yields results (in general) ranging in the [0, 1] interval, where a value of 0 indicates that the economy is closed with respect to financial flows and a value of 1 indicates a lack of domestic bias in the economy (total openness). Although the degree of openness in an economy is, in general, lower than 1, some particular economies might surpass this value showing an extremely open character. Differences in *DBO* among economies can be attributed to different obstacles to integration, among which we also find size. However, differences cannot be due to bias in the measure of openness, since we have corrected for domestic bias.

Degree of bank connectedness

In the second stage of our metric we analyze whether the connection of one banking system with others is proportional to the differing banking systems' sizes, or whether this connection does not show geographical neutrality. The latter instance would contribute to widen the gap between the current level of banking integration and the scenario corresponding to a financially globalized world. Thus, we define the *degree of bank connectedness* to measure

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[4] As documented by literature on home equity bias, the proportion of domestic assets held by domestic investors is too big in relation to the predictions of the standard portfolio theory (see Lewis [1999]).

the discrepancy between the cross-border banking flows in the real world and those corresponding to the SFBI.

In this network, the relative flow from country i to country j in terms of the total banking flows of country i, α_{ij}, is given by $\alpha_{ij} = X_{ij} / \sum_{j \in N \setminus i} X_{ij}$, where $i \neq j$ and $\alpha_{ii} = 0$. Let $A = (\alpha_{ij})$ be the square matrix of relative flows (the component ij of matrix A is α_{ij}). If the world banking system is *completely* connected (i.e., the banking flows between two countries are proportional to the relative size of their banking systems corrected by the *iceberg* effect), then the flow from country i to country j should be equal to $\beta^{\theta}_{ij} \hat{X}^{\theta}_{i}$, where $\beta^{\theta}_{ij} = (X_j / d^{\theta}_{ij}) / \sum_{j \in N \setminus i} (X_k / d^{\theta}_{ik})$ is the relative weight of country j in a distance-corrected world where country i is not considered. Note that $\sum_{j \in N \setminus i} \beta^{\theta}_{ij} = 1$ and that β^{θ}_{ij} is also the degree of banking openness between countries i and j in the fully connected world, with $\beta^{\theta}_{ii} = 0$. Let $B^{\theta} = (\beta^{\theta}_{ij})$ be the square matrix of degrees of openness in the fully balanced connected world.

Considering the previously defined matrices, A and B^{θ}, we define an indicator that measures the distance between the real distribution of banking flows and that corresponding to a fully balanced connected world. We consider the cosine of the angle of the vector of relative flows with the vector of the flows in a fully connected world, i.e., the inner product of those vectors. We call it the *degree of bank connectedness* of country i, DBC^{θ}_{i}, and it is defined as

$$DBC^{\theta}_{i} = \frac{\sum_{j \in N} \alpha_{ij} \beta^{\theta}_{ij}}{\sqrt{\sum_{j \in N} (\alpha_{ij})^2} \sqrt{\sum_{j \in N} (\beta^{\theta}_{ij})^2}} \tag{3.2}$$

Although the cosine of two vectors ranges between -1 and 1, the degree of regularity of direct banking connections always takes non-negative values since both vectors have only non-negative components. *DBC* measures whether economies meet international neutrality, and it is equal to 1 if, and only if, an economy meets the property of direct international neutrality. It approaches 0 for an economy whose flows are directed toward the smallest world economies.

Degree of total bank connectedness

In the third stage, we consider the indirect relationships between countries along with their importance. The *degree of total bank connectedness* evaluates the importance of both direct and indirect relationships that countries establish with each other. Both the matrix corresponding to the actual volume of cross-border asset trade, A, and the matrix corresponding to the volume of cross-border asset trade when banking markets are fully connected, B^{θ}, consider *direct* relative flows between countries. However, part of the flow from country i to country j may cross third countries, and those *indirect* flows also contribute to integration. This problem may be especially severe if we take into account recent episodes such as the subprime crisis, when a relevant volume of asset trade involved securities backed by low-quality subprime mortgages.

Defining $A^n = A \cdot A \cdot \overset{n}{\ldots} \cdot A$ as the n-times product matrix of A, and α_{ij}^n as the element ij of A^n, it is not difficult to show that α_{ij}^n is the relative flow that goes from i to j crossing $n - 1$ intermediate countries. Moreover, it is verified that $0 \leq \alpha_{ij}^n \leq 1$ for all $n \geq 1$. In the same way, we define $(B^{\theta})^n$, the elements of which evaluate the flow passing through all countries when banking markets in all countries are fully connected.

We can also define $\gamma_i \in (0, 1)$ as the cross-border trade which remains invested in country i, while $1 - \gamma_i$ is the volume of cross-border trade *redirected* from i to a third country. For estimating γ_i, an additional assumption is needed. Specifically, we assume that the share of cross-border flow between a country and country i which remains invested in country i is equal to the share of cross-border flow of country i that remains in the recipient country. If country i verifies this assumption, $\gamma_i = X_{ii}/X_{i\cdot}$. Although this assumption is more reasonable in the case of financial integration rather than banking integration, in the latter case the subprime episode indicates it may also be relevant.

Let Γ be the square diagonal matrix of internally invested flow proportions, so that the element ii of Γ is γ_i and the element ij, for $i \neq j$, is 0. The matrix of total relative flows from one country to another is the sum of the direct and indirect flows and can be estimated as $A^{\Gamma} = \sum_{n=1}^{\infty} \Gamma\, (I - \Gamma)^{n-1} A^n$ and $B^{\theta,\Gamma} = \sum_{n=1}^{\infty} \Gamma (I - \Gamma)^{n-1}\, (B^{\theta})^n$, where I is the identity matrix. Both A^{Γ} and $B^{\theta,\Gamma}$ depend on matrix Γ. In addition, α_{ij}^{Γ} is the element ij of the matrix A^{Γ} and $\beta_{ij}^{\theta,\Gamma}$ the element ij of the matrix $B^{\theta,\Gamma}$. Each element of these matrices is the weighted sum of the direct and indirect flows through any possible number of intermediate economies. We will define the *degree of total bank connectedness* of i as,

$$DTBC_i^{\theta,\Gamma} = \frac{\sum_{j\in N} \alpha_{ij}^{\Gamma} \beta_{ij}^{\theta,\Gamma}}{\sqrt{\sum_{j\in N} (\alpha_{ij}^{\Gamma})^2} \sqrt{\sum_{j\in N} (\beta_{ij}^{\theta,\Gamma})^2}} \tag{3.3}$$

The degree of total bank connectedness lies in the [0, 1] interval. It measures the distance of both direct and indirect bank asset trade of a country from what the volume of bank asset trade would be in a *fully* connected world bank system with no geographic bias.

Degree of banking integration

From the concepts introduced above we may define the *degree of banking integration*, which combines degrees of bank openness and bank total connectedness. Therefore, for the banking markets in country $i \in N$, we define its degree of bank integration as,

$$DBI_i^{\theta,\Gamma} = \sqrt{\min\left\{1/DBO_i^{\theta}, DBO_i^{\theta}\right\} \cdot DTBC_i^{\theta,\Gamma}} \tag{3.4}$$

It is the geometric average of its deviation from the balanced degree of banking openness and banking regularity of total connections. Therefore, $DBI_i^{\theta,\Gamma}$ depends on both the openness of the banking system and the balance in its direct and indirect flows with other banking systems. Moreover, if, and only if, the banking system verifies properties referred to at the beginning of the section, then $DBI_i^{\theta,\Gamma}$ will be equal 1.

For all indicators (DBO^{θ}, DBC^{θ}, $DTBC^{\theta,\Gamma}$, $DBI^{\theta,\Gamma}$), the cases in which $\theta = 0$ refer to distance-uncorrected indicators, whereas those in which $\theta = 1$ are distance-corrected indicators.

In relation to gravity equations literature, our indicators consider its two main regressors: the size of the trading partners and the distance between them. Therefore, one of the advantages of our approach is that instead of providing information on whether these variables are important for financial flows, it is possible to measure the gap from the scenario of complete banking integration (frictionless flows, or geographic neutrality) and the current level of integration under different hypotheses on the impact of distance.

Weighted global indicators

In the previous subsections we have defined several indicators that characterize the integration of each individual country and that, as the degree of banking integration, can also be summarized for the whole economy:

— Degree of global bank openness, $DGBO^{\theta} = \sum_{i \in N} a_i DBO_i^{\theta}$.
— Degree of global bank connectedness, $DGBC^{\theta} = \sum_{i \in N} a_i DBC_i^{\theta}$.
— Degree of global total banking connectedness, $DGTBC^{\theta,\Gamma} = \sum_{i \in N} a_i DTBC_i^{\theta,\Gamma}$.
— Degree of world banking integration, $DGBI^{\theta,\Gamma} = \sum_{i \in N} a_i DBI_i^{\theta,\Gamma}$.

The *DGBI* indicator is the most general quantitative approximation to the international banking markets' integration of countries, as it considers not only the degree of banking openness, but also the distribution of direct and indirect flows between countries, and the size of a country's banking sector. In light of the different concepts included in this definition, the indicator will be considered as an index of *banking globalization,* according to the properties described at the beginning of the section. The first two properties are an increasing function of *DGBI* for any country. The last one is verified because *DGBI* is a weighted average of the countries' degree of bank integration, where the weight of each country depends directly on its size. The degree of banking integration measures how close the world is to SFBI, which should be equal to 1 when all countries are *fully* integrated and achieve their theoretical potential of integration when distance is irrelevant.

3.3. Data

Our data set contains information on total assets held abroad by banks of a given country, and assets of a given country owned by foreign banks. The data on bilateral bank assets are provided by the Bank for International Settlements (BIS), which issues the international claims of its reporting banks on individual countries quarterly, geographically broken down by nationality of the reporting banks.

The data contains information on most of the largest world economies, and also on some specific countries with large banking systems such as Switzerland, totaling of 23 countries. The data on total assets are provided by the European Central Bank for European Union countries, and by the central bank of each country.

Our data set is also crucially determined by the available information, which was incomplete in terms of countries and sample years. Finally, only 22 countries and 13 years (1999-2011) were selected to perform the analysis.[5] Stretching the sample period in both dimensions, i.e., countries selected and length of the period, led inevitably to incomplete data sets and difficulties for drawing conclusions on the dynamics of banking globalization.

Furthermore, even if additional countries for which information was available for some years were included in the sample, the gains in terms of total bank assets were not substantial, as the constrained sample accounted for more than 90% of the enlarged sample.

As shown by columns 5 and 6 (total assets as percentage of GDP) in table 3.1, it is quite apparent that the US financial system is far less *bancarized* than large European countries such as Germany, Italy, France, or Spain. As of 2011, the share of the US banking system was quite small (13.97%), especially taking into account the size of the US economy. As also indicated in table 3.1, the total assets of the US banking system in terms of GDP are well below those of most countries in the sample.

Cross-border claims have also been increasing sharply for all countries and, as documented by some authors, today they are over 30 times larger in absolute terms than 30 years ago (McGuire and Tarashev 2006). This information is reported in columns 7 through

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[5] BIS provides data of 23 countries but we have discarded Finland from the analysis because a lack of homogeneity in its banking system data collection.

TABLE 3.1: Data by country, 1998 and 2011

Country	Total bank assets		Shares of the international banking markets		Total assets		Total consolidated foreign claims				Total consolidated foreign claims of the sample countries					
	Millions of current US dollars		%		% of GDP		% of GDP		% of total assets		Millions of current US dollars		% of their total foreign claims		% of total assets	
	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011
Australia	902,264	2,938,124	1.81	3.31	192.62	214.19	44.12	48.04	22.90	22.43	92,948	106,898	44.98	16.22	10.30	3.64
Austria	740,698	1,509,089	1.48	1.70	291.68	360.61	38.52	108.46	13.21	30.08	57,196	144,030	58.47	31.73	7.72	9.54
Belgium	1,046,467	1,484,310	2.10	1.67	335.74	290.17	211.11	59.95	62.88	20.66	556,174	203,003	84.52	66.19	53.15	13.68
Brazil	432,616	2,748,802	0.87	3.10	78.31	110.99	4.31	3.58	5.50	3.23	18,849	55,277	79.16	62.31	4.36	2.01
Canada	1,545,380	3,930,837	3.10	4.43	178.48	226.42	42.41	56.78	23.76	25.07	305,952	742,582	83.32	75.34	19.8	18.89
Chile	48,403	143,131	0.10	0.16	65.42	57.58	2.94	2.65	4.50	4.61	1,935	5,012	88.92	76.00	4.00	3.50
Denmark	563,810	1,098,283	1.13	1.24	265.17	330.13	20.77	73.91	7.83	22.39	35,271	189,804	79.85	77.19	6.26	17.28
Finland	234,723	820,061	0.47	0.92	142.90	308.21	35.19	8.79	24.62	2.85	44,399	15,815	76.82	67.63	18.92	1.93
France	5,050,174	8,635,799	10.12	9.73	281.78	311.42	75.52	100.55	26.80	32.29	1,138,705	2,150,751	84.14	77.14	22.55	24.91
Germany	8,074,994	10,345,597	16.18	11.65	333.15	289.75	106.29	78.23	31.91	27.00	2,106,130	2,132,834	81.75	76.36	26.08	20.62
Greece	269,235	549,545	0.54	0.62	139.61	183.96	25.90	48.58	18.55	26.41	31,143	56,948	62.35	39.24	11.57	10.36
Ireland	726,437	1,543,584	1.46	1.74	456.53	710.43	214.76	85.11	47.04	11.98	314,571	170,011	92.05	91.93	43.30	11.01
Italy	2,684,337	3,615,713	5.38	4.07	177.24	164.74	21.71	38.70	12.25	23.49	195,571	558,863	59.48	65.80	7.29	15.46
Japan	6,868,239	10,950,917	13.77	12.34	159.62	186.65	28.78	50.13	18.03	26.86	937,595	1,971,948	75.72	67.04	13.65	18.01
Mexico	278,937	487,328	0.56	0.55	39.83	42.18	0.30	0.42	0.75	1.00	1,103	3,185	52.75	65.16	0.40	0.65
Netherlands	1,861,585	3,664,532	3.73	4.13	345.82	438.21	221.22	156.95	63.97	35.82	1,066,096	1,094,268	89.52	83.37	57.27	29.86
Portugal	440,397	663,357	0.88	0.75	271.96	279.28	42.52	54.87	15.63	19.65	55,283	88,548	80.29	67.94	12.55	13.35
Spain	1,898,113	5,065,981	3.80	5.71	214.76	339.81	46.33	94.69	21.57	27.87	359,417	1,250,755	87.78	88.60	18.94	24.69
Sweden	719,334	1,589,919	1.44	1.79	228.57	295.45	68.93	160.66	30.16	54.38	168,157	600,877	77.51	69.50	23.38	37.79
Switzerland	1,808,589	2,968,359	3.62	3.34	556.42	466.98	481.49	278.29	86.53	59.59	1,375,771	1,375,286	87.91	77.75	76.07	46.33
Turkey	162,919	553,604	0.33	0.62	53.77	71.61	3.62	3.28	6.74	4.58	8,615	19,667	78.48	77.62	5.29	3.55
UK	6,234,589	11,056,376	12.50	12.46	335.14	454.70	88.02	166.02	26.26	36.51	1,127,175	2,631,286	68.84	65.18	18.08	23.80
US	7,303,226	12,403,492	14.64	13.97	65.86	82.17	7.56	20.09	11.48	24.45	619,892	2,084,624	73.94	68.73	8.49	16.81

Source: Comisión Nacional Bancaria y de Valores (2012), BIS (2012), Board of Governors of the Federal Reserve System (2012), European Central Bank (2012), Central Banks of Brazil, England, Denmark, Japan, Switzerland, Turkey (2012), Office of the Superintendent of Financial Institutions Canada (2012), Reserve Bank of Australia (2012), Statistics Sweden (2012) and the World Bank (2012).

12. For most of the countries there has been a sharp increase in foreign claims from 1998 to 2011, not only in absolute terms (columns 11-12) but also as a percentage of GDP (columns 7-8). The evolution of foreign claims as a percentage of total assets (columns 9-10) differs across countries: Austria, Denmark and US has duplicated this figure, meanwhile Belgium or Finland have halved. Finally, columns 13-16 report information on the representativeness of our sample, which varies depending on the country, but it is generally quite high.

3.4. Results

We provide a variety of results for our different indicators of banking integration. The presentation of the results is split between the three types of indicators—degree of bank openness, degree of regularity of bank connections, and degree of integration.

3.4.1. Degree of bank openness

Regarding the degree of bank openness, individual results for each country are provided in table 3.2. The information is reported for years 2003, 2007 and 2011, which are relevant periods in terms of the financial crisis timing. Whereas in 2003 most advanced economies were expanding at remarkably high rates, in 2007 the financial crisis started and contagion was fast across the different financial systems. Year 2011 is relevant as well, not only because of being the last year for which information is available, but also because the financial crisis was still affecting most Western economies—which largely dominate our sample. We also report results for both distance-uncorrected (first 3 columns) and distance-corrected indicators (last 3 columns). The last 3 rows in table 3.2 provide summary statistics on the three indicators—unweighted average, standard deviation and coefficient of variation.

Table 3.2 reveals a variety of relevant features. The first one is that degrees of bank openness are quite heterogeneous across countries. This is not surprising and coincides with previous findings such as those by Lane and Milesi-Ferretti (2008), who indicated

TABLE 3.2: **Degree of bank openness, distance-uncorrected ($DBO^{\theta=0}$) and distance-corrected ($DBO^{\theta=1}$) indicators, 2003, 2007 and 2011** (percentage)

Country	Degree of openness (DBO)					
	Distance irrelevant $DBO^{\theta=0}$			Distance relevant $DBO^{\theta=1}$		
	2003	2007	2011	2003	2007	2011
Australia	23.33	21.78	23.20	28.70	28.73	33.10
Austria	13.41	42.85	30.60	15.76	50.54	37.40
Belgium	64.23	75.11	21.02	72.16	85.04	23.37
Brazil	5.55	2.92	3.33	5.94	3.33	4.15
Canada	24.52	25.88	26.25	25.35	26.98	27.57
Chile	4.50	3.49	4.62	4.64	3.62	4.84
Denmark	7.92	31.06	22.67	9.28	36.95	27.31
France	29.83	42.61	35.80	35.08	50.53	42.75
Germany	38.10	45.95	30.60	53.34	59.44	40.04
Greece	18.65	16.63	26.57	20.51	18.59	29.78
Ireland	47.74	38.89	12.19	55.37	48.13	14.65
Italy	12.95	25.63	24.50	18.14	36.20	32.40
Japan	20.92	37.04	30.68	140.64	162.25	190.57
Mexico	0.75	1.36	1.01	0.81	1.46	1.08
Netherlands	66.46	79.52	37.37	80.43	96.82	47.81
Portugal	15.77	21.95	19.80	18.21	24.63	22.33
Spain	22.43	29.65	29.57	27.56	38.44	40.45
Sweden	30.60	53.39	55.38	33.55	58.87	62.54
Switzerland	89.80	86.79	61.67	125.89	120.50	87.00
Turkey	6.76	5.60	4.61	6.92	5.81	4.83
UK	30.03	36.07	41.76	43.42	53.92	62.50
US	13.46	18.24	28.47	19.44	24.97	38.95
Unweighted average	26.72	33.75	25.98	38.23	47.08	39.79
Standard deviation	22.61	23.94	15.46	37.43	39.86	39.64
Coefficient of variation	84.64	70.94	59.51	97.90	84.66	99.62

Source: Own calculations.

that the degree of financial integration is higher for advanced economies—although the indicators they use differ from ours (see also Obstfeld [2009]). The degree of openness is particularly low for Brazil, Chile, Mexico and Turkey, compared with the rest of the countries in the sample. Although some rich countries have low values in some years as well (e.g. Denmark and, to a lesser degree, Austria in 2003), these constitute usually exceptions and the evolution is positive—at least comparing 2003 and 2007.

We also observe remarkable discrepancies in the *evolution* of the degree of bank openness across countries. Underlying these discrepancies one may probably find how the crisis (both economic and financial) is affecting different sample countries. Specifically, in the case of the euro area countries, the degree of openness has decreased notably since the crisis started. Excluding Greece, whose degree of openness actually increased between 2007 and 2011 (from 16.63% to 26.57%, as indicated in the second and third columns of table 3.2) the degree of bank openness fell for *all* euro area countries.

However, despite this generalized tendency for all euro area countries, there are remarkable discrepancies among them. Focusing on the three first columns of table 3.2, corresponding to distance-uncorrected indicators, for some countries the decline has been abrupt; this is especially apparent in the case of Belgium and the Netherlands, whose $DBO^{\theta=0}$ fell from 75.11% to 21.02% and from 79.52% to 37.37% between 2007 and 2011, respectively—representing a whopping 72% and 42% decline, respectively. The fall has been more moderate for other euro area countries such as Austria, France or Germany, whose $DBO^{\theta=0}$ fell from 42.85%, 42.61% and 45.95% to 30.60%, 35.80% and 30.60%, respectively, representing more modest yet still remarkable declines between the same periods (29%, 16% and 33%). If we extend the analysis to a non-EU yet geographically close country such as Switzerland, the decline is also substantial (from 86.79% to 61.67%, representing a 29% deterioration). These countries have a common feature which might be explaining this trend, namely, all of them are net lenders. Although it remains an open question to ascertain the reasons of this decline—i.e. whether the economic crisis affecting their closest neighbors or for prudential considerations—the fact is that these countries' banking systems are now much more closed.

In contrast, for the rest of euro area countries tendencies are not exactly coincidental. Among these countries we find some of the most severely affected by the international crisis, namely, Italy, Portugal and Spain, whose $DBO^{\theta=0}$ remained virtually unchanged—they decreased from 25.63%, 21.95% and 29.65% to 24.50%, 19.80% and 29.57% between 2003 and 2007, representing a decline of 4%, 10% and 0.3%. Therefore, in the particular case of Europe and, more specifically, euro area countries, although the general tendency has been to become *less* financially integrated, the degree of heterogeneity is remarkable, the borrower countries being those with most declining $DBO^{\theta=0}$. These differing tendencies are partly responsible for the decline of the standard deviation, whose values for 2003 and 2007 are quite similar (22.61% and 23.94%, respectively), but then in 2011 it falls to 15.46%.

There are two particular countries for which results are more difficult to reconcile with those described in the paragraphs above. The first of these two cases is Greece, whose degree of bank openness is even higher than that of Belgium by 2011 (it has increased from 16.63% to 26.57%). The second case is Ireland, whose banking system particularities deserve a specific analysis. In this case, the decline has been from 38.89% to 12.19% between 2003 and 2011 (representing a 69% decline), being now, by and large, the most closed banking system of the euro area.

Regardless of the tendencies for each particular country or groups of countries, on average, as indicated at the bottom of table 3.2, the degree of bank openness increased between 2003 and 2007 (from 26.72% to 33.75%) and then it fell to 25.98% by 2011. Therefore, we could tentatively conclude that between the beginning and the end of the period, on average, the world's largest banking systems are *less* open. However, the standard deviation did actually decrease by a remarkable amount (from 22.61% by 2003 to 15.46% by 2011), pointing out the asymmetries in the evolution of the degree of bank openness—i.e., despite its average decline, there is a notable convergence process among countries.

The information in table 3.2 is complemented by the results corresponding to the distance-corrected degree of bank openness indicators yielded by equation (3.1) when $\theta = 1$. Few contributions have been taking these considerations into account, among which we should highlight the paper by Buch (2005), who also focuses on the relationship between distance and banking albeit employing a much different approach—without the explicit aim of *measuring* the degree of banking integration. In addition, she focuses on a very different period (1983-1999), finding that banks in her sample held significantly lower assets in distant markets, and that the importance of distance for foreign asset holdings of banks had not changed during the sample period analyzed. Related to this literature, Aviat and Coeurdacier (2007) and Coeurdacier (2009) have also documented that cross-border equity flows are heavily affected by distance, since this acts as a proxy for information asymmetries constituting ultimately a very large barrier to cross-border asset trade. Actually, according to Okawa and van Wincoop (2012), during the past decade there has been an *explosion* of papers estimating gravity equations for cross-border financial holdings. In their work, these authors derive a theoretical gravity equation for asset trade fixing some of the problems found in previous literature.

As indicated in section 3.2, our approach to correct for distance is based on Samuelson's iceberg-type transportation costs, which have been adapted to the context of trade integration indicators by Arribas, Pérez and Tortosa (2011c). However, despite the remarkable literature on distance and banking (see, for instance Buch 2005) in particular, and distance and finance, in general, the previous contributions did not take these ideas into account. A particular branch of finance literature has taken explicitly the effect of distance into account, although from a different perspective to ours. Specifically, Lewis (1999) and others have referred to the home-bias effect as the bias in favor of domestic securities or, as indicated by Coval and Moskowitz (1999), the preference for investing *close to home*. Regarding this, Cooper and Kaplanis (1994) reported for several countries the proportion of equity investment in domestic equity and domestic market capitalization as a proportion of the world equity market capitalization and, for some countries (and in general), this proportion was quite high (for instance, in the case of the US the proportion was 98%, and in the case of the UK, 86.7%; in cases such as Japan, for instance, it was only 43.7%). According to more recent evidence, however, despite investors hold a disproportionally high share of domestic assets, international diversification has decreased in almost every country, contributing to a decline of equity home bias.[6]

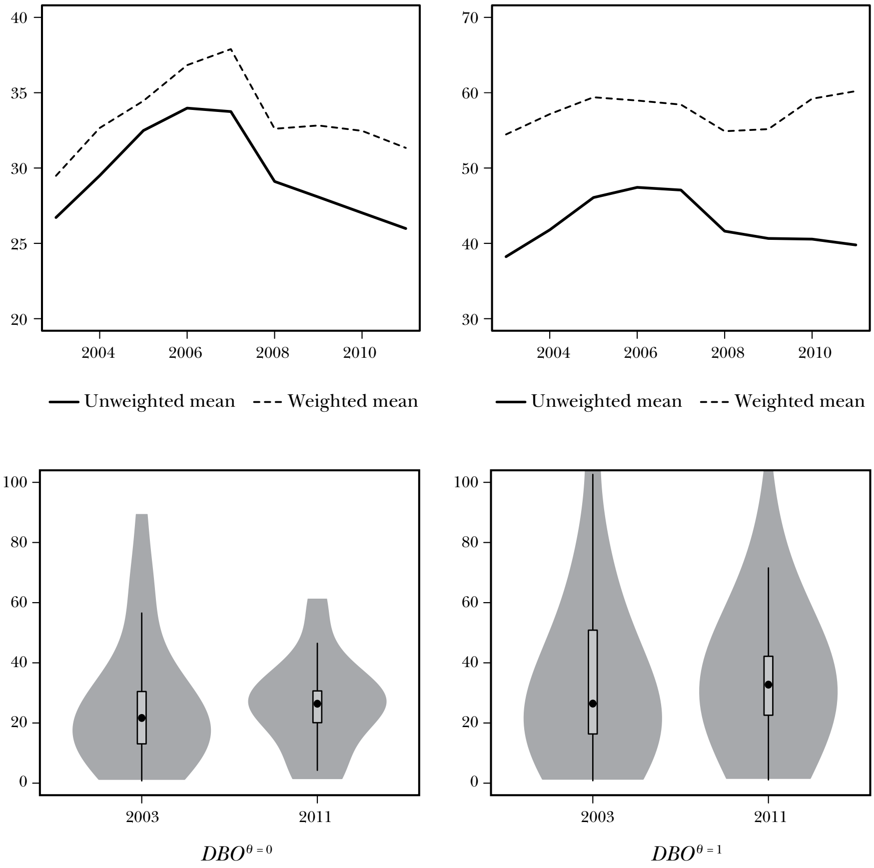
Discrepancies between the distance-corrected and distance-uncorrected indicators actually exist for several countries, which indicates how distance affects cross-border banking. The summary indicators in the last three rows of table 3.2 indicate that, on average, the distance-corrected degree of bank openness is higher than its distance-uncorrected counterpart, regardless of the year considered—by 2011 the average $DBO^{\theta=1}$ is more than 50% higher than $DBO^{\theta=0}$. However, in the same year, the standard deviation for the distance-corrected indicator more than doubles its distance- uncorrected counterpart, indicating distance affects some particular countries much more severely.

Among these countries we may highlight the cases of Switzerland and, most notably, Japan. For this particular country, in year 2011 the $DBO^{\theta=1} = 190.57\%$, which is more than six times its distance-uncorrected counterpart. This implies that for Japan distance is not a barrier and its foreign claims (i.e. the banking assets held abroad by Japanese nationals) arrive to geographically far countries in a greater extent than the predicted under the assumption of geographic neutrality. However, the distance component exists for *all* countries (i.e. in all instances $DBO^{\theta=1} > DBO^{\theta=0}$).

We also provide a graphical summary of the results in figure 3.1, where the evolution for both $DBO^{\theta=0}$ and $DBO^{\theta=1}$ is displayed. The upper panel represents the evolution of the average, both unweighted (solid lines) and weighted (dashed lines). In the case of the distance-uncorrected indicators ($DBO^{\theta=0}$), it is clearly apparent that, on average, banking integration has fallen to pre-crisis levels, yet for large financial systems the decline was more modest and occurred mainly during the first year of the crisis. In the case

[6] Related to the topic of equity home bias, Lane and Milesi-Ferretti (2003) have examined the trend in foreign asset holdings from a broader perspective. Specifically, they examine the effects of a number of factors (a measure for capital account liberalization, per capita GDP, stock market capitalization over GDP and trade flows over GDP) on foreign equity and FDI holdings over GDP, finding that trade flows, per capita GDP, and, more especially, stock market capitalization were important determinants of their dependent variable.

FIGURE 3.1: Degree of bank openness *($DBO^{\theta=0}$* and *$DBO^{\theta=1}$*), 2003-2011
(percentage)



Source: Own calculations.

of distance-corrected indicators ($DBO^{\theta=1}$), the upper-right panel shows that the level of banking integration has actually increased. This could be indicating that after the crisis took place, there is a strongest neighbors' bias.

The lower panel in figure 3.1 displays violin plots[7] for both $DBO^{\theta=0}$ and $DBO^{\theta=1}$. The lower left violin plot ($DBO^{\theta=0}$) clearly

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[7] This type of graphical representation combines box plots and densities (estimating via kernel smoothing). The box (representing the central 50% of the probability mass, or the interquartile range) is inside the violin, and a rotated kernel density plot is added to each side of the box plot. A black dot inside the box is also included to mark the median.

indicates that, comparing 2003 and 2011, banking integration shows greater convergence—although the most highly banking integrated countries are now more closed, the bulk of probability is shifting upwards. This convergence is also taking place for $DBO^{\theta=1}$, as shown by a shorter central box, although the aspect of the *violins* is very similar.

3.4.2. Degree of bank connectedness

Analogous results to those reported for the degree of openness in table 3.2 are reported for the degree of connectedness in table 3.3. In this case, the number of columns is higher because we report results considering different roles for both the distance (relevant or irrelevant) and the indirect links (existing, not existing).

The first 6 columns in table 3.3 report results for the scenario under which distance is irrelevant for cross-border asset holdings. The last 6 columns correspond to the opposite case (distance matters), which would be equivalent to the case in which the well-known home bias effect in asset holdings exists.

In addition, both the distance-uncorrected and distance-corrected indicators are split for the cases in which we allow for the existence of indirect links—$\gamma = 1$ when they do not exist, and country-specific γ when they are allowed to exist. Recall that γ is defined for each country as the proportion of cross-border flows which remain invested in the country (which are reported in table 3.4 for each country and for years 2003, 2007 and 2011). Therefore, we have a total number of 12 columns in table 3.3, combining distance-corrected and distance-uncorrected cases as well as the possibility of holding banking assets through indirect links—i.e. from third countries. Although allowing for this possibility increases the complexity of the analysis, we consider that its relevance over the last few years suggests it should be taken into account, especially if we consider this allows modeling the possibility of subprime lending.

Regardless of the source of variation considered (i.e. regardless of the θ or γ value), the average, displayed at the bottom of table 3.3, shows that banking connectedness has been falling sharply from 2003 to 2011. This pattern is more clearly shown in figures 3.2 and 3.3, for distance-uncorrected and distance-corrected

TABLE 3.3: Degree of bank connectedness distance-uncorrected and distance-corrected indicators, 2003, 2007 and 2011
(percentage)

Country	Degree of bank connectedness											
	Distance irrelevant ($\theta = 0$)						Distance relevant ($\theta = 1$)					
	Direct connections ($\gamma = 1$)			Total connections (γ country-specific)			Direct connections ($\gamma = 1$)			Total connections (γ country-specific)		
	2003	2007	2011	2003	2007	2011	2003	2007	2011	2003	2007	2011
Australia	53.72	65.38	52.59	53.59	65.29	52.39	61.56	70.31	59.63	60.51	69.00	53.64
Austria	80.56	84.34	73.27	81.01	84.60	73.87	84.28	92.12	83.31	84.81	90.78	83.30
Belgium	73.60	78.80	70.41	73.82	78.95	70.84	87.14	90.55	78.21	84.15	88.39	78.15
Brazil	75.08	66.23	61.98	75.18	66.38	62.31	75.90	66.95	62.84	71.48	61.67	57.44
Canada	59.10	57.19	54.45	63.52	62.38	61.66	65.22	64.09	61.33	57.77	57.85	55.17
Chile	61.58	53.16	65.62	61.59	53.18	65.65	62.80	54.23	66.61	57.19	47.86	62.05
Denmark	75.14	58.10	42.60	75.45	58.23	42.79	77.13	70.64	53.19	76.56	70.49	53.41
France	90.34	89.39	82.66	88.67	87.24	81.63	90.55	92.81	88.17	82.58	85.06	82.41
Germany	87.84	90.56	86.93	88.87	89.10	87.70	88.98	91.01	88.25	78.22	83.19	81.10
Greece	83.78	21.02	32.63	83.79	21.05	32.71	85.81	29.83	47.78	83.11	29.74	47.86
Ireland	81.02	80.64	48.81	81.57	81.38	49.82	90.89	87.20	53.00	90.02	86.40	53.81
Italy	83.95	69.51	61.60	84.63	70.32	62.62	85.87	78.84	71.76	84.23	78.23	72.06
Japan	75.05	73.99	70.92	74.98	73.94	70.86	78.40	80.78	76.05	65.85	74.41	66.27

TABLE 3.3 *(cont.)*: **Degree of bank connectedness distance-uncorrected and distance-corrected indicators, 2003, 2007 and 2011** (percentage)

Country	Degree of bank connectedness											
	Distance irrelevant ($\theta = 0$)						Distance relevant ($\theta = 1$)					
	Direct connections ($\gamma = 1$)			Total connections (γ country-specific)			Direct connections ($\gamma = 1$)			Total connections (γ country-specific)		
	2003	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**
Mexico	44.19	56.59	56.32	44.44	56.80	56.55	44.40	57.02	56.62	36.41	50.67	50.38
Netherlands	84.69	90.55	85.15	84.48	90.00	85.63	87.80	90.47	88.47	83.88	87.86	86.03
Portugal	79.97	64.14	48.93	80.19	64.40	49.23	83.50	74.89	61.70	82.68	73.79	61.37
Spain	50.83	72.53	65.32	51.25	72.84	65.75	63.65	80.09	73.91	61.74	77.95	70.99
Sweden	72.56	60.58	45.86	72.93	60.81	46.06	80.59	81.95	72.02	79.19	80.62	70.26
Switzerland	67.71	70.02	70.80	66.83	69.00	70.04	85.23	86.87	81.91	80.68	83.47	77.90
Turkey	77.97	78.99	76.02	77.99	79.03	76.09	79.25	80.41	76.99	77.22	80.85	76.42
UK	70.00	71.70	77.93	67.11	67.54	75.83	75.17	76.98	81.68	66.51	68.59	76.23
US	85.85	85.80	88.68	77.27	82.67	77.98	86.27	86.81	89.11	84.76	86.04	89.54
Unweighted average	73.39	69.96	64.52	73.14	69.78	64.46	78.20	76.58	71.48	74.07	73.31	68.45
Standard deviation	12.57	15.89	15.44	12.12	15.36	14.51	11.87	15.27	12.93	13.01	15.52	12.84
Coefficient of variation	17.13	22.71	23.93	16.57	22.02	22.51	15.17	19.94	18.09	17.56	21.17	18.76

Source: Own calculations.

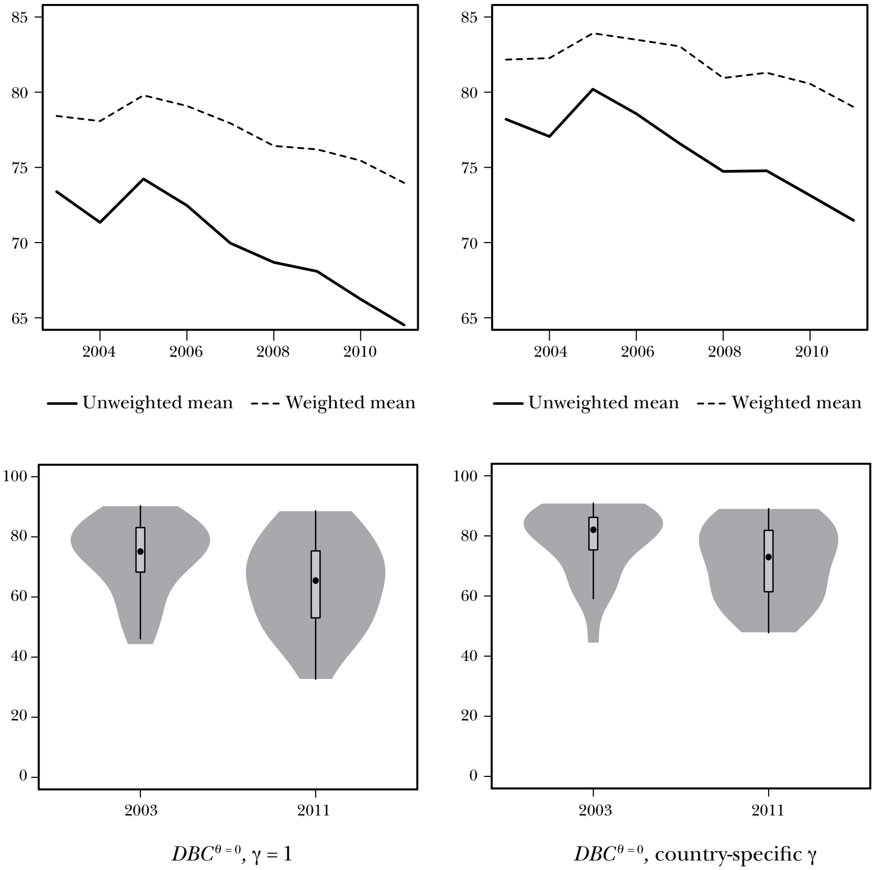
TABLE 3.4: Country-specific γ values, 2003, 2007 and 2011 (percentage)

Country	γ values		
	2003	2007	2011
Australia	77.10	78.73	77.57
Austria	86.79	57.83	69.92
Belgium	37.12	26.62	79.34
Brazil	94.50	97.14	96.77
Canada	76.24	75.02	74.93
Chile	95.50	96.52	95.39
Denmark	92.17	69.35	77.61
France	73.20	62.45	67.71
Germany	68.09	60.23	73.00
Greece	81.45	83.49	73.59
Ireland	52.96	62.04	88.02
Italy	87.75	75.89	76.51
Japan	81.97	65.97	73.14
Mexico	99.25	98.64	99.00
Netherlands	36.03	23.54	64.18
Portugal	84.37	78.22	80.35
Spain	78.43	71.93	72.13
Sweden	69.84	47.47	45.62
Switzerland	13.47	16.43	40.41
Turkey	93.26	94.43	95.42
UK	73.74	69.40	63.49
US	88.52	84.14	75.55
Unweighted average	74.62	67.98	75.44
Standard deviation	21.82	23.05	14.67
Coefficient of variation	29.24	33.90	19.44

Source: Own calculations.

indicators, respectively. In both figures, the upper panels show the evolution of the average degree of bank connectedness—both unweighted and weighted. Despite there were some ups and downs before 2007, since the financial crisis started the decline has been sharp, regardless of the role attached to distance (γ) or indirect

FIGURE 3.2: Degree of bank connectedness, distance-uncorrected indicators (*$DBC^{\theta=0}$*), 2003-2011
(percentage)

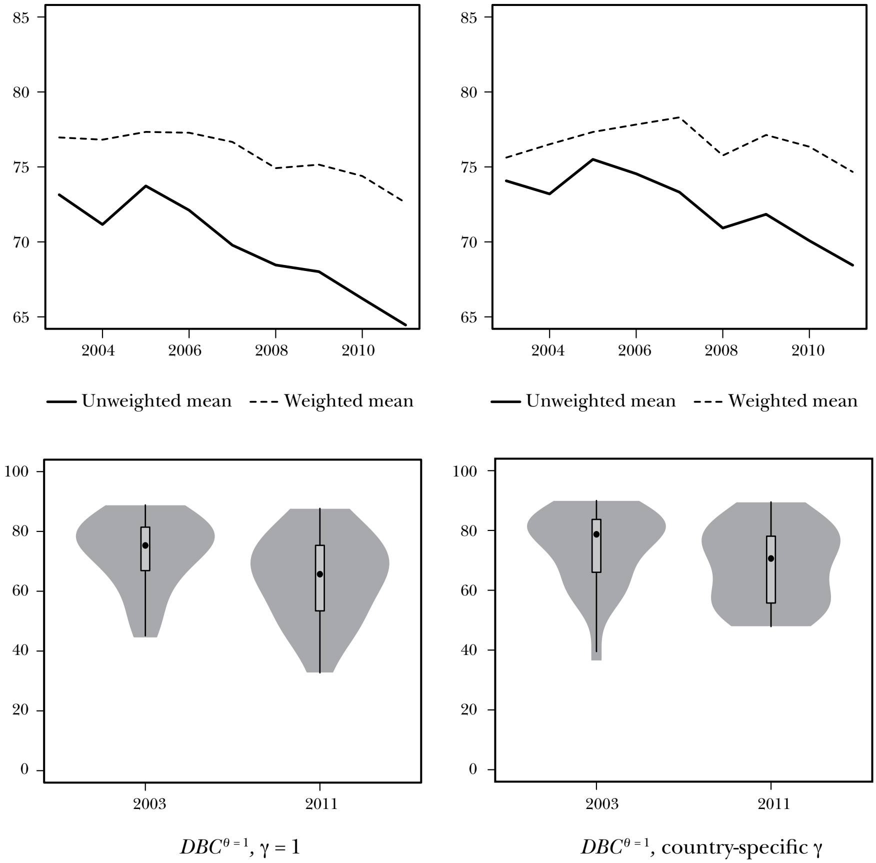


Source: Own calculations.

links *(θ)*. Some discrepancies between unweighted and weighted values also exist, with the weighted average higher (i.e. large banking systems are more highly connected), but tendencies are paralleled. The exact magnitudes of the averages, both unweighted and weighed, are reported in table 3.5.

The lower panels of figures 3.2 and 3.3 display the violin plots for each of the four variants of *DBC* considered. The violins reveal some patterns which the evolution of the average degree of bank connectedness conceals. Regardless of the flavor of the *DBC* considered, a common pattern emerges: although the mean, both

FIGURE 3.3: Degree of bank connectedness, distance-corrected indicators ($DBC^{\theta=1}$), 2003-2011
(percentage)



Source: Own calculations.

weighted and unweighted, has declined over the 2003-2011 period, this behavior has been largely caused by a substantial number of countries whose connectedness is, by 2011, much lower. In addition, although this only applies to the *g*-specific indicators, there is some amount of multi-modality emerging. This behavior had been partly anticipated by the summary statistics reported at the bottom of table 3.3, among which we find the values corresponding to the standard deviation which, in general, show an increasing tendency when comparing 2003 versus 2011.

3.4.3. Degree of bank integration

Considering jointly the degree of bank openness *(DBO)* and the degree of bank connectedness *(DBC),* we construct the indicator of bank integration *(DBI).* Its values for all countries and selected years (2003, 2007 and 2011) are reported in table 3.6.

Due to the way the indicator has been constructed, shown in equation (3.4), its evolution is completely explained by those of *DBO* and *DBI,* regardless of the parameters corresponding to the role of distance (θ) or indirect links (γ). This evolution is shown in figures 3.4 and 3.5 for both the distance-uncorrected and distance-corrected scenarios and, in the case of the weighted average, in table 3.5.

TABLE 3.5: Global degrees, 2003-2011
(percentage)

a) Distance-uncorrected

Year	$DGBO^{\theta=0}$	$DGTBC^{\theta=0}$		$DGBI^{\theta=0}$	
		$\gamma = 1$	γ country-specific	$\gamma = 1$	γ country-specific
2003	29.48	78.42	82.17	46.11	47.44
2004	32.66	78.08	82.27	48.52	50.09
2005	34.46	79.79	83.92	50.14	51.71
2006	36.83	79.09	83.49	51.82	53.50
2007	37.89	77.94	83.05	52.89	54.76
2008	32.61	76.43	80.94	48.67	50.22
2009	32.82	76.20	81.29	49.22	50.97
2010	32.47	75.45	80.56	48.66	50.43
2011	31.34	73.97	79.02	47.29	49.04

b) Distance-corrected

Year	$DGBO^{\theta=1}$	$DGTBC^{\theta=1}$		$DGBI^{\theta=1}$	
		$\gamma = 1$	γ country-specific	$\gamma = 1$	γ country-specific
2003	54.46	76.97	75.62	55.65	54.93
2004	57.15	76.82	76.51	57.17	57.00
2005	59.39	77.33	77.33	57.17	57.08
2006	58.96	77.28	77.83	58.40	58.58
2007	58.42	76.66	78.30	59.80	60.49
2008	54.88	74.92	75.76	56.78	57.04
2009	55.17	75.15	77.13	57.13	57.93
2010	59.20	74.39	76.35	56.52	57.33
2011	60.21	72.61	74.67	54.75	55.59

Source: Own calculations.

TABLE 3.6: Degree of bank integration, distance-uncorrected and distance-corrected indicators, 2003, 2007 and 2011
(percentage)

Country	Degree of bank integration											
	Distance irrelevant ($\theta = 0$)						Distance relevant ($\theta = 1$)					
	Direct connections ($\gamma = 1$)			Total connections (γ country-specific)			Direct connections ($\gamma = 1$)			Total connections (γ country-specific)		
	2003	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**
Australia	35.40	37.74	34.93	39.22	43.31	41.64	37.90	39.13	37.20	41.67	44.52	42.14
Austria	32.86	60.12	47.35	35.73	65.39	52.56	33.61	62.83	50.49	36.56	67.74	55.81
Belgium	68.76	76.93	38.47	72.99	81.94	40.69	74.81	82.47	40.54	77.92	86.70	42.73
Brazil	20.42	13.90	14.37	21.13	14.86	16.09	20.53	13.97	14.47	20.60	14.32	15.44
Canada	38.07	38.47	37.80	40.13	41.03	41.23	39.99	40.73	40.12	38.27	39.51	39.00
Chile	16.65	13.61	17.40	16.91	13.88	17.83	16.81	13.75	17.53	16.30	13.17	17.33
Denmark	24.40	42.48	31.08	26.45	46.38	34.19	24.72	46.84	34.73	26.65	51.03	38.19
France	51.91	61.72	54.40	55.77	66.40	59.08	51.98	62.89	56.19	53.82	65.56	59.36
Germany	57.85	64.51	51.58	68.85	72.77	59.26	58.23	64.67	51.96	64.59	70.32	56.98
Greece	39.53	18.69	29.44	41.46	19.78	31.21	40.01	22.27	35.63	41.29	23.51	37.75
Ireland	62.19	56.00	24.40	67.20	62.58	27.02	65.87	58.23	25.42	70.60	64.48	28.08
Italy	32.97	42.21	38.85	39.18	50.45	45.04	33.35	44.95	41.93	39.08	53.21	48.32
Japan	39.63	52.36	46.65	73.01	67.51	60.98	40.50	54.71	48.30	68.42	67.72	58.97

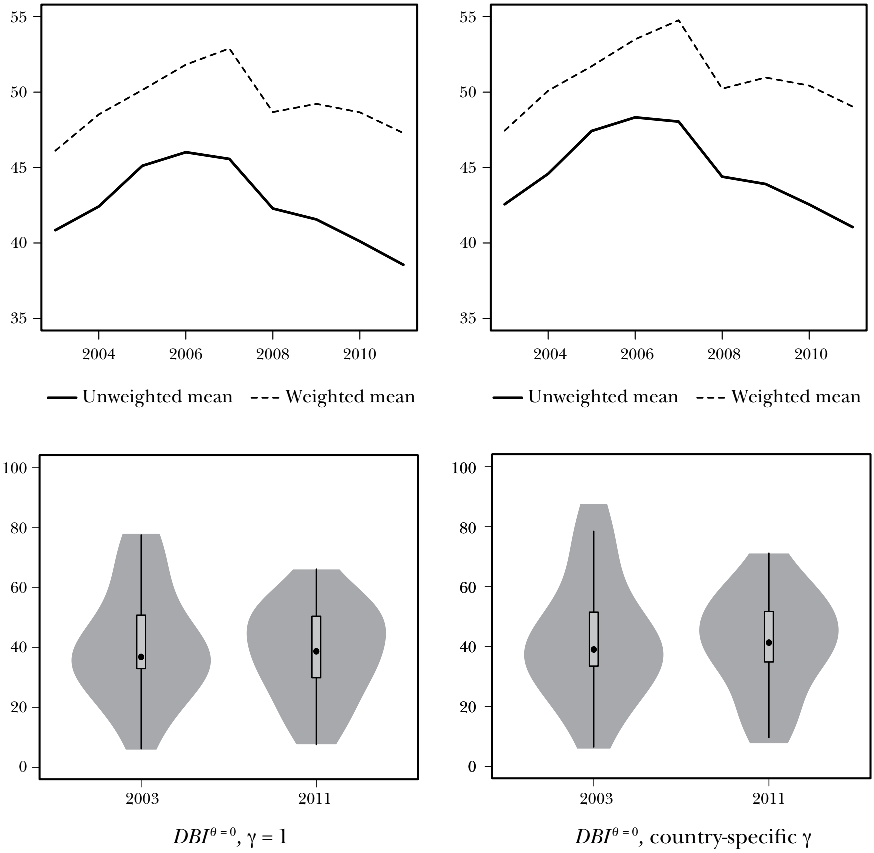
TABLE 3.6: *(cont.)*: **Degree of bank integration, distance-uncorrected and distance-corrected indicators, 2003, 2007 and 2011** (percentage)

Country	Degree of bank integration											
	Distance irrelevant ($\theta = 0$)						Distance relevant ($\theta = 1$)					
	Direct connections ($\gamma = 1$)			Total connections (γ country-specific)			Direct connections ($\gamma = 1$)			Total connections (γ country-specific)		
	2003	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**	**2003**	**2007**	**2011**
Mexico	5.77	8.79	7.54	5.99	9.09	7.81	5.79	8.82	7.56	5.42	8.59	7.37
Netherlands	75.02	84.86	56.41	82.43	93.35	63.99	76.39	84.82	57.50	82.14	92.23	64.14
Portugal	35.52	37.52	31.12	38.21	39.83	33.15	36.29	40.55	34.95	38.80	42.63	37.02
Spain	33.76	46.38	43.95	37.58	52.91	51.57	37.78	48.73	46.75	41.25	54.74	53.59
Sweden	47.12	56.87	50.40	49.46	59.83	53.67	49.66	66.15	63.15	51.54	68.89	66.28
Turkey	22.96	21.03	18.71	23.24	21.42	19.18	23.15	21.22	18.83	23.12	21.67	19.22
Switzerland	77.98	77.96	66.08	72.86	75.67	78.06	87.49	86.83	71.08	80.06	83.23	82.32
UK	45.85	50.85	57.05	53.98	60.35	68.84	47.51	52.69	58.41	53.74	60.82	69.03
US	33.99	39.56	50.24	38.76	45.43	55.11	34.07	39.79	50.36	40.60	46.35	59.05
Unweighted average	40.85	45.57	38.56	45.48	50.19	43.55	42.57	48.05	41.05	46.02	51.86	45.37
Standard deviation	18.74	21.44	15.56	20.76	23.36	18.71	20.34	22.66	16.64	21.27	24.12	19.45
Coefficient of variation	45.87	47.05	40.36	45.64	46.55	42.95	47.79	47.16	40.53	46.23	46.51	42.88

Source: Own calculations.

FIGURE 3.4: Degree of bank integration, distance-uncorrected indicators *($DBI^{\theta=0}$)*, 2003-2011

(percentage)

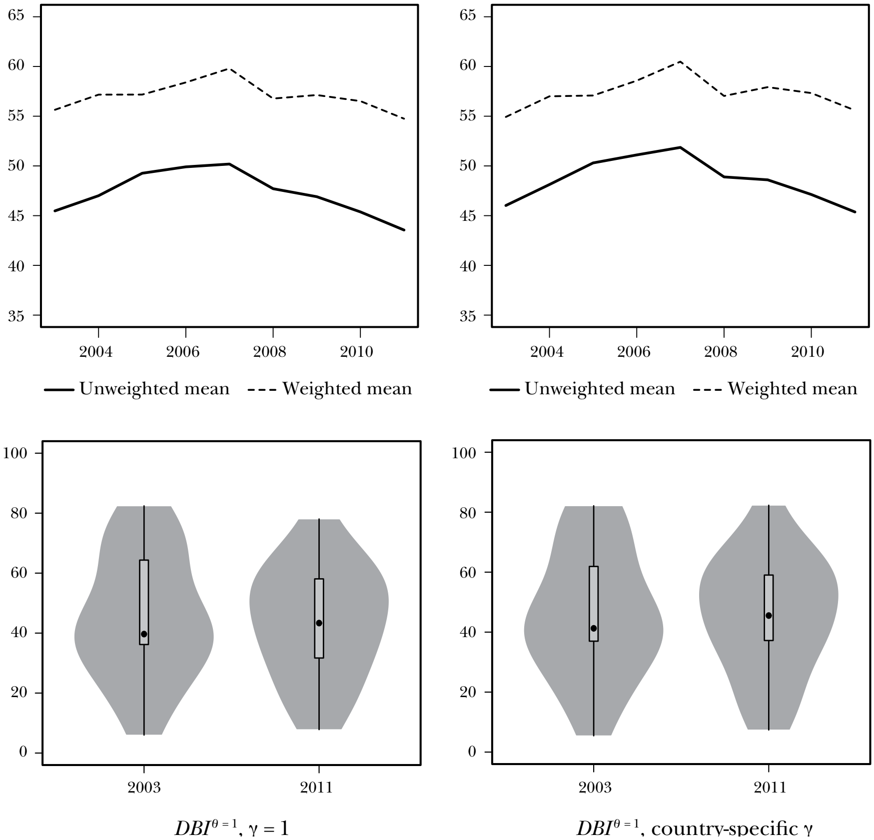


Source: Own calculations.

The patterns shown in the upper panels of figures 3.4 and next on 3.5 reveal a dual behavior. Before the beginning of the international financial crisis, in 2007, the pattern is, in general, increasing. Although in the particular case of the *DBI* when distance is irrelevant the evolution of the unweighted average start to decline slightly a bit earlier (in 2006, see the top panels in figure 3.4), in the case of the weighted average the change in the trend is obvious, and it takes part exactly in 2007. This slightly different behavior for the unweighted and weighted average can be partly explained because those countries more severely af-

FIGURE 3.5: Degree of bank integration, distance-corrected indicators *($DBI^{\theta=1}$)*, 2003-2011

(percentage)



Source: Own calculations.

fected by the financial countries were, generally, countries with large banking systems.

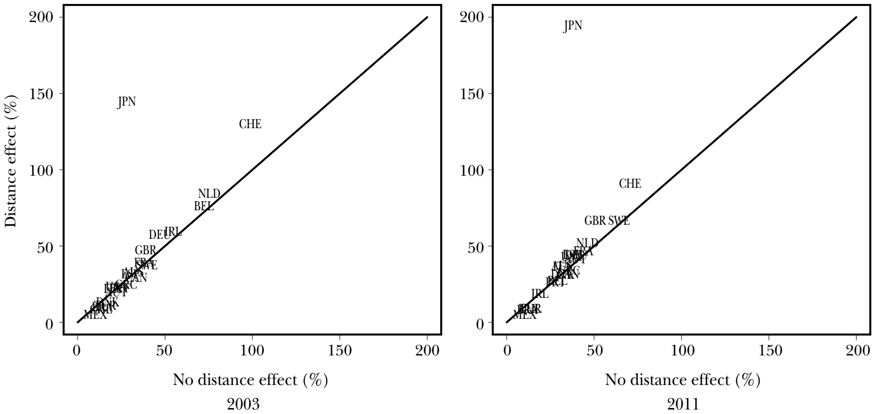
Because of this peculiar evolution, with two distinct periods, on average the *DBI* has similar values when comparing the initial year (2003) and final year (2011) only. This result is robust across the different scenarios considered, as shown by the values in the unweighted average results at the bottom of table 3.6, where discrepancies between the 2003 and 2011 unweighted average for any of the four indicators considered ($DBI^{\theta=0}$ and $DBI^{\theta=1}$, γ = 1 and country-specific γ) are always less than two percentage points. The dispersion indicator (standard deviation), reported at the bottom of table 3.6, shows a similar pattern, since the values are not very different when comparing years 2003 and 2011.

Although violin plots, displayed in the lower panels of figure 3.4 and 3.5, could provide additional information to that conveyed by the mean and the standard deviation, in this case static analysis of 2003 versus 2011 reveals slight differences. However, some of them were concealed by the evolution of the summary statistics reviewed (mean and standard deviation). Specifically, most countries, despite of the context of international economic and financial crisis, are actually increasing their levels of bank integration when considering our indicators. This is shown by probability mass (i.e. more countries) shifting upwards in *all* violin plots, implying that, regardless of our assumptions on the role of distance and the indirect connections, and despite the financial crisis which still affects many countries, banking integration is still growing. This result, despite being based on very different instruments, largely coincides with some of those obtained by Kleimeier, Sander and Heuchemer (2013a, 2013b), who show that financial crises have "significantly positive and often long-lasting effects on cross-border banking."

3.4.4. How distance and crisis affect bank integration

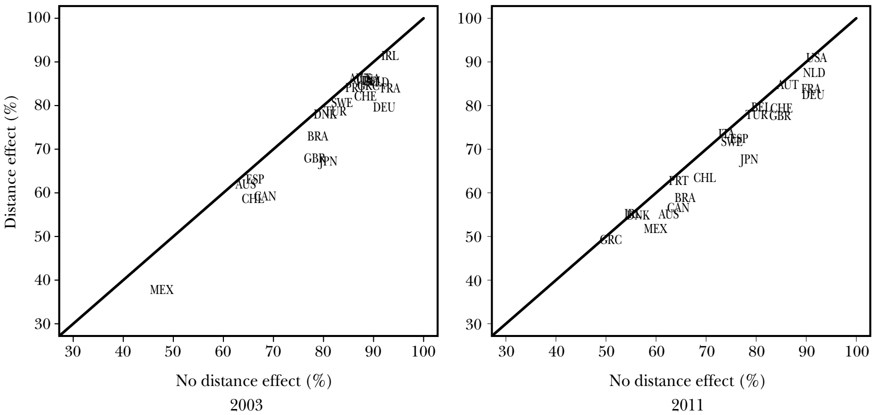
We also provide some insights about how distance and the present crisis might be affecting the indicators of bank openness, connectedness and integration. Specifically, figures 3.6, 3.7 and 3.8 provide scatter plots in which the distance-uncorrected indicators are represented in the *OX* axis and the distance-corrected ones in the *OY* axis. For all three figures the left panel refers to year 2003, and the right panel to year 2011. It is apparent that the role of distance is involved. In the case of the degree of bank openness (figure 3.6), the effect is the one we might expect from home bias effect on cross-border asset holdings literature: controlling for geographical distance implies that the degrees of openness increase, both in 2003 and 2011. This is apparent through both panels in figure 3.6, where most countries lie above the 45° line.

FIGURE 3.6: Degree of bank openness, distance-uncorrected vs. distance-corrected indicators, 2003 and 2011
(percentage)



Source: Own calculations.

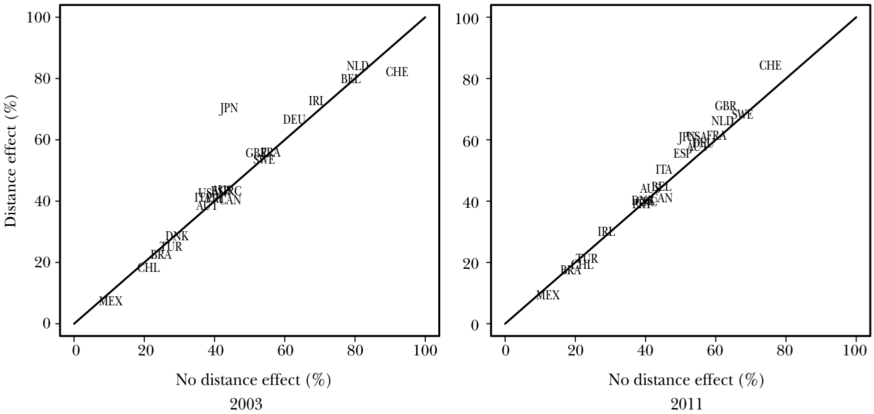
FIGURE 3.7: Degree of bank connectedness, distance-uncorrected vs. distance-corrected indicators, country-specific γ, 2003 and 2011
(percentage)



Source: Own calculations.

Nevertheless, in the case of the degree of bank connectedness (figure 3.7), the effect is the opposite. There is no home bias effect at all and we could even refer to it as *foreign* bias effect. However, the crisis is changing slightly this behavior, as countries are closer to the 45° line in 2011 than in 2003. Combining these

FIGURE 3.8: Degree of bank integration, distance-uncorrected vs. distance-corrected indicators, country-specific γ, 2003 and 2011
(percentage)



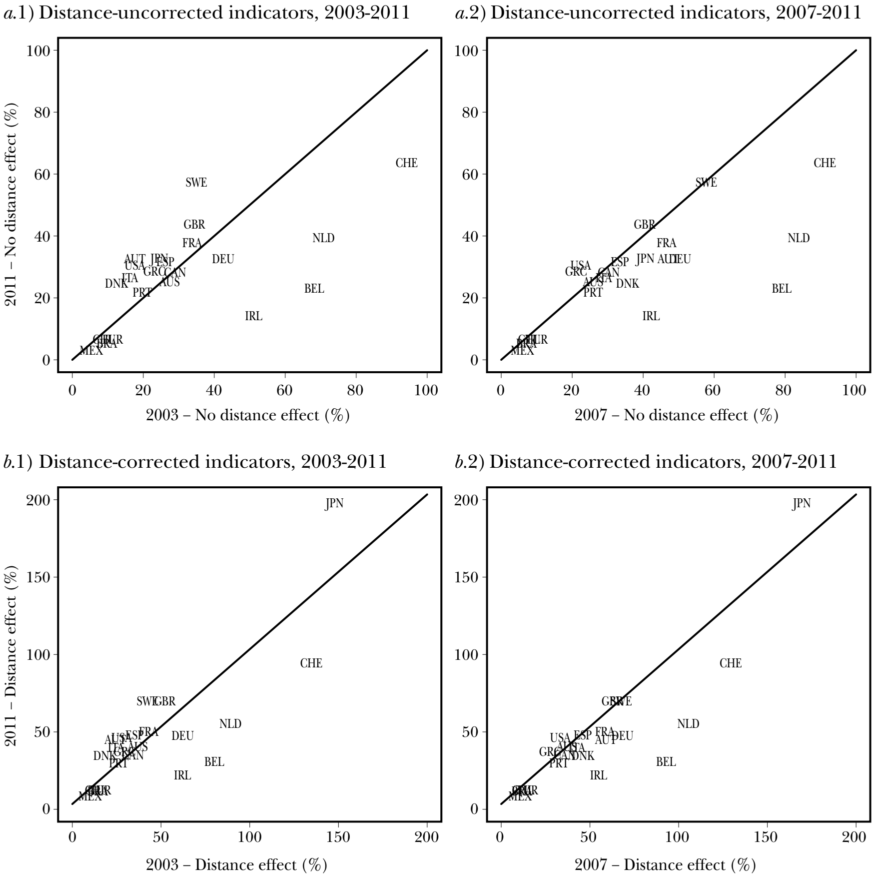
Source: Own calculations.

two effects, which turn out to be opposite, the degree of bank connection (represented in figure 3.8) shows that most countries lie close to the 45° line, with only slight changes between pre- and crisis periods.

The analysis in which the pre-crisis and crisis periods are compared is provided in figures 3.9, 3.10 and 3.11 for the degree of bank openness, the degree of bank connectedness and the degree of bank integration, respectively. For all three figures, the upper panels represent the distance-uncorrected indicators, whereas the lower panels represent the distance-corrected ones. In addition, the panels on the left compare year 2003 versus 2011, whereas those on the right compare 2007 versus 2011.

Although each country would deserve a specific analysis, there is one robust pattern across all 12 sub-figures contained in these three figures: the number and magnitude of changes in the relative positions are remarkable. Changes are more pronounced in the upper panels, corresponding to distance-uncorrected indicators, but they are substantial anyway. Both the degrees of bank openness *(DBO*, figure 3.9) and the degree of bank connectedness *(DBC*, figure 3.10) are affected (and, consequently, the *DBI* as well, figure 3.11), but perhaps the most radical changes are observed for the *DBO,* where some coun-

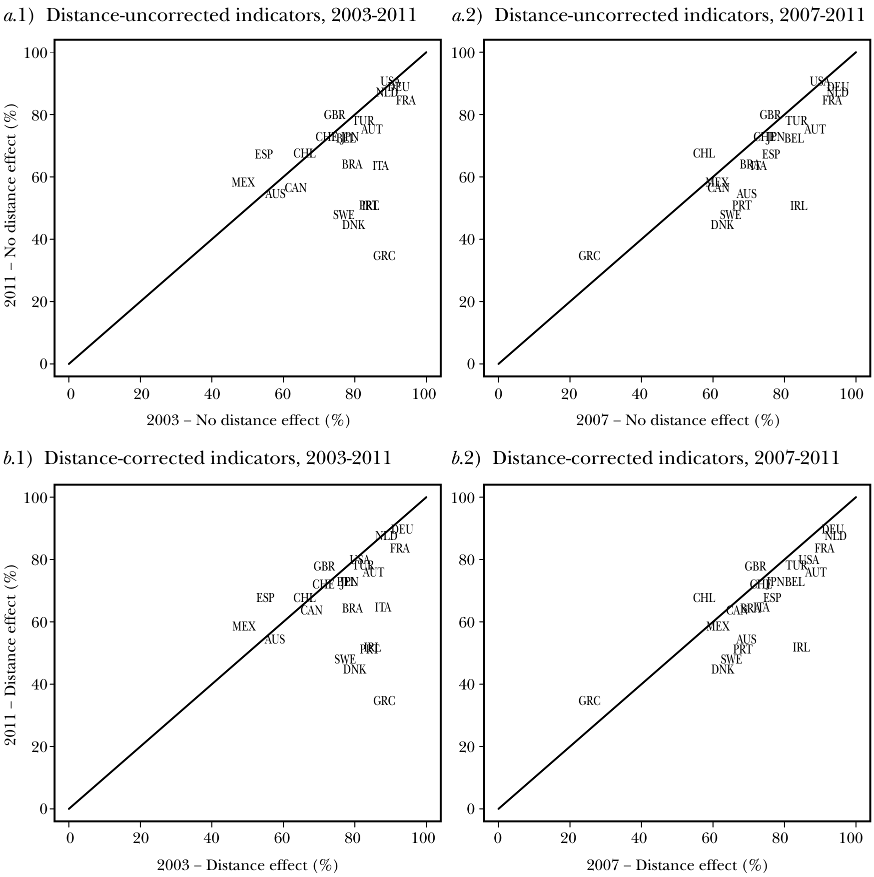
FIGURE 3.9: Degree of bank openness, 2003 vs. 2011 and 2007 vs. 2011
(percentage)



Source: Own calculations.

tries cross-border asset holdings have decreased substantially, regardless of whether we compare 2003 versus 2011 or 2007 versus 2011. However, it is important to note that although *some* countries are now less open, many countries improved when comparing years 2003 versus 2011 (see the upper-left panel in figure 3.9). Although this trend is more mitigated for the degree of bank connectedness (*DBC*, figure 3.10), the final result (i.e. the effect on *DBI*, figure 3.11) is dominated by the degree of openness.

FIGURE 3.10: Degree of bank connectedness, 2003 vs. 2011 and 2007 vs. 2011
(percentage)

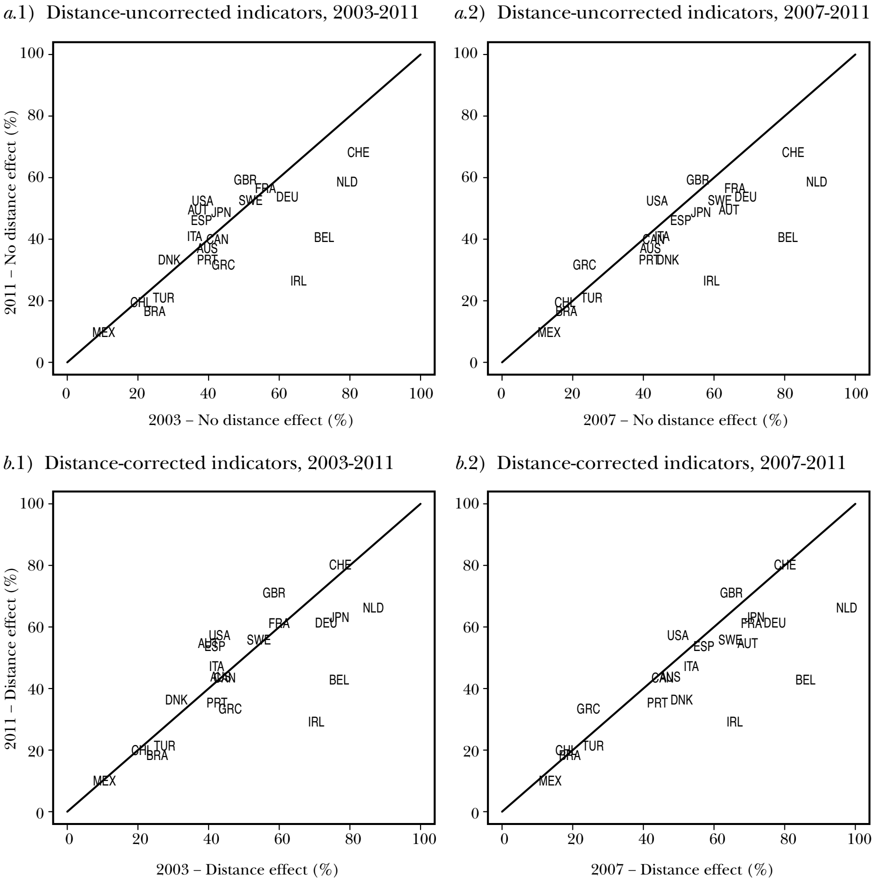


Source: Own calculations.

3.5. Conclusions

Cross-border banking has been increasing remarkably over the last 20 years, especially for developed countries and despite the strong impact of the financial crisis over the last five years, continuing a well-documented general expansion of international banking integration within the so-called Second Age of Globalization (Goldberg 2009; Obstfeld and Taylor 2004). Actually, the decade before the global financial crisis was marked by an increasing number of

FIGURE 3.11: Degree of bank integration, 2003 vs. 2011 and 2007 vs. 2011
(percentage)



Source: Own calculations.

cross-border financial and banking positions. Although the crisis is affecting economies and banking systems asymmetrically, even within the context of geographically close countries with strong financial and trade connections such as the case of the European Union, the impact of the financial crisis has been more homogeneous.

Regardless the recent financial crisis, literature on measuring globalization and, in particular, measuring banking globalization (or, equivalently, the degree of banking integration) was evolving rapidly before the crisis started. Literature on this particular issue, although substantial, is disperse, with several approaches which attempt to answer the question of how globalized banks are.

In the specific case of banking, trying to answer this question is more complex, since these types of firms offer a greater variety of products and services, most of which can be accessed only locally, and which affect differently retail and corporate banking. Therefore, in the particular case of banking *de jure* integration might be particularly far from *de facto* integration.

Some recent approaches have been considering the fact that economies and banking systems, today, are much more connected than some time ago. Assuming this, it is reasonable to use an approach which explicitly controls for this possibility, namely, a network analysis approach, according to which economies and banking (and financial) systems are nodes of this network or World Banking Web (WBW).

In a series of recent papers, Arribas, Pérez and Tortosa (2011a, 2011b) combine classic literature which measures cross-border asset holdings and analyzes their determinants and related questions with network approaches, which try to model the WBW. Accordingly, they propose measures of bank openness, bank connectedness and, ultimately, bank integration, which enable to measure how far we are from a hypothetically connected WBW—in which all banking systems have reached their full potential for banking integration, despite the risks of full banking integration put forward by (Stiglitz 2010). In this particular contribution we extend this recent literature to two cases which we consider relevant, namely, analyzing how the financial crisis affects the evolution of these indicators, and whether the—likely—home bias effect is either increasing or decreasing.

Results can be explored from multiple angles but, in general, they indicate that international banking integration is growing yet asymmetrically. Globally, comparing our initial and final sample years, the average degree of bank openness, connectedness and integration are either stagnant or growing. However, the degree to which the different sample countries are affected is heterogeneous. This result is coincidental with some recent findings and, therefore, should be considered as added robustness to this finding.

However, the way geographical distance affects the degree of banking openness, connectedness and integration is more involved. In this case, tendencies differ remarkably for the different indicators. Further research will focus on explaining these differences, and how they might either contribute to boost, or to jeopardize, future growth prospects of the countries in our sample.

Acknowledgements

The authors thank Co-Pierre Georg and Giorgio Fagiolo for their constructive criticism. This chapter is a result of the BBVA Foundation-Ivie Research Program. All authors acknowledge financial support from the Spanish Ministry of Science and Innovation (research projects ECO2011-23248, ECO2011-27227 and ECO2010-20584) and the Valencian regional government (PROMETEO/2009/066 and PROMETEO/2009/068). The usual disclaimer applies.

References

ALFARANO, Simone, and Mishael MILAKOVIĆ. "Network structure and N-dependence in agent-based herding models." *Journal of Economic Dynamics and Control* 33, no. 1 (2009): 78-92.

ARRIBAS, Iván, Francisco PÉREZ, and Emili TORTOSA AUSINA. "Measuring globalization of international trade: Theory and evidence." *World Development* 37, no. 1 (2009): 127-145.

—. "The determinants of international financial integration revisited: The role of networks and geographic neutrality." *Studies in Nonlinear Dynamics and Econometrics* 15, no. 1(2011a): article 4.

—. "A network perspective on international banking integration." *Journal of Policy Modeling* 33, no. 6 (2011b): 831-851.

—. "A new interpretation of the distance puzzle based on geographic neutrality." *Economic Geography* 87, no. 3 (2011c): 335-362.

AVIAT, Antonin, and Nicolas COEURDACIER. "The geography of trade in goods and asset holdings." *Journal of International Economics* 71, no. 1 (2007): 22-51.

BILLIO, Monica, Mila GETMANSKY, Andrew W. LO, and Loriana PELIZZON. "Econometric measures of connectedness and systemic risk in the finance and insurance sectors." *Journal of Financial Economics* 104, no. 3 (2012): 535-559.

BIS (Bank of International Settlements). Total Consolidated Foreign Claims. Basel, accessed 16 September 2012 in http://www.bis.org/statistics/consstats.htm.

BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM. Assets and Liabilities of Commercial Banks in the United States. Washington, D.C., accessed 16 September 2012 in http://www.federalreserve.gov/.

BUCH, Claudia M. "Distance and international banking." *Review of International Economics* 13 no. 4 (2005): 787-804.

CENTRAL BANK OF BRAZIL. Informações contábeis analíticas e consolidadas por segmento. Brasilia, accessed 16 September 2012 in http://www.bcb.gov.br/pt-br/paginas/default.aspx.

CENTRAL BANK OF CHILE. Santiago, accessed 16 September 2012 in http://www.bcentral.cl/index.asp.

CENTRAL BANK OF DENMARK. Balance sheets items of the MFI-sector by type of data and country. Copenhaguen, accessed 16 September 2012 in http://www.nationalbanken.dk/dnuk/specialdocuments.nsf.

CENTRAL BANK OF ENGLAND. Statistical Interactive Database. London, accessed 16 September 2012 in http://www.bankofengland.co.uk/Pages/home.aspx.

CENTRAL BANK OF JAPAN. Financial Institutions Accounts (FA). Tokyo, accessed 16 September 2012 in http://www.boj.or.jp/en/.

CENTRAL BANK OF THE REPUBLIC OF TURKEY. Electronic Data Delivery System-EDDS. Ankara, accessed 16 September 2012 in http://www.tcmb.gov.tr.

CENTRAL BANK OF SWITZERLAND. Banks in Switzerland 2012. Zurich, accessed 16 September 2012 in http://www.snb.ch.

CHINAZZI, Matteo, Giorgio FAGIOLO, Javier A. REYES, and Stefano SCHIAVO. "Post- mortem examination of the international financial network." *Journal of Economic Dynamics and Control* 37, no. 8 (2013): 1692-1713.

COEURDACIER, Nicolas. "Do trade costs in goods market lead to home bias in equities?". *Journal of International Economics* 77, no. 1 (2009): 86-100.

COMBES, Pierre-Phillippe. "Gravity models." In S.N. Durlauf and L.E. Blume, eds. *The New Palgrave Dictionary of Economics.* 2nd edition, London: Palgrave-Macmillan, 2008.

COMISIÓN NACIONAL BANCARIA Y DE VALORES. *Banca de Desarrollo. Portafolio de Información.* México, D.F., accessed 16 September 2012 in http://www.cnbv.gob.mx/Paginas/Index.aspx.

COOPER, Ian, and KAPLANIS, Evi. "Home Bias in Equity Portfolios, Inflation Hedging, and International Capital Market Equilibrium." *Review of Financial Studies* 7 (1994): 45-60.

COVAL, Joshua D. and MOSKOWITZ, Tobias J. "Home Bias at Home: Local Equity Preference in Domestic Portfolios." *The Journal of Finance* 54 (1999): 2045-2073.

ECB (European Central Bank). Consolidated Banking Data, Frankfurt, accessed 16 September 2012 in http://www.ecb.europa.eu/stats/money/consolidated/html/index.en.html, 2012a.

EICHENGREEN, Barry. "Trends and cycles in foreign lending." In H. Siebert, ed. *Capital Flows in the World Economy.* Tübingen (Germany): Mohr (1991): 3-28.

FAGIOLO, Giorgio. "Directed or undirected? A new index to check for directionality of relations in socio-economic networks." *Economics Bulletin* 3, no. 34 (2006): 1-12.

FAGIOLO, Giorgio, Javier REYES, and Stefano SCHIAVO. "World-trade web: Topological properties, dynamics and evolution." *Physical Review E* 79, no. 3 (2009): 036115.

—. "The evolution of the world trade web: a weighted-network analysis." *Journal of Evolutionary Economics* 20, no. 4 (2010): 479-514.

GOLDBERG, Linda S. "Understanding banking sector globalization." *IMF Staff Papers* 56, no. 1 (2009): 171-197.

IAPADRE, Lelio. "Regional integration agreements and the geography of world trade: measurement problems and empirical evidence." In P. De Lombaerde, ed. *Assessment and Measurement of Regional Integration*. London: Routledge (2006): 65-85.

KALI, Raja, Fabio MÉNDEZ, and Javier REYES. "Trade structure and economic growth." *Journal of International Trade & Economic Development* 16, no. 2 (2007): 245-269.

KALI, Raja, and Javier REYES. "The architecture of globalization: a network approach to international economic integration." *Journal of International Business Studies* 38 (2007): 595-620.

—. "Financial contagion on the international trade network." *Economic Inquiry* 48, no. 4 (2010): 1072-1101.

KLEIMEIER, Stefanie, Harald SANDER, and Sylvia HEUCHEMER. "E(M)U effects in global cross-border banking." *Economics Letters* 118, no. 1 (2013a): 91-93.

—. "Financial crises and cross-border banking: New evidence." *Journal of International Money and Finance* 32 (2013b): 884-915.

KOSE, M. Ayhan, Eswar PRASAD, Kenneth S. ROGOFF, and Shang-Jin WEI. "Financial globalization: a reappraisal." Working Paper no. 12484, Cambridge, MA: National Bureau of Economic Research, 2006.

KRUGMAN, Paul R. "Regionalism versus multilateralism: analytical notes." In J. de Melo and A. Panagariya, eds. *New Dimensions in Regional Integration*. Chapter 3, Cambridge: Cambridge University Press (1996): 58-89.

KUNIMOTO, Kazutaka. "Typology of trade intensity indices." *Hitotsubashi Journal of Economics* 17, no. 2 (1977): 15-32.

LANE, Philip R. "Financial globalisation and the crisis." BIS Working Paper no. 397, Basel: Bank for International Settlements, 2012.

LANE, Philip R., and Gian Maria MILESI-FERRETTI. "International financial integration." *IMF Staff Papers* 50 (2003): 82-113.

—. "The drivers of financial globalization." *American Economic Review Papers and Proceedings* 98, no. 2 (2008): 327-332.

LEAMER, Edward E. "A flat world, a level playing field, a small world after all, or none of the above? A review of Thomas L. Friedman's The World Is Flat." *Journal of Economic Literature* 45, no. 1 (2007): 83-126.

LEWIS, Karen K. "Trying to explain home bias in equities and consumption." *Journal of Economic Literature* 37, no. 2 (1999): 571-608.

MCGUIRE, Patrick, and Nikola TARASHEV. "Tracking international bank flows." *BIS Quarterly Review* (2006): 27-40.

MINOIU, Camelia, and Javier A. REYES. "A network analysis of global banking: 1978-2010." *Journal of Financial Stability* 9 (2013): 168-184.

OBSTFELD, Maurice. "International finance and growth in developing countries: What have we learned?" *IMF Staff Papers* 56, no. 1 (2009): 63-111.

OBSTFELD, Maurice, and Alan M. TAYLOR. *Global Capital Markets: Integration, Crisis, and Growth*. Part of Japan-US Center UFJ Bank Monographs on International Financial Markets, Cambridge: Cambridge University Press, 2004.

OFFICE OF THE SUPERINTENDENT OF FINANCIAL INSTITUTIONS CANADA. Financial Data Banks. Ottawa, accessed 16 September 2012 in http://www.osfibsif.gc.ca/osfi/index_e.aspx?articleid=3.

OKAWA, Yohei and VAN WINCOOP, Eric. "Gravity in international finance." *Journal of International Economics* 87, no. 2 (2012): 205-215.

PRASAD, Eswar S. and Raghuram G. RAJAN. "A pragmatic approach to capital account liberalization." *Journal of Economic Perspectives* 22, no. 3 (2008): 149-172.

RESERVE BANK OF AUSTRALIA. Assets of Financial Institutions, Sydney, accessed 16 September 2012 in http://www.rba.gov.au/.

RODRIK, Dani. "Who Needs Capital-account Convertibility?" *Essays in International Finance* no. 207, Princeton, NJ: Princeton University (1998): 55-65.

—. "How far will international economic integration go?" *Journal of Economic Perspectives* 14, no. 1 (2000): 177-186.

ROGOFF, Kenneth S., M. Ayhan KOSE, Eswar S. PRASAD, and Shang-Jin WEI. "Effects of financial globalization on developing countries: some empirical evidence." IMF Occasional Paper no. 220, Washington: International Monetary Fund, 2003.

SAMUELSON, Paul A. "The transfer problem and transport costs, II: Analysis of effects of trade impediments." *The Economic Journal* 64, no. 254 (1954): 264-289.

SCHIAVO, Stefano, Javier REYES, and Giorgio FAGIOLO. "International trade and financial integration: A weighted network analysis." *Quantitative Finance* 10, no. 4 (2010): 389-399.

SCHINDLER, Martin. "Measuring financial integration: a new data set." *IMF Staff Papers* 56, no. 1 (2009): 222-238.

STATISTICS SWEDEN. Financial Markets. Balance sheet for financial enterprises by kind of financial institute and item. Years 1996-2009. Stockholm, accessed 16 September 2012 in http://www.scb.se/default2154.aspx.

STIGLITZ, Joseph E. "Risk and global economic architecture: Why full financial integration may be undesirable." *American Economic Review* 100 (2010): 388-392.

VON PETER, Goetz. "International banking centres: a network perspective." *BIS Quarterly Review* (December 2007): 33-45.

WORLD BANK. World Development Indicators. Washington, D.C., accessed 16 September 2012 in http://data.worldbank.org/data-catalog/world-development-indicators.

4. Systemic Risk, Contagion, and Financial Networks: A Survey

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4.1. Introduction

In recent years, the issue of resilience of financial systems has occupied center stage in both theoretical and applied research (Allen and Babus 2008; Hasman 2012). After the events that culminated with the bankruptcy of Lehman Brothers on September 15, 2008, it has become increasingly clear that in order to explain phenomena such as contagion and systemic risk in financial markets, new methodologies able to address the deep causes of structural vulnerability of the financial sector were needed (Haldane 2009; Catanzaro and Buchanan 2013).

One of the main ideas around which some consensus has been emerging concerns the foremost importance of interaction structure among banks and financial institutions in channeling and amplifying shocks hitting any single agent in the system (May, Levin and Sugihara 2008). In other words, what happens at the aggregate level, i.e. the extent and depth of contagion, may be strongly related to the topology of the web of relationships linking banks and financial institutions in the system (Caldarelli et al. 2013). A better understanding of such a structure should therefore help us in evaluating systemic risk and predicting the aggregate impact of liquidity shocks.

To address these fundamental issues, network theory becomes central (Schweitzer et al. 2009). Indeed, the web of relationships between the main actors of the financial sector (e.g., the interbank market) can be represented as a graph (i.e., a network), where banks are the nodes and edges represent the existence of credit/lending relationships between any two parties. The weight of each edge might be proportional to the magnitude of the exposure between two institutions, while edge directionality may allow us to determine who is the creditor and who is the lender. Network theory allows one to statistically characterize the structure of such graphs and taxonomize them, according to their similarity or dissimilarity features (Caldarelli 2007; Newman 2010; Jackson 2010).

A sensible question therefore regards the way in which different classes of topological structures map into higher or lower systemic risk and resilience. This chapter surveys recent theoretical work that has been trying to recast this issue in terms of network connectivity. In other words, we focus on a simple research question: does a more connected banking network imply a more stable and resilient financial sector? In particular, we examine simple models that have been trying to explain the *robust-yet-fragile* property of the system: i.e. why connections can serve at the same time as shock-absorbers and shock-amplifiers. One of the main results is that, when the network is not too much connected, the higher the connectivity of the system, the higher risk-sharing and diversification happen. However, above a certain connectivity threshold, those connections that before served as a mutual insurance against shocks, can now act as mutual incendiary devices (Haldane 2009).

We discuss how the relevant literature has tried to explain the various ways in which bank and market characteristics—such as bank heterogeneity, moral hazard, imperfect information, changes in asset prices, and capital and liquidity requirements—interact with network connectivity in determining the stability of the financial system. More specifically, we focus on theoretical models that aim to describe and explain how contagion and default cascades might propagate when a financial system is hit by a negative shock (e.g. high demand for liquidity or a sudden default of a bank).

Due to space constraints, we choose not to cover the empirical studies done on the subject (see Upper [2011] and Hasman [2012] for more details on this stream of applied literature). Furthermore, we mostly focus on theoretical setups where the network structure is taken as given, and bank and market characteristics interplay in determining market (in)stability. Although we discuss some papers where the topology of interbank relationships is endogenous itself

(Babus 2007), we refrain from explicitly analyzing how bank and market features do affect network structure.

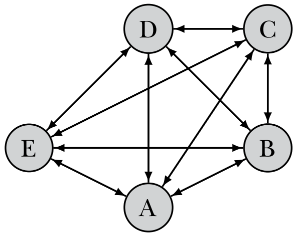
The survey is structured as follows. In section 4.2, we introduce some very stylized theoretical models that explain how, in a minimal setting, connectivity can determine stability or instability of the financial system. Section 4.3 focuses on more sophisticated and recent contributions that apply tools stemming from network theory to explain how the robust-yet-fragile property of the system can emerge in interbank networks. In section 4.4, we study the role played by heterogeneity in influencing systemic resilience, while in section 4.5, we analyze what happens when we introduce some more realistic assumptions regarding the structure of information available to the agents and the incentives to misbehave that banks might have. We also discuss how, by endogeneizing asset prices and adding capital and liquidity requirements, one can affect the probability and extent of contagion (section 4.6). Finally, section 4.7 comparatively discusses pros and cons of the main classes of models analyzed in the survey, and concludes with an appraisal of some of the most relevant research challenges ahead.

4.2. Connectivity, coordination and network formation

For a bank, holding interconnections with other banks always implies dealing with the trade-off between risk sharing and risk of contagion. Indeed, more interconnected balance sheets imply that a negative shock, say liquidity shocks, can be more easily dissipated and absorbed when a bank has multiple counterparties to whom discharge the negative hit. Additionally, connectivity may induce banks to bail out each other in order to prevent contagion, therefore avoiding the intervention of a central planner. However, on the flip side of the argument, a well-connected bank will also have a higher probability of being hit by a negative shock *through* one of its neighbors. Therefore, studying the role of the level and form of connectivity in the interbank credit market is crucial to understand how direct contagion works, i.e. how an idiosyncratic shock may travel through the network of banks and affect the balance sheets of multiple agents.

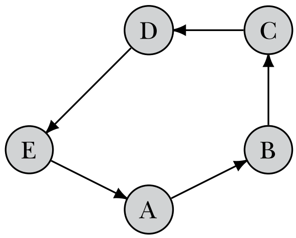
Existing contributions have explored this issue employing three main types of network structures: *directed complete graphs, directed cycle graphs* and *partitioned graphs.* A directed complete graph is a network in which edges are directed and all nodes are connected to each other (see figure 4.1). A directed cycle graph, instead, is a network where edges are directed and nodes are connected in a way that they form a single cycle (see figure 4.2). In other words, some number of vertices are connected in a closed chain. A partitioned graph is a network where some nodes are not connected (not even indirectly) with all the other nodes (see figure 4.3).

FIGURE 4.1: Directed complete graph



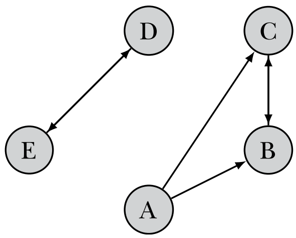
Source: Own elaboration.

FIGURE 4.2: Directed cycle graph



Source: Own elaboration.

FIGURE 4.3: Directed partitioned graph, example



Source: Own elaboration.

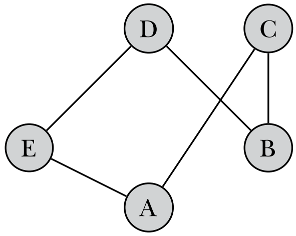
Allen and Gale (2000) seminal work is probably the most well-known contribution on the analysis of contagion through direct interbank credit linkages. In their minimal setting, only four banks are present. Each bank is located in a different region and liquidity shocks are deemed to be negatively correlated across regions. Different demands for liquidity are caused by the presence—in different fractions—of different types of consumers. Following Diamond and Dybvig's preferences (Diamond and Dybvig 1983), agents are of two types: *early-consumers* and *late-consumers*. In particular, assuming that only three time periods $t \in \{0, 1, 2\}$ exist, early-consumers prefer to consume their good at $t = 1$, while late-consumers prefer $t = 2$. However, at $t = 0$ their type is not known since the number of the two types of customers fluctuates randomly across regions albeit the aggregate demand for liquidity remains constant. In this context, banks cannot perfectly forecast the total demand for liquidity they will observe at times $t = 1$ and $t = 2$. This generates an incentive for creating an interbank market to exchange deposits at time $t = 0$, before banks observe the shocks. Regions with liquidity surpluses will provide resources to banks in regions with liquidity shortages provided, whose shocks are negatively correlated across regions. To study contagion, the authors observe what might happen in different network configurations when there exists an excess demand for liquidity at the aggregate level. From a network theory perspective, they consider directed weighted graphs where all edges have the same weights and linkages represent cross-holdings of deposits in different regions.[1] A non-monotonic relationship between completeness and incompleteness of markets is found. In particular, in the case of the directed complete graph, contagion is restricted to only one region, whereas in the case of the directed cycle graph, the crisis extends to all regions. Finally, in the case of the partitioned graph structure, contagion affects only two out of four regions.

[1] A weighted network is a graph where links are given positive weights that represent the strength of bilateral interactions. In weighted directed network, the weight of the directed link $i \rightarrow j$ may be different from the weight of the link $j \rightarrow i$.

An extension of Allen's and Gale's model is provided in Babus (2005). They study what happens when banks endogenously decide the amount of deposits they are going to exchange in the interbank market. Also, liquidity shocks are not necessarily negatively correlated across regions. They consider the case where there are six regions (and hence banks) in total and $\binom{6}{3}$ possible states of the world. In each state of the world, three regions will suffer a high liquidity shock while the other regions will face low liquidity demands. Additionally, banks are affected by an idiosyncratic shock that with a small probability will cause them to default. In terms of network structures, they analyze what happens only in undirected k-regular weighted graphs, i.e. in networks where all nodes have the same degree k (see figure 4.4), a link exists if two banks exchange deposits at time $t = 0$ and edge weights—representing the amount of deposits exchanged—are endogenously chosen.[2] They assume incomplete information regarding the network configuration. Therefore, when the network is incomplete, there would be two sources of uncertainty. First, banks will not know how many of their neighbors are affected by high liquidity demand shocks. Second, they will not know how many links there exist connecting them with banks of *different types,* i.e. with banks that face a liquidity shock different than the one they observe. Instead, in a complete graph, the only uncertainty would regard the types of one's own neighbors. The main result is that banks will allocate their deposits to minimize the loss of value they will incur when one of theirs neighbors is liquidated assuming that the *worst case scenario* occurs. Additionally, in incomplete networks, the allocation which is *ex-ante* optimal, is found to be *ex-post* suboptimal for any realization of the state of the world with except to the worst case scenario. On the contrary, in a complete network, *ex-ante* and *ex-post* optimality coincide since the worst case scenario is realized for any distribution of the liquidity shocks. As a consequence, an incomplete network

[2] In a directed network, the in-degree (respectively, out-degree) of a node is defined as the number of incoming (respectively, outcoming) links of a given node. The degree of a node is simply the sum of its in-degree and out-degree, i.e. the total number of links of a node.

FIGURE 4.4: Undirected *k*-regular graph, example with *k* = 2

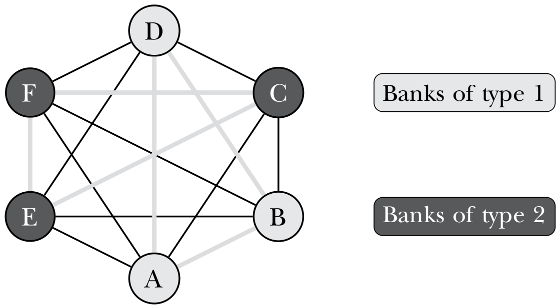


Source: Own elaboration.

is not only more risky in terms of systemic risk—as already found in Allen and Gale (2000)—but decisions made by banks in terms of their exposures are *(ex-post)* suboptimal.

Another interesting extension of the basic framework of Allen and Gale (2000) is instead explored in Babus (2007). In this model, the link formation process is endogeneized and the network is an undirected binary graph where an edge exists only when two banks decide to exchange deposits at time $t = 0$. The assumptions are the same as in the previous model, with just a few differences: there are $2n$ regions (and hence banks), instead of just six regions (and banks), and liquidity shocks are negatively correlated between regions in a predetermined way. As a consequence, there is no uncertainty caused by the absence of a precise correlation structure of the shocks. In order to simplify the model, the author also assumes that the network formation game is played only between banks of the same type. Instead, banks of different types are assumed to be connected as a *complete bipartite graph*. That is, each bank is connected to all banks of type different than its own (see figure 4.5). Given the information about the correlation structure of the shocks, banks can fully insure against liquidity fluctuations and therefore they need only to prevent losses through contagion. Each bank will choose a network structure where the loss of value will incur on their deposits, when one of their neighbors is liquidated, is minimized and the loss should not be higher than the maximum amount of the illiquid asset each bank can liquidate without going bankrupt. If that were not the case, each bank would have been better off by staying out of the interbank market. The limit loss is identi-

FIGURE 4.5: Complete bipartite graph (example): black edges are given, grey edges are determined endogenously



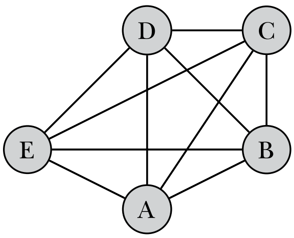
Source: Own elaboration.

cal for each bank and it is independent of the number of links a bank has. Instead, it depends on the average fraction of early consumers present in the system, which in turn depends on the probabilities of observing early and late consumers in the population. By using the notion of *bilateral equilibrium* (as introduced in Goyal and Vega [2007]), the author shows that the network structures which emerge in equilibrium are very likely to support systemic stability, with a probability of contagion that goes to 0 as the number of banks increases. Furthermore, the completeness of the graph is just a sufficient condition for stability, not a necessary one. Indeed, most of the networks turn out to be incomplete.

In order to explore the role played by the type of uncertainty in driving the main results, Freixas, Parigi and Rochet (2000) use a similar setting as in Allen and Gale (2000), but assume that the source of uncertainty is not when agents consume, but where they are going to consume. Consumers have different preferences with respect to *where* they are going to be *when* it is time to consume. There are two types of risk-neutral consumers: *travelers* who consume in other locations and *non-travelers* who consume only in their home location. Travelers, if an interbank market is not in place, will withdraw their money at period $t = 1$—when they discover their type—and carry it to another region. In essence, in this setting, we have a *space-coordination* problem, not a *time-coordination* problem as in Allen and Gale (2000). In this case, banks can decide to create credit lines that give the right to a travel customer coming from, for instance, region i to withdraw when he is in another region *j*, the place where she is planning to consume. Once again, from a network theory standpoint, we are dealing with directed weighted graphs where linkages represent cross-holdings of deposits in different regions. Such credit lines are the mechanism through which contagion can be transmitted in case a bank is not solvent. Insolvency is caused by the fact that banks also invest in risky projects that may provide a cash flow which is not sufficient to repay the contractual obligation they have with their customers. Therefore, a negative exogenous shock on the risky investments may lead to insolvency and contagion. Three possible configurations of the interbank market are studied: the *credit chain interbank funding* case (i.e. a directed cycle graph), where consumers are located around a circle with travelers moving to their clockwise adjacent location (as in Salop's model, see Salop 1979); the *diversified lending* case (i.e. a directed complete graph), where travelers spread uniformly in all locations, and the *autarkic* case (i.e. all nodes are isolated vertices), when banks do not have open credit lines with banks in other regions. Notice that credit flows will be in the direction opposite to agents' movements. Considering what would happen under the different configurations it emerges that, in the diversified case, an insolvent bank is able to share more of its losses with its neighbors. As a consequence, interbank connections allow the system to be more resilient to defaults. However, on the flip side, this also means that market discipline is weakened in the diversified case, compared to the credit chain network case since an insolent bank might be able to survive. In the credit chain network, instead, a smaller loss can trigger contagion with respect to what would happen in the diversified case. Additionally, the diversified lending configuration is always stable when the number of banks is large enough, while additional nodes have no impact on the stability of the credit chain structure. Lastly, the autarkic configuration is proven to be the safest option. However, in autarky, banks will invest less money on the risky assets and efficiency would be lower compared to having open credit lines with banks. Therefore, there is a trade-off between having a risky interbank credit market and a safe autarkic payment mechanism that foregoes investment opportunities.

Another possible source of uncertainty concerns the initial endowment of money that each bank receives. In order to investigate whether this may have an effect in the trade-off that exists between risk-sharing and risk of contagion in the design of an optimal interbank network, Leitner (2005) assumes that at $t = 0$ each bank needs to have an endowment of at least one unit of good in order to be able to invest. Otherwise, it would be impossible to invest in the project. Therefore, in this context, we have an undirected binary graph where a link exists between two agents when they can transfer endowments among themselves, and a negative liquidity shock would mean observing an endowment smaller than one. Additionally, the project itself will produce a cash flow only if the investing bank and all its neighbors are investing one unit of good in the project. As a consequence, being part of an interbank market has two effects: on one side, a bank hit by a negative liquidity shock can use its connections to collect enough resources to allow itself to invest in the project; on the other side, a negative shock affecting just one neighbor, preventing it from investing in the project, will also cause all its neighbors to default. It also means that when agents are not linked together, only the one who realizes high endowments will invest and they will not have any incentive in helping unfortunate banks. Instead, when a connection is indeed present, the same agent will help their neighbors, otherwise all projects will fail by contagion. Therefore, an incentive will exist for safe banks to bail out troubled banks, without any action from the controlling authority. In order to make the constraints more binding, the author also assumes that banks cannot commit *ex-ante* to: (i) pay out of their initial endowments; (ii) pay out of their projects' cash flows; and (iii) invest in their projects. That is, we are in the extreme situation where agents cannot commit to pay anything and where they will invest on their projects only if they can succeed (i.e. if their connected neighbors are investing too). The result is that even linkages that create the threat of contagion can be optimal. Coordination, in this case, will be achieved through a central planner who proposes an optimal allocation of the endowments and an optimal investments vector to the banks. Then, agents decide whether to accept or reject the proposal which would be executed only if all agents accept. Otherwise, if at least one of them refuses, no transfers are made and agents remain in autarky. The results they obtain are that: *ex-ante,* a fully linked network (i.e. undirected complete graph, see figure 4.6) Pareto dominates an unlinked network (i.e. all nodes are isolated) if the probability that—by pooling all available resources together—all projects could be financed is higher than the probability that a generic bank has to be able to finance a project on its own. However, *ex-post* an unlinked network is better than a fully linked network if, and only if, the realization of the endowments is such that their sum is smaller than the number of banks, but there exists at least one agent with endowment higher than one. The reason being that in a fully linked network no investments will take place, while in an unlinked network at least the agent with endowment greater than one will invest. Moreover, also intermediate network structures—i.e. partitioned graphs—are possible and the probability of adding an additional bank to an existing group is found to depend non-monotonically on the probability of observing negative liquidity shocks. It is possible that when the probability of a shock increases, the disadvantage of adding an agent actually decreases. Lastly, when endowments are identically and independently distributed, it is always the case that for a sufficiently large number of banks, the system converges to optimality with a fully linked network whenever the expected individual amount available for investments is greater than one.

FIGURE 4.6: Undirected complete graph



Source: Own elaboration.

4.3. Connectivity and phase transitions

In order to explain the robust-yet-fragile tendency that financial systems exhibit, a good starting point is to develop simple but formal (analytical) models that can explain phase transitions in contagion occurring when connectivity and other properties of the network vary.

A perfect example of such an approach is the model in Gai and Kapadia (2010). The authors study how the probability and potential impact of contagion is influenced by aggregate and idiosyncratic shocks, network topology and liquidity. The framework employed adopts techniques and concepts coming from the literature of complex networks (e.g. Callaway et al. 2000; Newman, Strogatz and Watts 2001; Strogatz 2001; Watts 2002; Newman 2003), and uses numerical simulations to illustrate and clarify the analytical results obtained. The authors find that the financial system exhibits a robust-yet-fragile tendency. When the probability of contagion is very low, its effects can have widespread consequences. Higher connectivity reduces the probability of default when contagion has not started yet. However, when contagion begins, higher connectivity increases the probability of having large default cascades.

The model portrays N financial intermediaries (i.e. banks), randomly linked together in a directed weighted network where link weights represent interbank liabilities. The banks' balance sheet is formally modeled and it includes, for a generic bank i, interbank assets (denoted by A_i^{IB}) and liabilities (L_i^{IB}), illiquid assets (A_i^M, e.g. mortgages) and deposits (D_i, exogenously determined). As an additional simplifying assumption, total interbank asset positions are assumed to be evenly distributed among all incoming links (i.e. risk sharing is maximized). A bank is solvent if, and only if:

$$(1-\phi)A_i^{IB} - qA_i^M - L_i^{IB} - D_i > 0 \qquad (4.1)$$

where ϕ is the fraction of banks with obligations to i that have defaulted and q is the resale price of the illiquid asset (with $q \in (0, 1]$).

Furthermore, a *zero recovery assumption* is made: when a bank fails, all its interbank assets are lost.

Contagion is modeled by randomly defaulting a node in the network and then observing whether a chain reaction starts. Initially, all banks are solvent and defaults can spread only if the banks neighboring a defaulted node are *vulnerable*. By definition, a bank is vulnerable whenever the default of one of its neighbors causes a loss to its balance sheet such that the solvency condition is no more met. Vulnerability crucially depends on the capital buffer of the bank, which is defined as $K_i \equiv A_i^{IB} + A_i^{M} - L_i^{IB} - D_i$, and on the in-degree of the node.

Define a vulnerable cluster as the set of banks reached following an outgoing link from a vulnerable bank to its end and then to every other vulnerable bank reachable from that end. *Phase transitions* occur when the average size of the *vulnerable cluster* diverges. In particular, phase transitions happen only for intermediate values of average degree and when the initial defaulting bank is within one degree of separation of the vulnerable cluster. Let $\overline{z}$ be the upper bound for the node-average degree z when the phase transition still occurs and $\underline{z}$ be the lower bound. Then, the probability of contagion (i.e. the probability of the average vulnerable cluster size to diverge) is found to depend non-monotonically in $z \in [\underline{z}, \overline{z}]$: for low values of z connectivity, the higher z, the higher is the probability of contagion and larger the size of the vulnerable component, i.e. risk-spreading effects prevail. For high values of connectivity, instead, the risk-sharing effect prevails. Indeed, when z is too low (i.e. $z < \underline{z}$), the network is insufficiently connected to spread contagion. On the contrary, when z is too high (i.e. $z > \overline{z}$), the probability that a bank is vulnerable is too small and contagion cannot spread since there are too many safe banks. When z is very close to $\overline{z}$, the system exhibits a robust-yet-fragile tendency, with contagion occurring rarely, but spreading very widely when it does take place. In addition, once the assumption on the uniform distribution of incoming links is withdrawn, the authors show that their main results still hold, with the only difference that the *window-of-contagion* becomes wider since an uneven distribution of exposures makes banks more vulnerable to the default of some of their counterparties for higher values of z than it would have been otherwise. Finally, numerical simulations show that lowering capital buffers both widens the contagion window and increases the probability of contagion for fixed values of z. Also, when liquidity risk is added—i.e. the price of the illiquid asset is allowed to vary—both the contagion window $[\underline{z}, \overline{z}]$ and the extent of contagion widen.

In Gai and Kapadia (2010) model, shocks hitting the system were not heterogeneous in size. However, intuition suggests that another possible source of phase transitions in contagion models can come from the size of the shock. In order to address this point, Acemoglu, Ozdaglar and Tahbaz-Salehi (2013) use a model where the size of the shock is linked to total excess liquidity in the system. They employ a framework where there are again three time periods and N financial institutions (i.e. banks). Banks observe an initial random endowment e and they can invest in a project that requires e units of capital. However, agents cannot use their own financial resources to invest but they need to borrow them. Furthermore, lending and borrowing opportunities are constrained in the sense that a generic bank i can borrow only a given maximum amount of money from a bank j and this relationship does not need to be symmetric. The entire set of such constraints is described by a directed weighted graph where each edge weight represents this opportunity constraint. Borrowing and lending decisions are endogenously determined by the agents, and a bank can also decide to borrow from outside financiers. Therefore, the existence of a link does not imply that a lending agreement is indeed active.

The project can be liquidated prematurely at a loss or kept until maturity to $t = 2$. Once a bank invests in a project, it will also be accountable for an additional external obligation that must be paid with priority over the other obligations. Stability and resilience of the financial system are defined respectively as the inverse of the expected number of defaults and the inverse of the maximum number of possible defaults. In terms of network structures, they study what happens in a regular directed weighted complete graph, in a regular directed weighted cycle graph and in the γ-*convex combination* of both. That is, a graph where the resulting weighted adjacency matrix can be obtained as a linear combination of the complete and cycle graphs. As far as the size of the shocks is concerned, they consider two cases. One in which a small shock hits the system and one in which a large shock hits the system. A shock is considered small if its size is smaller than the total *excess liquidity* present in the system.[3] Provided that total interbank liabilities and claims are above a certain threshold, delivering sharp implications, as far as the relation between size of the shock and network resilience, is concerned. When a small shock hits the system, the cycle graph turns out to be the least resilient and least stable network, whereas the complete graph is the most resilient and most stable. A convex combination of the two becomes less stable and less resilient as γ increases (the higher the γ, the closer the graph is to the cycle network configuration). Conversely, when the shock is large, the complete and cycle graphs are the least stable and least resilient financial networks. The authors also find that for any δ-connected financial network,[4] for small values of δ the system is strictly more stable and resilient than the cycle and complete configurations.

Such a phase transition occurs because two different *shock absorbers* interplay when negative liquidity shocks hit the system. The first shock absorber is excess liquidity of non-distressed banks, i.e. a negative shock is attenuated once it reaches banks with excess liquidity. The second absorber concerns the fact that, in weakly connected graphs (as the ones implied by δ-connected networks), senior creditors can be forced to bear a greater proportion of losses, limiting the spread of contagion. As a consequence, when a shock is large—i.e. the total excess liquidity is insufficient to

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[3] That is, smaller than the product of the number of banks present in the model times the difference between the cash flows obtained from the investments and the amount of the obligations needed to be paid, which are associated with the investment in the project. Instead, if the opposite holds, the shock is considered to be large.

[4] A financial network is defined to be δ-connected if it contains a collection of banks $M \subset N$ for which the total obligations of banks outside M to any bank in M is at most $\delta \geq 0$, and the total obligations of banks in M to any bank outside of M is no more than δ.

contain it—the second mechanism of absorption comes into play and creates the phase transition.

Furthermore, the authors also consider what would happen if instead of having a single shock, multiple (identical) shocks hit the network. In such a case, a shock is defined to be small if its size is lower than total excess liquidity divided by the number of shocks and it is considered large otherwise. With multiple shocks, equilibrium regimes also depend on two threshold values for the total interbank liabilities and claims: a lower bound $\underline{\varepsilon} > 0$ and an upper bound $\overline{\varepsilon} > \underline{\varepsilon}$. If shocks are small and interbank liabilities and claims are above $\overline{\varepsilon}$, the complete graph would be the most stable and resilient, while the cycle graph would be the least stable and resilient. If shocks are large, when interbank liabilities and claims are above $\overline{\varepsilon}$ complete and cycle graphs would be the least stable and resilient, while the δ-connected system would be strictly more stable than the complete and cycle cases when δ is small. Conversely, when interbank liabilities and claims are above $\underline{\varepsilon}$ but below $\overline{\varepsilon}$, the cycle graph would be the most stable and resilient, while the complete one would be the least stable and resilient. This last (new) result suggests that—in such specific parameterization—claims of senior creditors will be used more effectively as a shock absorption mechanism in the cycle graph than in the complete graph.

Finally, the model allows for an investigation of the consequences of endogeneizing lending decisions. This is done by permitting agents to determine the structure and terms of their bilateral interbank agreements. As far as efficiency is concerned, results suggest that banks are not able to internalize the effects that their lending decisions have on agents different than their immediate creditors. Therefore, since such *financial network externality* cannot be internalized by banks, optimal graphs are either too sparsely or too densely connected as compared to what would have been socially efficient. In addition, a second form of phase transition takes place. When long-term returns from the investment project are made partially pledgeable above a given threshold, there are no network effects on contagion since the excess liquidity within the system can be efficiently reallocated to distressed banks. Therefore, regardless of the network structure of the financial system, no defaults will occur.

So far, we have learnt that phase transitions may be strictly linked, in nontrivial ways, to average properties of the whole network, i.e. average degree. This seems also to imply that understanding contagion effects on networks should require monitoring the detailed structure of the entire network and its evolution over time. Amini, Cont and Minca (2012) challenge this idea and develop an analytical model to study the resilience of the financial system. In particular, they observe how a phase transition occurs whenever the magnitude of the shock is above a certain threshold which is in turn determined by the connectivity structure of the financial system. As in the other cases, the interbank market is modeled as a weighted directed graph where each node represents a bank and link weights are interbank assets and liabilities. Banks have stylized balance sheets that include interbank assets, interbank liabilities and other forms of assets and liabilities (e.g. deposits). The net worth of a bank, as given by its capital, represents the capacity of each bank to withstand a loss before becoming insolvent. The capital ratio is defined as the ratio between capital and interbank assets (not total assets). In this framework, the in-degree of a bank would correspond to the number of creditors and the out-degree to the number of debtors. Every directed link represents an exposure between two institutions. Furthermore, a link is called *contagious* if it represents an exposure that is larger than the capital of the lending bank. They also introduce a resilience measure that is a function of the distributions of in- and out-degrees and on the proportion of contagious links in the network. When the resilience measure is positive, as long as the initial fraction of defaults is below a certain threshold, no cascades will occur. Instead, when such measure is negative, with high probability any node belonging to a connected set that represents a positive fraction of the financial system can trigger the collapse of the whole system. These results hold without assuming a specific probabilistic model for the degree sequence of the nodes or the balance sheet data of banks as long as some mild assumptions are satisfied. Put it differently, they show that positivity of the resilience measure is a necessary condition for avoiding the collapse of the entire financial system. Shocks are applied to the banks' balances sheet by exogenously reducing its external assets by a certain fraction. Then, they study how the default of a given share of nodes affects the resilience and stability of the financial network. They show that there exists a threshold about the size of the negative shock above which the network becomes unstable and vulnerable to contagion. That is, there is a phase transition that indicates the maximal tolerance for stress of a network. Put it differently, if the resilience measure is positive, then as the initial fraction of defaults converges to 0, also the probability of having contagion does. However, if the resilience measure is negative, contagious links percolate and we can have global cascades for any arbitrarily small fraction of initial defaults. As a consequence, from a policy point of view, the resilience measure suggests that it is important to monitor only the subgraph of the contagious links. Therefore, it is crucial to monitor capital adequacy of institutions with respect to their largest exposures, i.e. the ones that can cause a bank to fail entirely. This also implies that there is no need to monitor the entire network.

4.4. Homogeneity versus heterogeneity

In the foregoing sections, we have discussed a number of models that are mainly concerned with the structure of the financial network, but that make fairly simplifying assumptions on the characteristics of banks. However, intuition suggests that bank intrinsic characteristics may play a key role in determining the stability of the interbank market. In this section, we shall therefore analyze how bank heterogeneity, along different dimensions, influences the resilience and the stability of the financial system.

A first dimension along which bank heterogeneity determines the level of systemic risk concerns their size. This issue is studied in Iori, Jafarey and Padilla (2006), who build a model where the banks' primary purpose is to invest consumers' deposits. Resources invested will remain illiquid until the investments reach maturity and investment opportunities are stochastic and bank-specific. In the system there are N_t banks at each time-step t. Each bank observes stochastic liquidity shocks that can cause them to be short in liquidity and for this reason banks form an interbank lending market. The linkages between banks are described by the binary undirected graph randomly generated from an Erdös-Rényi model (Erdös and Rényi 1960) with parameters (p, N_t) (p is the probability that a link exists). As a result of the random shocks to liquidity, at any t, each bank would be either in a *borrowing state,* i.e. it has a liquidity deficit, or in a *lending state,* i.e. it has a surplus of liquidity. Then, during the simulation, each *borrowing bank* will contact, at random, different neighboring *lending banks* in order to receive enough credit that will allow the bank to pay off its obligations, either towards other banks (i.e. interest rates from previous loans) or towards its depositors (i.e. interests on deposits). For each transaction, the amount exchanged between banks is equal to the minimum between demand and supply. Also, a borrowing bank does not receive the liquidity requested until it has lined up enough credit—possibly from many counter-parties—to ensure that it will not fail during the current period. The matching procedure iterates until no further trades are available. Then, banks left with negative holdings of liquidity or that fall short of their remaining debt obligations default. Defaulted institutions are removed from the system and their assets are distributed to depositors and creditors. As mentioned, banks can be either homogeneous or heterogeneous in their size. In the former case, they all have the same amount of deposits at the beginning of the simulations; while in the latter initial deposits are normally distributed. Fluctuations of deposits during the simulations are modeled in three different ways. In the first case, deposits vary proportionally to the square root of each bank's size (model *A);* in the second case, deposits vary proportionally to banks mean size (model *B);* and in the third case, banks face identical deposits distributions, but differ by a scale factor in their investment opportunities distributions (model *C).*

Simulations show that, in the homogeneous case, model *A* and model *B* give qualitatively similar results: increasing connectivity increases stability since more banks—*ceteris paribus*—survive when the density of the network is higher. Higher reserve requirements, instead, interact non-linearly with the risk of bank failures. Increasing reserves requirements initially increases the number of failures, but after a certain point the effects are reversed. That is, increasing reserves stabilizes banks at the individual level, but also reduces the insurance that each institution provides to each other, and the amount of resources shared will be reduced. However, when the threshold is set high enough, the individual stability effect completely dominates the second one and the interbank market freezes due to lack of disposable liquidity. At lower values of reserves, instead, the opposite holds. In terms of contagion, two properties are consistently observed (for a wide range of parameterizations): higher connectivity leads to a slowing down of the rate at which banks fail, i.e. *knock-on* effects from the failure of individual banks are not significant. In the heterogeneous case, increasing connectivity improves the stability of the system, while increasing heterogeneity makes the system more stable in model *A* but not in model *B* and *C*, where heterogeneity makes them more unstable. Once contagion occurs, an increase in connectivity leads to fewer failures at low levels but to more failures after a certain threshold. Therefore, connectivity stabilizes the system up to a certain point, but—whenever defaults start—higher interconnectedness may lead to default avalanches.

Amini, Cont and Minca (2010) analyze instead the role of heterogeneity due to connectivity in the network. In other words, instead of looking at bank heterogeneity in terms of their sheer size, they focus on the number and size of the connections that banks have (i.e., node degree and exposure sequences are heterogeneous across nodes). As in the previous works, the model portrays *N* banks and a directed weighted graph representing the financial system. Nodes represent banks, whereas edge weights describe exposures. Node in-degree denotes the number of debt obligations of that bank and node out-degree represents the number of credit obligations. A bank's balance sheet is composed by interbank assets and liabilities, deposits, capital and other assets. Finally, capital ratio is defined as the ratio of bank's capital over interbank assets.

In their numerical simulations, Amini, Cont and Minca (2010) analyze three cases: in model *A*, the network is scale free with heterogeneous weights (i.e. exposures).[5] In model *B*, the network is still scale free but link weights are homogenous. In model *C* an Erdös-Rényi graph (Erdös and Rényi 1960) with homogeneous weights is employed. Across the three models, nodes have the same average degree. That is, the total number of links in the three networks is the same. This allows the authors to assess how results change when *average connectivity* is kept constant but the actual network topology changes along other dimensions. Scale-free networks are obtained using the random graph model introduced by Blanchard, Chang and Krüger (2003). In this model, for a given out-degree sequence, an arbitrary out-going edge is assigned to an end-node i with probability proportional to $[nd_{out}(i)]^{\alpha}$, where $nd_{out}(i)$ denotes the out-degree for node i and $\alpha > 0$ is a constant parameter. As a consequence, there is a positive correlation between in- and out-degrees with out-degrees being Pareto distributed, and in-degrees being Poisson distributed.

The main result is that the most heterogeneity is introduced, the least the resilience of the network. Indeed, model *C* is found to be the most resilient. Also, average connectivity turns out to be too-simple statistics to explain network resilience. Knowing more detailed information regarding the topology of the network, e.g. the degree distribution or the distribution of link-weights, is essential to understand how contagion may evolve. Furthermore, when the network is scale free, there exists a minimal capital ratio such that, below a certain threshold, the number of defaults diverges. Additionally, given the initial default of a single node, the size of the default cascade increases with the in-degree of the initial defaulting node.

Bank heterogeneity in terms of degrees and assets is instead studied by Caccioli, Catanach and Farmer (2012), who extend the Gai and Kapadia (2010) model. To explore the role of degree heterogeneity, they replace the usual Erdös-Rényi random graph (Erdös and Rényi 1960) with a scale-free one wherein node in- and out-degrees are power-law distributed. The network is a directed weighted graph where, once again, edge weights

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[5] More precisely, distribution of link weights follows a Pareto distribution.

represent exposures (i.e. interbank liabilities and assets). Simulations show that a scale-free topology reduces probability of contagion but does not impact its extent, when the defaulting bank is chosen at random. However, scale-free networks are more fragile when a high-degree node is the target of an attack. Hence, probability of contagion is higher in the case of a targeted attack, even though extent of contagion remains unaffected. The robust-yet-fragile property of the financial system is therefore preserved.

As far as assets heterogeneity is concerned, Caccioli et al. (2012) study how contagion evolves when banks' balance sheets are highly non-uniform, i.e. when the distribution of assets is power-law. The ratio of the total amount of interbank assets over total interbank liabilities is kept constant across nodes. As a consequence of this new configuration, banks are no longer uniformly exposed to the failure of one of their neighbors. Instead, diversification will be less effective in this scenario. When the network is modeled according to an Erdös-Rényi random graph (Erdös and Rényi 1960) and assets are distributed according to a power-law distribution, the authors observe that the window of contagion gets wider as compared to the case when assets were uniformly distributed.

Combining the two forms of heterogeneity (over both degrees and assets), it is possible to investigate whether the systemic importance of an institution depends on whether it is *too-big-to-fail* or rather because it is *too-connected-to-fail.* Results indicate that two different regimes co-exist. When average connectivity is low, probability of contagion due to the failure of the most connected bank is higher than that due to the failure of the biggest node. However, when connectivity is high, the opposite holds. Since real networks appear to be closer to the second scenario, it seems that having banks that are too-big-to-fail is indeed the issue. Additionally, as in previous cases, the extent of contagion is not altered by assuming heterogeneous assets distributions instead of a uniform assets distribution. In terms of capital requirements, the authors also find that targeted policies that increase capital buffers for few, well-connected nodes are not an effective measure to reduce probability of contagion, when heterogeneity is only on the degree distribution of nodes. However, in presence of heterogeneity on balance-sheet sizes, a targeted policy that increases the capital buffers of biggest banks when average connectivity is high leads to a reduction of the contagion probability.

Caccioli et al. (2012) also analyze what happens when disassortative mixing is introduced. That is, when well-connected banks tend to connect with nodes that have few connections, and viceversa. They found that—when an Erdös-Rényi random graph (Erdös and Rényi 1960) is used—disassortativity reduces the probability of contagion. Instead, assortativity in node mixing increases the instability of the system. The underlying intuition is that, in a disassortative network, highly connected nodes act as a screen reducing the probability of failure of less-connected nodes, with whom they are linked. Instead, in an assortative network, poorly connected nodes would have been linked only among themselves and that would make them more prone to failure in case of the default of a neighbor.

A last source of heterogeneity that has been analyzed in the literature regards default probabilities. To explore this issue, Lenzu and Tedeschi (2012) analyze a case where link formation is endogenous and agents differ in their *threshold probability of default:* the higher the threshold probability, the higher bank expected profits. The model depicts a discrete-time system where there are N banks that are interconnected through credit relationships. A bank's balance sheet is composed of long term assets, short term debt and equity. Since no liquidity is immediately available in the market, it must be exogenously generated. Therefore, liquidity surpluses are generated as positive shocks affecting individual banks, while liquidity needs are modeled as negative liquidity shocks. As a consequence, contagion may arise when a bank is hit by an exogenous negative shock to liquidity.

The authors study systemic risk when two random banks are shocked independently, one with a positive shock on liquidity and the other with a negative shock of the same magnitude. The banking network is analyzed as a *flow network,* where credit lines are seen as a way to let the liquidity flow from the node with a liquidity surplus to the one that has a shortage. Furthermore, specific constraints on the lending capacities between each pair of nodes are established. These constraints define the maximum liquidity flow allowed through existing links. Therefore, the flow network is a directed weighted graph where the weight of each edge specifies the liquidity capacity of the link. Transfers of liquidity happen through bilateral lending agreements entered by banks, where the probability that a lender borrows money to another bank depends on the creditworthiness of the borrower —as determined by its expected future profits. Therefore, link formation behaves according to a *preferential attachment* mechanism, where safest and most profitable agents are able to secure more credit lines than weaker banks. *Lending capacity,* in this case, is defined as being the maximum amount of liquidity that a generic lender *i* is willing to provide to a generic borrower *j*. The strength with which preferential attachment works depends on a *herding* parameter that determines the *signal credibility* of the agent: the higher the parameter, the higher the trust on the expectation about others' profits. For low values of the credibility parameter, the graph generated corresponds to a random graph with a binomial (or Poisson) in-degree distribution, where the number of in-neighbors is the number of potential lenders a bank can rely on when additional liquidity is needed. As credibility increases, the graph evolves from an exponential graph, to a scale-free and finally, for high values of credibility, to a pseudo-star. In other words, when credibility is high, herding behavior emerges.

In terms of failures that occur because banks cannot raise any money, the authors find that even though random networks are characterized by a low credibility signal, they are more efficient in re-allocating liquidity—after the double liquidity shock—from banks that have a surplus to the banks that have a shortage. Instead, as the network becomes scale-free with the increase in the credibility signal, banks become more prone to failure due to *illiquidity*. In particular, there would be just a small number of highly trusted agents, leaving all others with very few credit lines and hence being more exposed in case of negative liquidity shocks.

As far as defaults caused by contagion are concerned, instead, the authors observe that betweenness centrality[6] and graph diameter[7] describe pretty well the frequency of default for different levels of credibility. Betweenness decreases linearly with credibility and therefore also re-allocation efficiency decreases, since having more paths passing through the nodes means also that defaults of illiquid banks are less frequent. Defaults for insufficient flow, instead, depend mainly on the diameter of the network. The lower the diameter, the easier it is to transfer liquidity from nodes with surpluses to nodes with shortages. When credibility levels increase, the network becomes more fragmented and therefore the diameter increases making default cascades more likely. In terms of node median capacity, the authors observe that a sharp decrease in median capacity leads to higher instability. In a random network, different banks have roughly the same capacity, whereas when the in-degree distribution becomes power law, capacity is concentrated in fewer nodes. That is, there will be few very large nodes and many smaller nodes. This also means that only few nodes will be able to transfer liquidity. Hence, most of the nodes do not have access to many lenders and thus will fail for lack of liquidity. The average capacity, however, increases with credibility, suggesting a strong heterogeneity in participants' size. This heterogeneity leads the system to be more fragile since there exists a positive correlation between heterogeneity and the number of bankruptcies.

4.5. Imperfect information, moral hazard and bank runs

As we have seen so far, network topology and node characteristics may interact in non-trivial ways to determine the stability and resil-

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[6] Betweenness centrality measures node centrality in a network. It is equal to the number of shortest paths from all nodes to all others, which pass through that node.

[7] The diameter of a graph is the longest shortest path (i.e., the longest graph geodesic) between any two nodes of the graph, where a geodesic between any two nodes is defined as the shortest path (i.e. the shortest number of edges) that must be traversed to go from a node to the other one.

ience of the financial system. However, foregoing results strongly depend on two related assumptions. First, financial markets are characterized by perfect information. Second, no misbehavior on the side of banks is considered.

Starting from this observation, a number of contributions have explored setups where either information about the financial robustness of agents is imperfect or banks have an incentive to misbehave.

For example, Battiston et al. (2012a) analyze the issue of default cascades in a model where banks' balance sheets are interlinked through an exposure matrix, and imperfect information regarding agents' financial robustness characterizes the financial system. In other words, the network is a directed weighted graph where edge weights represent interbank assets and liabilities which can be either short- or long-term. This determines two possible externality mechanisms occurring when a bank defaults. First, a default of a neighbor implies a reduction of the lender's equity. Second, since agents borrow also short-term and information is imperfect, bank runs may lead to fire-selling that will cause a further loss for the agent. The first mechanism is called *external effect of the first type,* while the second is *dubbed external effect of the second type.* The model studies N financial institutions (i.e. banks) connected in a credit network. Banks also trade financial obligations with agents outside the interbank market (i.e. depositors). On the asset side, banks have short-term (liquid) assets, long-term (illiquid) assets, interbank liabilities, bank reserves, and long-term assets such as mortgages or bonds which are not traded within the interbank network. On the liability side, we have short-term debts, long-term debts, interbank liabilities, deposits, and long-term bonds held by the households. The equity base (or net worth) will be determined as a difference between total assets and total liabilities. In turn, the equity ratio of each bank is defined as the ratio of equity over long-term (network) assets and it is used as an indicator of *financial robustness.*

Imperfect information is caused by the fact that agents know which banks have defaulted, but they do not know the exposures to their counterparties, and—therefore—they cannot compute their level of robustness. In terms of external effects of the first type, the law of motion that models the equity ratio implies that financial robustness worsens when the number of defaulting counterparties of the bank increases. Additionally, banks are assumed to evenly share their exposures with their neighbors. Given this formulation, the main determinant of default cascades will be the fraction of defaulting counterparties, which will in turn depend on the probability of having k_{fi} defaults among k_i partners. If defaults are not correlated and the portfolio is large, having several simultaneous defaults among counterparties will be quite rare. Default cascades are studied in a case where the graph is regular with degree k and the initial distribution of robustness is assumed to be Gaussian.

Four possible scenarios might emerge. First, a fragile system is prone to systemic default, even if there are no exogenous shocks. That is, cascade size tends to one as the mean of the distribution of the equity ratios of banks (i.e. the average robustness of the financial system) decreases. Conversely, cascade size remains constant with k when average robustness is low enough. Put it differently, the structure of the network and the level of diversification do not matter.

Second, diversification does prevent systemic defaults, but only when the overall financial conditions are not *too bad*. That is, when financial robustness is not very different across agents and the exogenous shocks are not large, increasing connectivity makes the system more resilient.

Third, diversification may lead to an increased systemic risk for a specific range of values. That is, when initial robustness is heterogeneous and many agents are fragile, an increase in connectivity means that the momentum caused by an initial set of defaults will not be dampened and it will indeed trigger a systemic default when diversification is high.

Fourth, when the system is already fragile, diversification has no effect relatively to the exogenous shocks. That is, systemic default will occur regardless of the level of connectivity whenever agents are fairly homogeneous and average robustness is low.

In terms of external effects of the second type, the authors analyze the case when imperfect information leads to bank runs, i.e. short-term investors do not roll over their debt causing a liquidity problem to banks. Bank i may be *illiquid* even if it is still *solvent,* i.e. even if net worth remains positive. Then, i will need to sell part of its long-term assets, such as securitized mortgages, to cover the value of liabilities to be repaid. Given imperfect information, the authors assume that there is a bank run of *all* creditors whenever the number of defaults is larger than a certain threshold that increases with the financial robustness of agent i. Therefore, by adding the external effects of the second type, a new law of motion for financial robustness will be obtained, where also the role played by fire-sells caused by bank runs is taken into account. When also the external effects of the second type are added, default cascades scenarios change as follows. First, diversification prevents systemic defaults whenever bank runs and large exogenous shocks are absent. In particular, as long as average robustness is positive and that the number of agents is large, there always exists a level of diversification that makes systemic defaults to disappear. Second, when bank runs are present, diversification has an ambiguous effect on systemic risk. The cascade size is first decreasing in k, but—after a certain threshold—it increases with diversification. Third, as also found before, when the system is already fragile, diversification has no effect relatively to the exogenous shocks. Additionally, when partial asset recovery is admitted, the system becomes more robust when diversification is small. However, when diversification is large, then there are no differences with respect to the case when there is no asset recovery.

We now turn to analyze models where banks have an incentive to misbehave. Brusco and Castiglionesi (2007) study how the structure of the interbank market influences financial contagion in the presence of both liquidity shocks and moral hazard. In particular, they show that contagion is a rare event since it is optimal to create financial linkages across regions and invest in the long-term asset only if the probability of bankruptcy is very low. The authors analyze first a model where only two banks and two regions are present and then a model with multiple regions (i.e. banks), studying what happens in network structures *à la* Allen and Gale (2000). That is, the networks are directed weighted graphs where all edges have the same weights and links represent cross-holdings of deposits between different regions.

In the basic model, there are three periods ($t \in \{0, 1, 2\}$), one divisible good (i.e. money), two banks, two regions and three types of assets: (i) an illiquid *safe* asset; (ii) a *gambling* illiquid asset; and (iii) a liquid *short* asset. The latter takes one unit of the good at period t and stores it until $t + 1$, keeping the same value. The safe and gambling assets, instead, generate a profit at period $t + 1$. The gambling asset produces higher returns (but only in probability), whereas the returns from the safe asset are certain. Furthermore, the opportunity to invest in the gambling asset is a random variable and—when the returns are positive—a fraction of the profits is not observable by the depositors and it is appropriated entirely by the banks owners. This last feature of the model is what creates the moral hazard problem. Each region contains a continuum of *ex-ante* identical consumers (depositors) which are—once again—characterized by Diamond-Dybvig's preferences (Diamond and Dybvig 1983). This generates liquidity shocks in the regions. Additionally, there is a second class of agents, called *investors,* which are risk-neutral and are endowed with some units of good at period $t = 0$. Investors can either consume their endowment or buy shares of banks which entitle them to receive dividends. In terms of contracts offered, banks can make contingent contracts, specifying the fraction of each dollar of deposit to be invested in the liquid short-term asset and illiquid long-term asset. However, no control can be enforced on whether the bank is investing in the safe or in the gambling asset. Also, banks respond just with limited liability. The authors show that, given bank's capital and given a contractual obligation of a certain amount of units of good to be invested in the long-term asset, the bank will invest in the safe asset only if the capital of the bank exceeds a given threshold. Therefore, depositors will invest in the long-term asset knowing which is the minimum level of bank capitalization necessary to avoid the moral hazard problem.

As far as liquidity shocks are concerned, we have that the two regions are negatively correlated in terms of liquidity needs. Therefore, banks find it useful to exchange deposits as a coinsurance instrument against regional liquidity shocks since the exchange eliminates aggregate uncertainty and allows the financial system to achieve the first-best equilibrium even when moral hazard behaviors are possible, provided that there is a sufficient amount of capital available. Instead, when the capital available is scarce, there are still parameters configurations where the optimal contracts for depositors will prevent moral hazard only in autarky, but not when financial markets are opened. The reason being that the possibility of coinsurance makes the investment in the long-term asset very attractive, making the depositors willing to accept the risk of their investments being misused by diverting money from the safe long-term asset to the gambling long-term asset. Also, the expected utility generated by the optimal contract will be a decreasing function of the probability of observing the gambling asset and it will converge to the first-best solution when such probability goes to 0 (i.e. when there is no opportunity to invest in the gambling asset). Thus, if financial instability is accepted as a consequence of the opening of the interbank market, it must be the case that instability is a rare event.

The authors consider also scenarios where there are multiple regions and still one representative bank per region. They observe that the results obtained by Allen and Gale (2000) are reversed. That is, a more connected interbank deposit market increases the number of regions hit by bankruptcies as compared to the case where an incompletely connected market is considered. Contrary to Allen and Gale, here bankruptcies are caused by the moral hazard problem—i.e. banks investing in the gambling asset—not by an aggregate liquidity shock that is higher than what the aggregate resources of the financial system could bear. Furthermore, in such a case, no contagion would actually occur given the premises of Brusco's and Castiglionesi's model, since contracts can be made contingent on aggregate liquidity shocks. The only *non-contractable* variable is the return on the gambling asset, which is the only source of contagion and financial instability.

The role of bank misbehavior is also analyzed in Castiglionesi and Navarro (2008), where now returns from investments—unlike in Brusco and Castiglionesi (2007)—also depend on the network structure of the interbank market, which is represented as an undirected binary graph. The setup still envisages three agents: consumers, banks and investors (i.e. banks' shareholders). There are three periods ($t \in \{0, 1, 2\}$), one divisible good (i.e. money) and N regions. As usual, each region hosts one representative bank and a continuum of risk-averse consumers, which are endowed with one unit of good at $t = 0$. Consumers, however, will consume only at $t = 2$ and they have to deposit their endowment in the representative bank of their region until that date. Each bank receives a random endowment of dollars, which represents the bank's capital and it is owned by the investors. An interbank market exists and therefore banks can make transfers across regions. As a consequence, the total amount of capital for bank i would be the sum of the endowment and of the interbank transfers. The sequence of events is the following: at $t = 0$ banks receive their capital and choose the financial network; at $t = 1$ banks' transfers are made and investments are chosen; and at $t = 2$ cash flows are realized and depositors are paid. In terms of investments, banks can choose between two different long-term assets: a safe asset and a gambling asset.

As mentioned, unlike in Brusco and Castiglionesi (2007), here returns from investments depend on the network structure of the interbank market. More precisely, return to bank i for each unit invested (regardless of the asset chose) is equal to $f(k_i)R$, where k_i is the number of neighbors of i and $f(.)$ is a function such that $f' > 0$, $f'' < 0$, $f(0) = 1$ and $f(N - 1) = \rho > 1$. Therefore, the same amount invested in autarky (i.e. $k_i = 0$) will yield lower returns with respect to the same investment made in an open interbank market (when $k_i > 0$).

However, a trade-off exists. Connectivity is beneficial in terms of returns from investments, but has a negative effect on the actual probability that the project chosen by a given bank succeeds: whenever a bank fails, also all its neighbors will fail. For example, if we have a fully connected network with $N - 1$ banks investing in the safe project and only one bank investing in the gambling project, the probability of success for each bank will be only equal to the probability of observing returns from the gambling asset. Instead, if autarky would have been chosen, $N - 1$

banks would have been successful with probability one, while only one bank—the one investing in the gambling project—would have been successful with a probability equal to the likelihood of realizing returns from the gambling asset. This implies that the authors assume a very strong form of fragility within the system. Similarly to Brusco and Castiglionesi (2007), the authors show that banks have an incentive to invest in the gambling asset whenever they are under-capitalized. In particular, banks will invest in the safe asset only if bank capital is greater than a given threshold. This cut-off value is decreasing in the number of neighbors of a generic bank i, increasing in the number of gambling neighbors and increasing in the probability of success of the gambling asset. In this setting, the authors show that the decision of joining a (possibly) fragile financial network can be justified (i.e. optimizing) even when the decision is made *after* that the endowments are realized, not only when there is still uncertainty about them. Therefore, uncertainty on endowments is not a necessary condition to form a fragile financial network, unlike what happened in Leitner (2005).

The model allows one to draw sharp conclusions in terms of optimal network configurations. For example, in the social planner case, a *core-periphery* structure emerges as the *constrained first-best* (CFB) solution to the problem. In particular, we have that the core is composed by the banks that are investing in the safe asset which will be all connected to one another. Instead, in the periphery, we will have gambling banks that can eventually be connected to some core banks and some peripheral banks, depending on the value of the parameters. That is, the higher the probability of success of the gambling asset, the more connected the periphery will be, since the risk of bankruptcy will be sufficiently low that the advantages coming from portfolio diversification (i.e. $f(k)$) will outweigh the risk of collapse. When, instead, the decision process is decentralized, we observe that core-periphery structures are still achieved (when no bank transfers are assumed), even though they may not be exactly equal to the optimal configurations and—in general—investment profile will not be efficient. However, when the probability of success of the gambling asset is high enough, the decentralized solutions are very close to the social planner solutions. Instead, when the probability of success if low, inefficient structures arise in the decentralized case.

4.6. Financial robustness, asset price contagion, capital and liquidity requirements

In addition to the determinants of systemic risk discussed so far, financial-system stability may be also influenced by the actual portfolio composition of banks. Indeed, the amount of capital and liquidity held by the banks, as well as the effects that endogenous changes in asset prices have on stability, all contribute to determine how negative shocks propagate through the interbank network. This issue is taken up in a series of articles, which we briefly review in this section.

A first set of papers (e.g. Cifuentes, Ferrucci and Shin 2005; Nier et al. 2007) show how asset price changes, liquidity and capital requirements interact with connectivity in determining the resilience of the financial system.

For example, Cifuentes et al. (2005) study how capital requirements on banks can cause perverse effects when portfolios valuations are mark-to-market, mainly because financial institutions do not internalize the externalities entailed in their network relationships. In this setting, they demonstrate that systemic resilience and connectivity are non-linearly related, as it was shown by Allen and Gale (2000). However, more interconnected systems may be riskier than less connected ones under particular circumstances.

The authors consider N interlinked financial institutions (i.e. banks), which are connected through an exposure matrix. Hence, we deal here with a directed weighted graph where linkages represent interbank assets and liabilities. Bank liabilities are mark-to-market and banks are assumed to have limited liability (equity cannot be negative). Also, there is the priority of debt over equity, implying that equity value is positive only if the notional obligations and payments of a bank coincide. Banks are required to have a minimum level of capital ratio, i.e. the ratio of bank's equity value to the mark-to-market value of its assets must be above a pre-specified threshold ratio. When banks do not satisfy this requirement, they can sell assets for cash to reduce the size of their balance sheet and hence reduce the denominator, making the capital-asset ratio larger. In addition, it is assumed that banks cannot short sell the assets and that they can sell their illiquid assets only when all their liquid assets have already been sold. Demand for the illiquid assets is downward sloping. In order to compute the equilibrium, the authors use an iterative algorithm that determines at each round the set of banks that are oversized or insolvent and then computes the quantity of the illiquid asset that needs to be sold. Given this quantity, the equilibrium price is computed. Then, all banks re-evaluate their portfolios according to the mark-to-market requirements and the algorithm checks whether all banks are solvent under the new price. If that is the case, the process stops. Otherwise, the procedure is reiterated until an equilibrium is found where all banks are solvent.

Notice that the actual portfolio composition of banks has a direct effect on banks' intrinsic creditworthiness, resilience to shocks and susceptibility to contagion. This implies that banks with significant holdings of liquid assets are less exposed to fluctuations of the price of the illiquid asset, face lower credit risk and create less externalities on the system when they need to settle their liabilities through selling. This happens because they will be selling more of the liquid asset, which has a fixed price, than of the illiquid asset. This generates less price fluctuations. However, banks do not internalize the positive externalities they have on the system when they hold more liquidity, therefore privately determined liquidity is suboptimal. Liquidity and capital requirements have several effects on systemic resilience. In particular, liquidity requirements may be more effective than capital buffers in fore- stalling systemic effects, with liquidity and system connectivity that are substitutes for systemic stability for a wide range of parameter values. Furthermore, high liquidity requirements reduce the impact of contagion via the asset-price channel.

Mixed results are obtained as far as system connectivity is concerned. In particular, more connected systems may lead to higher resilience or higher systemic risk depending on the strength of contagion that occurs through the asset prices channel. That is, without this additional channel, increased connectivity is always beneficial, since it reduces the impact of a single default. When prices are endogenously changed, more connections may imply having more actors selling units of the illiquid asset to recover from their losses—especially when liquidity requirements are low—and therefore this may lead to an increased price impact. However, the asset price channel of contagion may disappear entirely when the number of interlinkages is high enough to allow banks to stand the losses only by selling liquid assets. Therefore, the effects of connectivity on systemic risk are non-linear.

The impact of portfolio composition on systemic risk is further analyzed by Nier et al. (2007), who employ a simulation model to analyze how the ability of the interbank network to absorb negative shocks is related to: (i) banks' capitalization; (ii) size of exposures; (iii) degree of connectivity; and (iv) degree of concentration in the banking sector.

In Nier et al. (2007) the interbank system is modeled as a network where the N nodes are banks and links represent directional lending relationships between two nodes (i.e. a directed weighted graph). The network structure is randomized using an Erdös-Rényi random graph (Erdös and Rényi 1960). For any realization of the network, individual balance sheets for each bank i are randomly populated with external assets, interbank assets, bank equity, consumers deposits and interbank borrowings. To study systemic risk, the external assets of a given bank are hit by a negative idiosyncratic shock with size s_i, which wipes out a certain percentage of the external assets' value. The authors assume priority of (insured) customer deposits over banks deposits, which in turn have a priority over equity. A bank defaults whenever the size of the shock is greater than bank's equity. Losses are evenly distributed among creditors and depositors (provided the priority rules outlined before). Therefore, contagion may occur when the shock is not fully absorbed by the first bank being hit, and it transmits through the interbank network to bank i's creditors. In addition to this basic setting, two extensions of the initial model are analyzed. In the first one, liquidity risk is incorporated in the analysis. An inverse demand function for banking assets is assumed such that when a shock hits a bank, the price of external assets will decline with fire-sales and the total loss suffered will be magnified. In the second extension, a *tiered network structure* is assumed. In other words, the N banks are split in two groups. First-tier banks are tightly connected nodes, which have a high probability of being connected among them, and a smaller likelihood of being connected with banks in the second group. The latter banks, which form the periphery, are mainly connected to first-tier nodes.

One of the main results of the model is that lower levels of equity increase in a non-linear way the number of contagious defaults, i.e. for high levels of equity the system is immune to contagion, while when the equity falls below a given threshold there is a sharp increase in the risk of a systemic breakdown. Furthermore, one can show that the bigger the size of interbank liabilities, the higher is the risk of *knock-out* defaults.

As it happens in other models of systemic risk, contagion is a non-monotonic function of the degree of connectivity. Indeed, for low levels of connectivity, its increase enhances the chances of contagious defaults, while for high levels of connectivity, a further increase reduces the probability of a systemic breakdown.

However, connectedness and the level of capitalization interact, i.e. for less-capitalized systems higher connectivity leads to higher contagion, while for well-capitalized systems the opposite holds. Moreover, higher concentration of the banking system tends to make the interbank network more vulnerable. Liquidity has a similar effect: when liquidity effects are introduced, systemic risk increases.

Finally, as far as network structure is concerned, tiered-structures are not necessarily more prone to systemic risk than non-tiered banking systems.

A second stream of contributions explore instead the role played by the evolution of the financial robustness of each bank in determining how fragile the interbank market is when feedback effects are present.

With this aim in mind, Battiston et al. (2012b) develop a dynamic model of financial robustness where banks are connected in a network of credit relationships. That is, we have a directed weighted graph where edge weights represent interbank assets and liabilities. Financial robustness is defined as the ratio of equity to total assets. This ratio is also used as a proxy for the financial creditworthiness of an agent i and its evolution over time is described using a system of stochastic differential equations. The goal is to build a model that can capture two different features of the financial network: *financial acceleration* (i.e., current variations in equity that depend on past variations in equity itself) and *interdependence* (financial robustness of an agent depends on variations in the robustness of his neighbors).

Financial robustness is modeled as a jump-diffusion process and it is assumed that neighbors of i react whenever they perceive it went through an *atypical* decrease. Therefore, the external finance premium charged by i's counterparties does not depend on the absolute value of agent i's financial robustness, but on its (relative) variations when perceived as atypical. Furthermore, the *sensitivity* of counterparties' reaction and the *amplitude* of the effect of such reaction are parameters of the model. Sensitivity, amplitude and the size of the variations of the idiosyncratic shocks, all determine the strength of the *trend enforcement effect*. The higher the ratio of the amplitude over the sensitivity and size of the variations, the more frequently a negative variation in robustness will be followed by another negative variation, implying that the expected time of default of the agent will be shorter. Additionally, in the presence of financial acceleration, the probability of default increases monotonically with the amplitude of neighbors' reactions. Interdependence, instead, is modeled by considering a set of N agents connected through a network of obligations which is described by an exposure matrix which is also the *weighted adjacency matrix* of the interbank network.[8] *Out-degree* of agent i is going to represent the number of counterparties or neighbors that one bank has and it is a rough measure of the degree of diversification of the agent. The authors also assume that the graph is always regular, i.e. all agents have the same out-degree k. To take into account the fact

[8] I.e. the square matrix W whose generic entry w_{ij} represents the weight of the link from i to j, and is 0 if banks i and j are not linked in the network.

that *i*'s assets include *j*'s liabilities and that the value of a bank's portfolio will depend on the value of the assets of its neighbors, a first order linear degree of dependence between the robustness of the agents is assumed. As a consequence, the average effect of the trend reinforcement depends also on the average level of connectivity as determined by k. When connectivity is not high (small k), it is unlikely that a bank hit by a negative shock will be further penalized; but, when connectivity increases, the fluctuation magnitude gets dominated by the magnitude of the effect of the penalty (i.e. the external finance premium that has to be paid). Put it differently, an increasing level of diversification k in the network is beneficial at first, since it will imply smaller fluctuations to the portfolio and hence longer time to default; however, beyond a certain threshold of k, whenever a bank suffers a *relatively* large negative shock, the effect of trend reinforcement will kick in. In terms of probability of default, when financial acceleration is absent, such probability is decreasing with k; however, once financial acceleration is introduced, diversification is at some point counterproductive and it increases the probability of default. In terms of systemic risk, higher connectivity implies an increase in the correlation of banks trajectories of robustness. As a result, the probability that several banks fail, conditional to the default of at least one of them, is increasing with k. Moreover, when the default of an agent has external effects on its neighbors, the probability of multiple defaults is also growing with k.

In order to study bankruptcy cascades, the authors assume that when bank i defaults, its neighbors' robustness will be decreased by an amount which is proportional to their relative exposure. This implies that only small- or large-sized cascades will appear in the system. In particular, systemic risk is not—in general—monotonically decreasing with risk diversification. The financial system is more likely to be trapped near the threshold at which large cascades occur when the diversification is large, and there exists an optimal level of risk diversification that does not coincide with full diversification.

4.7. Discussion and outlook

This chapter has surveyed recent research trying to explain the ways in which bank and market characteristics—such as bank heterogeneity, moral hazard, imperfect information, changes in asset prices, and capital and liquidity requirements—interact with network connectivity in determining the stability of the financial system.

We have seen that the level of connectivity influences the probability of the system to remain stable. However, the role played by connectivity depends also on how the structure of the network interacts with additional factors which are specific to the interbank market. Heterogeneity of banks, liquidity and capital requirements, incentives to misbehave and indirect contagion via price changes on common assets are all phenomena that can modify the role played by connectivity within the financial system.

Stylized models, as the ones introduced by Allen and Gale (2000), Babus (2005, 2007), Freixas, Parigi and Rochet (2000) and Leitner (2005), all agree that graph incompleteness increases systemic risk and they also stress that having an incomplete network structure is *ex-post* suboptimal (Babus 2005), unless the resources present in the financial system are so scarce that every agent would be better off on its own (Leitner 2005). However, Babus (2007) also stresses how completeness is just a sufficient condition for stability, not a necessary one. Indeed, most networks can still be incomplete but have a low probability of contagion.

More complex analytical and numerical models show how the financial system exhibits a *robust-yet-fragile* property, specifying in a more precise way how connectivity influences stability. In particular, connectivity and size of shocks interact in determining how a financial system may move from a state of stability to a state of instability in an abrupt way (Gai and Kapadia 2010; Acemoglu, Ozdaglar and Tahbaz-Salehi 2013; Amini, Cont and Minca 2012) and complete graphs could even be detrimental when the total values of interbank liabilities and claims traded within the network are large (Acemoglu et al. 2013).

Banks diversity is proven to be another source of fragility for the financial system (Iori, Jafarey and Padilla 2006; Amini, Cont and Minca 2010; Caccioli, Catanach and Farmer 2012; Lenzu and Tedeschi 2012; Battiston et al. 2012a). As Iori, Jafarey and Padilla (2006) show, increasing connectivity is beneficial only when banks have the same size. Instead, when banks are heterogeneous in size, an increase in connectivity may still lead to less failures, but only when interconnectedness is at low levels. Above a given threshold, initial defaults lead to avalanches.

Banks can also be allowed to vary in terms of individual connectivity, with degree and exposure sequences distributed according to scale-free power law distributions (Amini, Cont and Minca 2010; Lenzu and Tedeschi 2012). However, also this type of heterogeneity is proven to be detrimental for stability. Networks where banks can be heterogeneous in connectivity or size will also suffer in case of shocks that directly attack *too-big-to-fail* or *too-connected-to-fail nodes* (Caccioli, Catanach and Farmer 2012). Initial financial robustness can also be heterogeneous across banks. As Battiston et al. (2012a) show, increased connectivity may lead to an increase in systemic risk whenever initial robustness is heterogeneous and many banks are fragile since an initial set of defaults will indeed trigger a systemic default.

Furthermore, when shocks are caused by the misbehavior of the agents, the role of connectivity structurally changes. As shown by Brusco and Castiglionesi (2007), when a moral hazard problem is present and banks can invest in a gambling asset, having a more interconnected interbank market increases the extent of contagion in case of bankruptcies. Moreover, when returns from investments are a function of connectivity—the higher the connectivity of the node, the higher the potential gains—and banks can gamble, Castiglionesi and Navarro (2008) show that *core-periphery* structures emerges.

Imperfect information may also exacerbate contagion by inducing bank runs and fire-sells that also change the effects of connectivity on contagion. For example, Battiston et al. (2012a) demonstrate how imperfect information on the exposures of defaulting banks can lead to bank runs and the role played by connectivity is uncertain in such cases. Indeed, the size of the cascade of defaults is initially decreasing with higher diversification but, after a certain threshold, the dynamics are reversed.

Prudential regulation has also an impact on the stability of the financial system. Liquidity and capital requirements, by altering the behavior of banks, have several effects on systemic resilience. Cifuentes et al. (2005) show that when contagion spreads also through the asset prices channel, liquidity can be a substitute for connectivity to increase systemic stability. Also, liquidity requirements are more effective than the ones on capital. As far as connectivity is concerned, we have that higher connectivity may lead to an increase of systemic fragility especially when liquidity requirements are low. However, for high enough level of interconnectedness, the price contagion channel does entirely disappear. The same result about the non-monotonic effects of connectivity is also obtained by Nier et al. (2007), when we consider the level of capitalization of the system instead of the level of the liquidity requirements.

Additionally, when financial acceleration is introduced (Battiston et al. 2012b), it appears that systemic risk is not—in general—monotonically decreasing with risk diversification. Instead, the optimal level of connectivity does not coincide with full diversification since—at some point—increasing a further increase in connectivity raises also the probability of contagion. Furthermore, conditional to the default of at least one bank, the probability of observing a cascade of defaults is increasing with the level of connectivity.

The main conclusion that can be drawn from the papers covered in this survey is that, depending on the assumptions made, average graph connectivity is found to have a strong impact on systemic resilience. Furthermore, such relationship is almost always non-linear, which implies that policy measures have to be carefully implemented in order to decrease the strength and extent of systemic risk.

Albeit the recent years witnessed a huge increase in contributions dealing with financial networks, contagion and systemic risk, the agenda of relevant research questions seems still full of items.

The first point that requires—in our view—a deeper understanding is the very relationship between network structure and systemic risk in contagion processes. Indeed, most of the existing work has been focusing on a crude and necessarily partial proxy of the topological structure of the financial network, namely its overall connectivity (i.e. density or average degree). Many other details of the topological structure may in fact be relevant to explain diffusion and contagion. For example, the distribution of node clustering[9], the graph-component distribution or the community structure of the graph[10] might all be relevant to understand the extent and strength of avalanches triggered by the default of (or a shock hitting) any single bank. It may be indeed argued that in more clustered graphs, or in networks where there are a smaller and more interconnected number of communities, diffusion may take place more easily.

More generally, more work is needed to map the generic properties of homogeneous classes or families or graphs (i.e. lattices, regular networks, small-world networks, scale-free networks, etc.) into different contagion behaviors. In particular, the role of link-weight distributions, i.e. the heterogeneity of link intensities, should be more carefully scrutinized. In most of existing models, indeed, one assumes that links are weighted in homogeneous ways, i.e. one simply equally distributes aggregate node values among existing links. Intuition suggests that the precise type of link-weight heterogeneity can go a long way in explaining the extent of contagion in financial networks. Since there are not so many models of weighted-directed formation in the literature, this research avenue also requires a deeper knowledge of the network-formation mechanisms, which describes the birth-death of links and evolution of the associated weights.

This could pave the way toward a better understanding of the different impact that local versus global network statistics can have on contagion and systemic risk. For example, nodes may be

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[9] Node clustering is defined in a binary graph as the probability that any of two partners of a given node are themselves partners.

[10] A component of a graph is a minimal subset of nodes that are connected, i.e. for which any two nodes are connected by a path going through the nodes of the subset. A community structure is a partition of the nodes of the graph, induced by observed topology, where the nodes in each set of the partition are more strongly linked between each other than they are with nodes belonging to different sets of the partition. See Newman (2010) for an introduction.

central in the network at a local level, because they hold many connections, but being poorly globally central because the nodes they are linked with are themselves of a little importance in the system. Therefore, sometimes it is more useful to have less links but with very important nodes. This trade-off is mostly absent in existing studies (with the exception of Lenzu and Tedeschi 2012), which mostly explore the role of average connectivity, without looking at global centrality indicators.

Finally, there still seems to exist a large gap between the network structures used in systemic-risk models and real-world evidence.[11] Whereas the literature now features a lot of empirical studies looking e.g. at the empirical properties of real-world (country-specific) interbank markets, a large part of theoretical models still employ very rudimental network structures to describe connectivity patterns among banks.[12] This is legitimate, as one would like to obtain efficiency and optimality results, and in general play with simple structures in mathematically-constructed models that can deliver sharp and closed-form implications. Nevertheless, using simulation-based models, it might be worthwhile to build more realistic models where the financial network is shaped as much as possible as the one that we can observe in the real world.

References

ACEMOGLU, Daron, Asuman OZDAGLAR, and Alireza TAHBAZ-SALEHI. "Systemic risk and stability in financial networks." NBER Working Paper no. 18727, Cambridge, MA: National Bureau of Economic Research, 2013, available at NBER. http://www.nber.org/papers/w18727.

[11] In the last years, a long list of papers has been exploring the statistical properties of real-world inter-bank networks. See for example Sheldon and Maurer (1998); Blåvarg and Nimander (2002); Furfine (2003); Martínez Jaramillo et al. (2012); Boss et al. (2004); Cifuentes (2004); Upper and Worms (2004); Wells (2004); Amundsen and Arnt (2005); Lublóy (2005); Elsinger, Lehar and Summer (2005, 2006); Soramaki and Galos (2005); Müller (2006); Degryse and Nguyen (2007); Frisell et al. (2007); Cocco, Gomes and Martins (2009); Craig and von Peter (2010); Iyer and Peydro (2011); Mistrulli (2011).

[12] With some notable exceptions where the employed network can be somewhat calibrated to real-world data, see for example Amini, Cont and Minca (2010), among others.

ALLEN, Franklin, and Ana BABUS. "Networks in finance." Working Paper no. 08-07, Philadelphia, PA: The Wharton Financial Institutions Center, 2008, available at SSRN. http://ssrn.com/abstract=1094883.

ALLEN, Franklin, and Douglas GALE. "Financial contagion." *Journal of Political Economy* 108, no. 1 (2000): 1-33.

AMINI, Hamed, Rama CONT, and Andreea MINCA. "Resilience to contagion in financial networks." Working Paper, December 2010, available at SSRN. http://ssrn.com/abstract=1865997.

—. "Stress testing the resilience of financial networks." *International Journal of Theoretical and Applied Finance* 15, no.1, February 2012.

AMUNDSEN, Elin, and Henrik ARNT. "Contagion Risk in the Danish Interbank Market." Working Paper no. 29/2005, Copenhagen: Danmarks Nationalbank, 2005, available at http://www.nationalbanken.dk/C1256BE9004F6416/side/096E4F0B594E00B2C125706E00480612/$file/wp29.pdf.

BABUS, Ana. "Contagion risk in financial networks." In K. Liebscher, ed. *Financial Development, Integration and Stability*. Cheltenham, UK: Edward Elgar (2005): 423-440.

—. "The formation of financial networks." FEEM Research Paper no. 69.2007, Milan: FEEM (Fondazione Eni Enrico Mattei), 2007, available at SSRN. http://ssrn.com/abstract=939754. [Previous version published as Discussion Paper no. 2006-093/2, Amsterdam, Tinbergen Institute, 2006].

BATTISTON, Stefano, Domenico DELLI GATTI, Mauro GALLEGATI, Bruce GREENWALD and Joseph STIGLITZ. "Default cascades: When does risk diversification increase stability?" *Journal of Financial Stability* 8, no. 3 (2012a): 138-149.

—. "Liaisons dangereuses: Increasing connectivity, risk sharing, and systemic risk." *Journal of Economic Dynamics and Control* 36 (2012b): 1121-1141.

BLANCHARD, Philippe, C. H. CHANG, and Tyll KRÜGER. "Epidemic Thresholds on Scale- Free Graphs: the Interplay between Exponent and Preferential Choice." *Annales Henri Poincaré* 4, suppl. 2 (2003): S957-S970.

BLÅVARG, Martin, and Patrick NIMANDER. "Interbank exposures and systemic risk." In *Risk Measurement and Systemic Risk*. Proceedings of the Third Joint Central Bank Research Conference, Bank for International Settlements, Basel, 7-8 march 2002, 287-305.

BOSS, Michael, Helmut ELSINGER, Martin SUMMER, and Stefan THURNER. "Network topology of the interbank market." *Quantitative Finance* 4, no. 6 (2004): 677-684.

BRUSCO, Sandro, and Fabio CASTIGLIONESI "Liquidity coinsurance, moral hazard, and financial contagion." *The Journal of Finance* 62 (2007): 2275-2302.

CACCIOLI, Fabio, Thomas A. CATANACH, and J. Doyne FARMER. "Heterogeneity, correlations and financial contagion." *Advances in Complex Systems* 15, suppl. no. 2 (2012): 1250058.

CALDARELLI, Guido. *Scale-Free Networks: Complex Webs in Nature and Technology*. Oxford University Press, 2007.

CALDARELLI, Guido, Alessandro CHESSA, Fabio PAMMOLLI, Andrea GABRIELLI, and Michelangelo PULIGA. "Reconstructing a credit network." *Nature Physics* 9 (2013): 125-126.

CALLAWAY, Duncan S., M. E. J. NEWMAN, Steven H. STROGATZ, and Duncan J. WATTS. "Network robustness and fragility: Percolation on random graphs." *Physical Review Letters* 85 (2000): 5468-5471.

CASTIGLIONESI, Fabio, and Noemí NAVARRO. "Optimal fragile financial networks." *Second Singapore International Conference on Finance 2008,* EFA 2008 Athens Meetings Paper, 2008, available at SSRN. http://ssrn.com/abstract=1089357.

CATANZARO, Michele, and Mark BUCHANAN. "Network opportunity." *Nature Physics* 9 (2013): 121-123.

CIFUENTES, Rodrigo. "Banking Concentration: Implications for Systemic Risk and Safety- net Design." In L. A. Ahumada, J. R. Fuentes, N. Loayza and K. Schmidt-Hebbel, eds. *Banking Market Structure and Monetary Policy. Central Banking, Analysis, and Economic Policies* Book Series, Santiago, Central Bank of Chile (2004): 359-385.

CIFUENTES, Rodrigo, Gianluigi FERRUCCI, and Hyun Song SHIN. "Liquidity risk and contagion." *Journal of the European Economic Association* 3, no. 2-3 (2005): 556-566.

COCCO, Joao F., Francisco J. GOMES, and Nuno C. MARTINS. "Lending relationships in the interbank market." *Journal of Financial Intermediation* 18, no. 1 (2009): 24-48.

CRAIG, Ben R., and Goetz VON PETER. "Interbank Tiering and Money Center Banks." Working Paper no. 10-14, Federal Reserve Bank of Cleveland, 2010, available at SSRN. http://ssrn. com/abstract=1687281.

DEGRYSE, Hans, and Grégory NGUYEN. "Interbank exposures: An empirical examination of contagion risk in the Belgian banking system." *International Journal of Central Banking* 3 (2007): 123-171.

DIAMOND, Douglas W. and Philip H. DYBVIG. "Bank Runs, Deposit Insurance, and Liquidity." *Journal of Political Economy* 91 (1983): 401-419.

ELSINGER, Helmut, Alfred LEHAR, and Martin SUMMER. "Using Market Information for Banking System Risk Assessment." Working Paper, August 2005, available at SSRN. http://ssrn.com/abstract=787929.

—. "Risk assessment for banking systems." *Management Science* 52, no. 1 (2006): 1301-1314.

ERDÖS, Paul, and Alfréd RÉNYI. "On the evolution of random graphs." *Magyar Tud. Akad. Mat. Kutató Int. Közl* 5 (1960): 17-61.

FREIXAS, Xavier, Bruno M. PARIGI, and Jean-Charles ROCHET. "Systemic Risk, Interbank Relations, and Liquidity Provision by the Central Bank." *Journal of Money, Credit and Banking* 32, no. 2 (2000): 611-638.

FRISELL, Lars, Mia HOLMFELDT, Ola LARSSON, Milan OMBERG, and Mattias PERSSON. "State-Dependent Contagion Risk: Using Micro Data from Swedish Banks." *Mimeo,* Department of Financial Stability, Sveriges Riksbank, October 2007.

FURFINE, Craig. "Interbank exposures: Quantifying the risk of contagion." *Journal of Money, Credit and Banking* 35 (2003): 111-128.

GAI, Prassana, and Sujit KAPADIA. "Contagion in financial networks." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science* 466, no. 2120 (2010): 2401-2423.

GOYAL, Sanjeev, and Fernando VEGA REDONDO. "Structural holes in social networks." *Journal of Economic Theory* 137, no. 1 (2007): 460-492.

HALDANE, Andrew G. "Rethinking the financial network." *Speech delivered at the Financial Student Association,* Amsterdam, April 28, 2009.

HASMAN, Augusto. "A critical review of contagion risk in banking." *Journal of Economic Surveys,* 2012, doi:10.1111/j.1467-6419.2012.00739.x.

IORI, Giulia, Saqib JAFAREY, and Francisco G. PADILLA. "Systemic risk on the interbank market." *Journal of Economic Behavior and Organization* 61, no. 4 (2006): 525-542.

IYER, Rajkamal, and José Luis PEYDRO. "Interbank contagion at work: Evidence from a natural experiment." *Review of Financial Studies* 24 (2011): 1337-1377.

JACKSON, Matthew O. *Social and Economic Networks.* Princenton, NJ: Princeton University Press, 2010.

LEITNER, Yaron. "Financial networks: Contagion, commitment, and private sector bail-outs." *The Journal of Finance* 60 (2005): 2925-2953.

LENZU, Simone, and Gabriele TEDESCHI. "Systemic risk on different interbank network topologies." *Physica A: Statistical Mechanics and its Applications* 391, no. 18 (2012): 4331-4341.

LUBLÓY, Ágnes. "Domino effect in the Hungarian interbank market." *Hungarian Economic Review* 52 (2005): 377-401.

MARTÍNEZ JARAMILLO, Serafín, Biliana ALEXANDROVA KABADJOVA, Bernardo BRAVO BENÍTEZ, and Juan Pablo SOLÓRZANO MARGAIN. "An Empirical Study of the Mexican Banking System's Network and Its Implications for Systemic Risk." Bank of Mexico Working Paper no. 2012-07, August 2012.

MAY, Robert M., Simon A. LEVIN, and George SUGIHARA. "Complex systems: ecology for bankers." *Nature* 451 (2008): 893-895.

MISTRULLI, Paolo E. "Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns." *Journal of Banking and Finance* 35, no. 5 (2011): 1114-1127.

MÜLLER, Jeanette. "Interbank Credit Lines as a Channel of Contagion." *Journal of Financial Services Research* 29, no. 1 (2006): 37-60.

NEWMAN, Mark E. J. "Random graphs as models of networks." In S. Bornholdt and H. G. Schuster, eds. *Handbook of Graphs and Networks: From the Genome to the Internet.* Weinheim (Germany): Wiley-VCH (2003): 35-68.

—. *Networks: An Introduction.* Oxford University Press, 2010.

NEWMAN, Mark E.J., Steven H. STROGATZ, and Duncan WATTS. "Random graphs with arbitrary degree distributions and their applications." *Physical Review* E 64 (2001): 026118.

NIER, Erlend W., Jing YANG, Tanju YORULMAZER, and Amadeo ALENTORN. "Network models and financial stability." *Journal of Economic Dynamics and Control* 31, no 6 (2007): 2033-2060.

SALOP, Steven C. "Monopolistic Competition with Outside Goods." *The Bell Journal of Economics* 10, no. 1 (1979): 141-156.

SCHWEITZER, Frank, Giorgio FAGIOLO, Didier SORNETTE, Fernando VEGA REDONDO, Alessandro VESPIGNANI and Douglas WHITE. "Economic networks: The new challenges." *Science* 325, no. 5939 (2009): 422-425.

SHELDON, George, and Martin MAURER. "Interbank lending and systemic risk: an empirical analysis for Switzerland." *Revue Suisse d'Économie et de Statistique* 134 (1998): 685-704.

SORAMAKI, Kimmo, and Peter GALOS. "Systemic Risk in Alternative Payment System Designs." ECB Working Paper no. 508, Frankfurt: European Central Bank, 2005, available at SSRN. http://ssrn.com/abstract=750788.

STROGATZ, Steven H. "Exploring complex networks." *Nature* 410 (2001): 268-276.

UPPER, Christian. "Simulation methods to assess the danger of contagion in interbank markets." *Journal of Financial Stability* 7, no. 3 (2011): 111-125.

UPPER, Christian, and Andreas WORMS. "Estimating Bilateral Exposures in the German Interbank Market: Is there a Danger of Contagion?" *European Economic Review* 48, no. 4 (2004): 827-849.

WATTS, Duncan. "A simple model of global cascades on random networks." *Proceedings of the National Academy of Sciences* 99 (2002): 5766-5771.

WELLS, Simon J. "Financial Interlinkages in the United Kingdom's Interbank Market and the Risk of Contagion." *Bank of England Working Paper* no. 230, 2004, available at SSRN. http://ssrn.com/abstract=641288.

5. Hubs and Resilience: Towards More Realistic Models of the Interbank Markets

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5.1. Introduction

In the last decades, more and more efforts have been directed to the study of interbank financial data using tools initially developed in the natural sciences, with the aim to shed light on the contagion effects of shocks through interbank linkages. In particular, a better understanding of the link between the topology of a financial system, where an intricate network of financial entities (like banks and hedge funds) are connected together through a complex web of financial instruments, and the stability of the system itself, namely the ability of networks to absorb shocks and adapt the structure in order to maintain efficiency, became a major issue (Battiston et al. 2009). The relevance of the network structure for regulatory reform of the banking sector has been emphasized by Haldane and May (2011), among others.

The risk of a global systemic failure of the whole system is strongly related to the topological features of the financial network, and it gives rise to the crucial concept of systemic risk. Since the pioneering work of Allen and Gale (2000), in which the relevance of the structure of a financial system for its stability has been highlighted, the study of systemic risk using network approaches has attracted

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the attention of economists and scientists in general. Nier et al. (2007) have studied a simple but versatile random network structure, where the nodes of the networks represent banks and the edges represent interbank liabilities, combined with a representation of the banks' balance sheet. They show how the resilience of the whole system to idiosyncratic shocks is affected by the topological features of the system, such as the connectivity of the nodes. May and Arinaminphaty (2010) provide an analytical explanation of these results using a mean-field approach, providing more insights into the connections between complexity and stability.

The main aim of this chapter is to expand this line of research into the determinants of systemic risk in simulated banking systems. By systemic risk we mean the risk of a whole financial system, in this case a set of banks, to collapse as an aftereffect to the initial default of a single unit or a small cluster. After the default of the first bank, the shock is transmitted through the whole system due to a web of debt relationships. This domino effect may cause the whole system to fail. As in the case considered by Nier et al. (2007) and May and Arinaminphaty (2010), our networks are static since the single nodes, namely the banks, are not allowed to change their behavior during the spread of the shock, they just passively absorb the propagation of the losses. We are, therefore, considering a situation in which the spread of the shock through the system is faster than the potential changes of the topological features of the interbank network that would be manifested after the reaction of the banks themselves.

In network theory, if high-degree nodes attach to low-degree ones, the resulting graph is said to display a *disassortative mixing* or *disassortative behavior*. A simple way to identify such a structure consists in studying the distribution of the average degree of the neighbors of the nodes belonging to the network. In the case of disassortative mixing, this distribution should be a decreasing function in the degree of the nodes, as a consequence of the attitude of high-degree nodes to link with low-degree ones, and *vice versa*. Disassortative mixing is a frequent feature of real networks, examples are the internet, the World Wide Web, protein interactions and neural networks (Caldarelli 2007). Interestingly, also most of the interbank money markets seem to be characterized by disassortative behavior, as documented by Boss et al. (2004) for the Austrian interbank market, Soramäki et al. (2006) for the US Fedwire Network, Iori et al. (2008) for the Italian interbank market, and Imakubo and Soejima (2006) for the Japanese interbank money market. Therefore, it seems important to include the well-established stylized fact of disassortative mixing also in the study of artificial financial networks, since this particular structure could affect the ability of a system to absorb shocks. Another feature that is often present in real networks is a characteristic power law degree distribution that produces the so-called *scale-free networks.* Scale-free networks are characterized by the presence of hubs, namely nodes with a degree that is much higher than the mean degree of the other nodes. Therefore, in a scale-free network, there is a high probability that many transactions would take place through the high-degree nodes of the network. The presence of such hubs make systems in general more prone to a break-down in case of targeted attacks, as the downside of their high connectivity in terms of the shortest paths between any two nodes belonging to the system. Again, in real interbank money markets scale-free degree distributions have been frequently reported. Examples are Inaoka et al. (2004) and Imakubo and Soejima (2006) for the Japanese interbank market, and Boss et al. (2004) for the Austrian interbank market, while there exist divergent results for the Italian interbank market (Iori et al. 2008; Finger, Fricke and Lux 2013).

Empirical evidence on the size distribution of a bank's balance sheet can be found in, for example, Ennis (2001) and Janicki and Prescott (2006). For the US, the banking system is characterized by a large number of small banks and a few large banks, and the size distribution seems to be lognormal with a Pareto-distributed tail. A study on the evolution of the banking system in a European Country can be found in Benito (2008), where the presence of few big hubs in the Spanish banking system is highlighted, and, again, the distribution is highly skewed, and it has become more skewed during the last decades.

We construct a Monte Carlo framework for an interbank market characterized by the above empirical features via what is called a *fitness algorithm* (De Masi, Iori and Caldarelli 2006). With a particular choice of such a function as a generating mechanism for our network, we can make sure that our artificial banking sector also displays a power law degree distribution, disassortative behavior and heterogeneity in the banks' sizes. In particular, in interbank markets characterized by a power law in the size distribution, the default of a single small or medium-sized bank will not affect the stability of the entire system: as one might expect, the losses are easily absorbed by the banks which have deposits on the liability side of the failing bank's balance sheet, and no domino effect occurs. The situation changes when the initially defaulting bank is one of the hubs of the system. In this case, the propagation of the shock proceeds like the propagation of a circular wavefront in the water: starting from an initial node, the shock will hit at the same time nodes that are directly linked to the source. Moreover, each time a new node is hit by a wave, it also will become a source itself, expanding the range of nodes that will potentially be affected by the shock. Those are the kind of network effects we are interested in. Note that the results reported so far in the literature using network approaches in order to study domino effects in interbank markets have mostly used either random network models or networks constructed from aggregate data via a maximum entropy principle (see Upper 2011, for an overview). Both approaches are very likely to underestimate the extent of a contagious spread of disturbance due to the very homogeneous level of activity and connectivity in such artificial networks. In contrast, the above stylized facts show strong heterogeneity for the levels of activity (size of the balance sheets, as well as the extent of connectivity, namely the degree distribution). In addition, the pronounced negative assortativity is also not covered by random networks or those constructed from entropy principles. Moreover, random networks are characterized by a binomial degree distribution (see, for example, Caldarelli 2007), and so no major hubs exist in such a system. Using power law degree distributions, the process of propagation of endogenous shocks could bring about different results, and should in principle give a more realistic picture of the underlying phenomena.

Next, section 5.2 introduces the generating mechanism for realistic (along certain important dimensions) interbank markets, section 5.3 provides a summary of the main properties of the networks produced by our model, and section 5.4 introduces the mechanism for the propagation of the shocks and shows the result from the Monte Carlo simulations. Finally, section 5.5 concludes.

5.2. Generating mechanism for a scale-free banking system

We consider an interbank market (IbM) composed of n financial entities linked together by their claims on each other. It seems natural to use network theory in order to represent and study such a system: each bank in the IbM will be represented as a node in the network, and the information of the loans among banks will be included in the edges of the network. These edges are directed and weighted, the weight of the link starting from node i and pointing to node j being the total amount of money that bank i lends to bank j. In order to proceed a modest step towards a more realistic representation on the interbank market, we will construct our financial system in a way to represent the documented empirical features highlighted in the introduction. Following Nier et al. (2007), we use the scheme represented in figure 5.1 in order to represent the banks' balance sheet. The assets A_i of each bank $(i = 1, 2, \ldots, n)$ are partitioned into interbank loans l_i and external assets e_i:

$$A_i = l_i + e_i \tag{5.1}$$

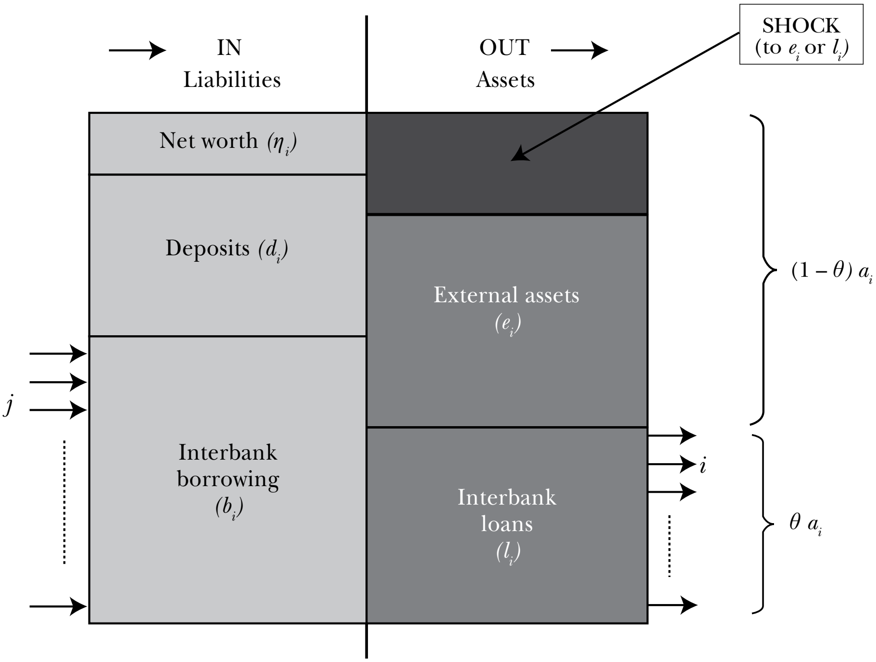
The liabilities I_i of each bank are partitioned into the internal borrowing b_i, customers' deposits d_i, and the net worth η_i:

$$I_i = b_i + d_i + \eta_i \tag{5.2}$$

Solvency requires that the difference between banks' assets and liabilities is positive, that is:

$$\eta_i \equiv (l_i + e_i) - (d_i + b_i) \geq 0 \tag{5.3}$$

FIGURE 5.1: Banks' balance sheet



If equation (5.3) is not fulfilled, bank i becomes insolvent. Note that we could instead impose a minimal capital requirement and intercept the bank's operations if its capital falls below a threshold. For most purposes that would leave our results qualitatively unchanged as it would just lead to a linear rescaling of the balance sheet.

Following Nier et al. (2007), we impose the following relations, which hold for all banks belonging to the IbM:

$$e_i = \theta A_i \tag{5.4}$$

$$l_i = (1-\theta)\, A_i \tag{5.5}$$

$$\eta_i = \gamma A_i \tag{5.6}$$

This enables us to characterize the evolution of the banks' balance sheet using the common pair of parameters θ and γ. Unlike Nier et al. (2007), who investigate a banking sector with banks of equal size of balance sheets and interbank liabilities, we try to mimic some of the documented dimensions of heterogeneity in the banking sector.

The empirical properties of real interbank networks that we attempt to reproduce are the disassortative behavior and power law in the degree and size distributions. To this end, we arrange the nodes on a scale-free network according to the following algorithm:

1. We start with an assumption on the distribution of the size of the banks. Using A_i as parameter indicating the size of a bank, we assume that $\rho\,(A_i) \propto A_i^{\tau}$ (and $A_i \in [a, b]$) so that the sizes distribution will follow a power law, and in the following we will use $\tau = 2$. We note that since this formalism defines the size distribution over a finite range, the numbers a and b defining the absolute range of bank sizes will also be of some relevance.
2. Once we have drawn the n-element set $\{A_i\}$, i.e. the distribution of the total external assets of the banks, we compute the external assets e_i, the interbank loans l_i and the net worth η_i, according to equations (5.4)-(5.6).
3. We use now the size parameter A_i as the *peculiarity* of the node. This basically means that we add interbank liabilities to the system in relation to the sizes of each pair of potential trading partners. In order to build up networks in this way, we use a *probability function* $P(A_i, A_j)$*:* this function provides the probability that a bank i (characterized by total external assets A_i) lends money to bank j (characterized by total external assets A_j). In most real IbMs, a pool of small and medium-sized banks usually lend money to the biggest banks of the system, which in turn redistribute liquidity to external financial markets or within the IbM itself (Iori et al. 2008; Cocco, Gomes and Martins 2009; Lux and Fricke 2012). The choice of an appropriate probability function allows to reproduce those important em-

pirical observations. In the following, we will use the three following alternative probability functions for generation of links:

$$P_1\left(A_i, A_j\right) = \left(\frac{A_i}{A_{max}}\right)^{\alpha} \cdot \left(\frac{A_j}{A_{max}}\right)^{\beta} \tag{5.7}$$

$$P_2\left(A_i, A_j\right) = c \cdot \left(A_i + A_j\right) \tag{5.8}$$

$$P_3\left(A_i, A_j\right) = H\left(A_i + A_j - z\right) \tag{5.9}$$

where A_{max} denotes the size of the balance sheet of the biggest bank in the system, α, β c and z are constants, and H is the classic Heaviside step function. Section 5.3 will present the main topological properties of networks produced by functions (5.7), (5.8) and (5.9). With any of these probability functions, we can build the $n \times n$ probability matrix $P \in M_{n \times n}$, with entries $p_{ij} = P_s(A_i, A_j) \in [0, 1]$, and $s = 1, 2, 3$;[2]

4. The next step consists in constructing the adjacency matrix A of the network, according to the rule:

$$a_{ij} = \begin{cases} 1, & \text{with probability } p_{ij} \\ 0, & \text{with probability } (1 - p_{ij}) \end{cases}$$

In contrast to a standard random network with constant connectivity, the probabilities p_{ij} are drawn from one of the probability functions of equations (5.7) to (5.9). In this way we reproduce the systematic tendency of accumulation of links at larger entities and the disassortative nature of empirical banking networks.[3]

---

[2] We note here that random networks are a particular case of our generating algorithm; in fact, each function with the form $P(A_i, A_j) = p$ will generate random networks characterized by a density p.

[3] It is possible, especially for symmetric probability functions, to have situations where $a_{ij} = a_{ji} = 1$. Since loops are not allowed in our model (they would

5. We also assume that banks loan money to other banks according to their peculiarity; since loans are supposed to produce returns, it seems natural to assume that financial entities will have more intense links with banks with high peculiarity (balance sheet size). Including this notion in the probability functions we can compute the load l_{ij} (the volume of credit) on the link between bank i and bank j as:

$$l_{ij} = \frac{l_i p_{ij}}{\sum_{j \in \Omega_i} p_{ij}} \tag{5.10}$$

   where Ω_i denotes the set of nodes for which $a_{ij} = 1$;
6. In the last step, we compute the internal borrowing b_i as:

$$b_i = \sum_j l_{ji} \tag{5.11}$$

   and the customers' deposits d_i as:

$$d_i = (e_i + l_i) - (\eta_i + b_i) \tag{5.12}$$

Deposits are, thus, the residual in the construction of the banks' balance sheet that is adjusted in a way to guarantee consistency. While this leads to a certain degree of heterogeneity of the size of deposits across banks, this is not necessarily an unrealistic feature of our system.

Let us also emphasize that in the algorithm there are two levels of randomness: the first appears in step 1, in the determination of the sizes of the nodes, while the second appears in step 4, in the realization of the probability matrix. Thus, for a fixed sequence of the sizes $\{A_i\}$, several different realizations of the network are possible.

---

mean that bank i and j are both borrower and lender of each other), we have to use a criterion for the elimination of one of the edges. A possible choice is to randomly eliminate one of the two links $i \rightarrow j$ or $j \rightarrow i$; however, other choices are possible as well, if the aim is to enforce the disassortative behavior of the networks (see section 5.3).

5.3. Topological properties and the probability function

The representation of the financial system in our model depends on the choice of the probability function. In this section, we will show in detail how the topological structure of the network is determined by functions (5.7), (5.8) and (5.9). One of the main features of this kind of networks is the presence of power laws in the degree distributions of both *in*- and *out-degree*. In particular, it is easy to see that the relations between the probability function and the degree distributions are:[4]

$$P(k_{in}) = \rho\left[F_{in}^{-1}\left(\frac{k_{in}}{n}\right)\right] \cdot \frac{d}{dk_{in}} F_{in}^{-1}\left(\frac{k_{in}}{n}\right) \tag{5.13}$$

$$P(k_{out}) = \rho\left[F_{out}^{-1}\left(\frac{k_{out}}{n}\right)\right] \cdot \frac{d}{dk_{out}} F_{out}^{-1}\left(\frac{k_{out}}{n}\right) \tag{5.14}$$

where n is the number of nodes in the network,

$$n \cdot F_{in}(A_i) = k_{in}(A_i) = n \cdot \int_a^b P_s(t, A_i)\rho(t)dt \tag{5.15}$$

is the mean in-degree depending on the fitness parameter A_i and

$$n \cdot F_{out}(A_i) = k_{out}(A_i) = n \cdot \int_a^b P_s(A_i, t)\rho(t)dt \tag{5.16}$$

is the mean out-degree. In the above equations, a and b denote respectively the lower and the upper limits for the support of the distribution of bank sizes: $A_i \in [a, b]$. With probability functions (5.7), (5.8) and (5.9), we obtain respectively:

$$P_1(k_{in}) \propto k_{in}^{-\frac{1+\beta}{\beta}}, P_1(k_{out}) \propto k_{out}^{-\frac{1+\alpha}{\alpha}} \tag{5.17}$$

---

[4] The derivation of the following equations, well known in literature (see, for example, Caldarelli 2007), is also reported in the appendix of this chapter.

$$P_2(k_{in}) \propto (c_1 k_{in} + c_2)^{-2},\ P_2(k_{out}) \propto (c_3 k_{out} + c_4)^{-2} \tag{5.18}$$

$$P_3(k_{in}) \propto k_{in}^{-2},\ P_3(k_{out}) \propto k_{out}^{-2} \tag{5.19}$$

In the same way, it is possible to see that the average degree of a neighbor is determined by:

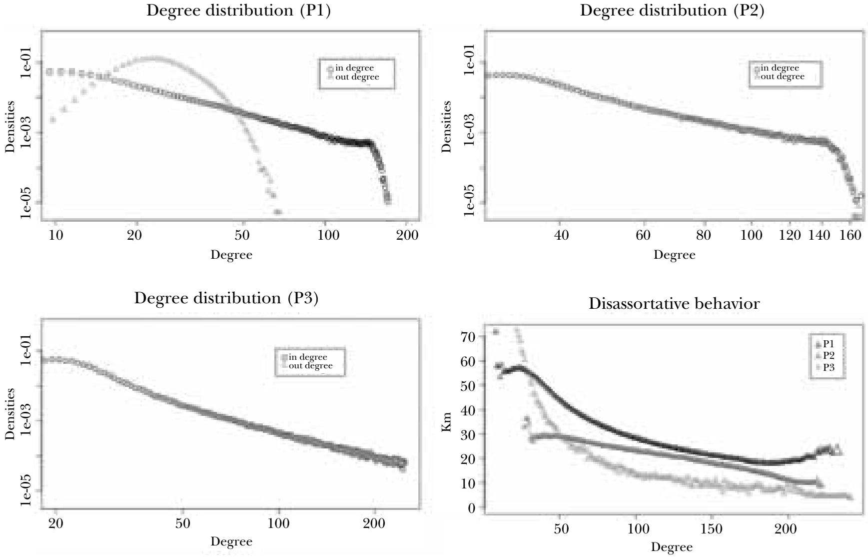
$$\langle k_{nn} \rangle (A_i) = \frac{N}{k(A_i)} \cdot \int_a^b p(A_i, t) k(t) \rho(t) dt \tag{5.20}$$

where $k(A_i)$ is the mean *total degree* of node i, as a function of its own fitness parameter.

As we can see, with all three kinds of probability functions, the results are scale-free networks (i.e., a power-law distribution of degrees). Since equation (5.20) involves the mean total-degree of a node, $k(A_i)$, there is no closed-form solution for this expression for the three probability functions. The disassortative behavior can, however, be confirmed via numerical integration of equation (5.20) (see figure 5.2). It is apparent from equations (5.17) to (5.19), that it will be possible to change the exact shape of the degree distributions as well as the degree of disassortative behavior by modifying the parameters of the probability functions, and the distribution of the fitness parameters. Figure 5.2 shows the degree distributions and the average neighbor degree for functions (5.7), (5.8) and (5.9), for parameters $\alpha = 0.25$, $\beta = 1$ and $z = 0.6 \cdot A_{max}$. With this choice of the parameters we get tail indices in the in-degree distribution equal to, respectively, −2, −2 and −2, and -5, −2 and −2 for the out-degree distributions. Moreover, a clear disassortative behavior is observed in all the three cases.[5]

[5] In order to reinforce the disassortative behavior, one could use a criterion for the elimination of the loops different from the one described in footnote 2. In particular, if both the edges $i \to j$ and $j \to i$ are present in the network, one could eliminate the one starting from the biggest node of the two: this mechanism would contribute to mimicking real interbank network structures, where mostly small banks lend money to big banks, as described in the introduction.

FIGURE 5.2: Topological properties of simulated networks



Note: The first three panels show the in- and out-degree distributions for the three probability functions (5.7), (5.8) and (5.9). The last panel shows the mean neighbor degree as a function of the *total degree* of the nodes. The curves in the last panel are decreasing with the degree itself, indicating that big nodes are connected to a multitude of small and medium-sized nodes, which themselves are connected with only a (relatively) small number of hubs.

5.4. Simulation results

In this section we present results from our simulation engine. The design of the simulations will be the same for all the following experiments: the first step consists in generating a Monte Carlo realization of our banking system as explained in section 5.2. In the second step we destroy the largest bank: this shock is assumed to wipe out all the external assets from the balance sheet of the initially failing bank. For each simulation run, we count the overall number of defaults, as well as the number of defaults in each single phase of the shock propagation. We report the average number of defaults across all banks. In the following, the number of banks will be fixed at 250, and we will use probability functions (5.7), (5.8) and (5.9) with parameters $\alpha = 0.25$, $\beta = 1$ and $z = 0.6 \cdot A_{max}$; furthermore the two limits a and b will be fixed at 5 and 100 respectively. We will investigate later how those limits affect the resilience of the system. Of course, other choices are possible both for the parameters and for the probability functions.

In the following section, we will initially use as our exemplary case the probability function (5.7): for systems produced by equation (5.7) we will vary only one parameter at a time, and we will study how this changes the domino effects. At the end of the section we will show for all the functions (5.7), (5.8) and (5.9) the results obtained by varying simultaneously the percentage of net worth γ and the percentage of interbank borrowing θ. Moreover, in section 5.4.4 we present a comparison between the result obtained with scale free networks and the results obtained with random networks and networks generated via a maximum entropy principle. Section 5.4.5 shows how the absolute size of the largest hub affects the contagion process.

5.4.1. Transmission of shock

Here we study the consequences of an idiosyncratic shock hitting one of the banks in the system, and elaborate on how the aftereffects (usually the number of defaults) depend on the structural parameters of the system. There are several ways in which a shock can propagate through a financial system. First, propagation will occur through the direct bilateral exposure between banks (namely, financial entities holding in their balance sheets liabilities of other entities and incurring, for endogenous reasons, solvency problems, will transmit their losses to their creditors), correlated exposure of banks to a common source of risk (banks holding correlated portfolios can increase the probability of multiple and simultaneous failures), effects arising from endogenous fire-sales of assets by entities in distress, and informational contagion. We will focus here on the first of those mechanisms, noting that idiosyncratic shocks are a clear starting point for studying knock-on defaults due to interbank exposure.

In our subsequent analysis, the shock starts form one bank, and it consists in wiping out a certain percentage of its external assets (the *source* of the shock). Let p_i be that percentage, and let s_i be the size of the initial shock:

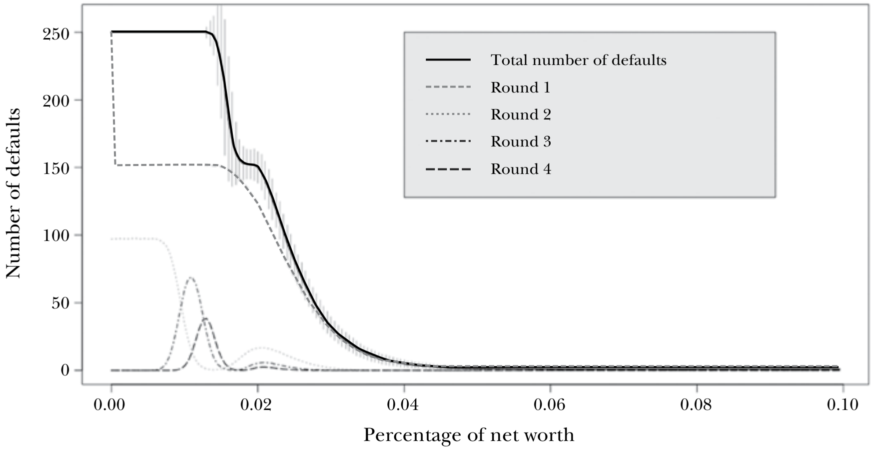
$$s_i = p_i \cdot e_i \tag{5.21}$$

This loss is first absorbed by the bank's net worth η_i, then its interbank liabilities b_i and last its deposits d_i, as the ultimate *sink*. That is, we assume priority of (insured) customer deposits over bank deposits which, in turn, take priority over equity (net worth). If the bank's net worth is not big enough to absorb the initial shock, the bank defaults and the residual is transmitted to creditor banks through interbank liabilities. And in case these liabilities are not large enough to absorb the shock, some of the losses have to be absorbed by depositors. Formally, if $s_i > \eta_i$, then bank i defaults. If the residual loss $(s_i - \eta_i)$ is less than the interbank borrowing b_i of the failed bank, then all residual loss is transmitted to creditor banks. Otherwise, if $(s_i - \eta_i) > b_i$, then all of the residual cannot be transmitted to creditor banks and depositors receive a loss of $(s_i - \eta_i - b_i)$. Creditor banks receive an amount of the residual shock proportional to their exposure to the failed bank. In turn, this loss is first absorbed by their net worth. If their net worth is not big enough to completely absorb the shock, it will be transmitted first to their creditors bank, and possibly also to their depositors. The part that is transmitted through the interbank channels may cause further rounds of contagious defaults, and in this way the shock spreads through the network. The transmission continues spreading through the system until the shock is completely absorbed or, alternatively, the system has completely failed. In the following, we will consider always the worst situation, namely that all the external assets of one bank are wiped out: $p_i = 1$. For our analysis of mechanical short-run effects of a shock this is not an unrealistic assumption. Partial recovery of claims to defaulted entities requires certain legal proceedings that can be extremely time consuming. Over short horizons, the *de facto* situation is that no payment can be enforced on a defaulted claim.

5.4.2. Bank capitalization

In this first experiment we investigate the effects of banks' net worth on the resilience of the entire banking system; the parameter θ will be fixed at 0.8, so that each bank will invest 20% of its total assets in the interbank market, and the remaining 80% in some external markets. We will let the parameter γ vary

FIGURE 5.3: Bank capitalization and contagion effects



Note: Number of defaults as a function of the percentage of net worth γ, for probability function (5.7). The other parameters are fixed at: $\theta = 0.8$, $a = 5$, $b = 100$. The picture shows both the total number of defaults (bold black line) together with the standard deviation of the mean value (thin vertical bars), and the number of defaults occurring during the first four phases of the propagation of the shock. Dashed and dotted lines represent subsequent rounds.

from 0 to 0.1.[6] Figure 5.3 shows the result: we report both the total number of defaults (black bold line), and the number of defaults in the first four phases of the propagation of the shock. The thin vertical bars represent the standard deviation of the black line across our 200 replications of the simulations.

As one could expect, when the percentage of net worth tends to 0, the total number of defaults increases to 250: in particular, a threshold value ($\gamma = 0.0143$ in the picture) exists below which the system fails completely, and below $\gamma = 0.008$ it breaks down within only two rounds. This is a demonstration on the so called *small-world* effect: the diameter of this kind of networks is roughly about two when measured from the largest bank belonging to the system, and so in only two rounds the shock will have reached almost any bank of the IbM. At the other end, when the percentage of net worth is beyond an upper threshold value, no defaults are reported and no domino effects set in.

[6] Remember that by mere rescaling γ could also be interpreted as the excess over the required minimal capital requirement.

Interestingly, the shape of the line describing the total number of defaults is far from linear. Starting from the value $\gamma = 0.1$, we can observe that below the value $\gamma \cong 0.05$ the first defaults appear, and inspection shows that these are typically small banks connected to the initially failing bank. As γ decreases further, we observe a sharp increase in the number of defaults, and this growth stops at the value $\gamma \cong 0.02$ where the curve enters a *plateau:* at this point, all the banks belonging to the first *shell* around the initially failing bank have failed, and the banks which are not directly connected to the first failing unit have enough net worth to survive the shock. As the percentage of net worth decreases further, also the banks outside the first shell are no more able to absorb the perturbation, and the total number of defaults sharply moves up to 250.

It is interesting to have a look at the number of defaults in the different rounds. In the first round (dashed line in figure 5.3), banks that fail are directly connected to the initially shocked bank, and when the dashed line reaches its *saturation* at $\gamma \cong 0.018$ the complete first shell (composed on average of 153 units) has failed. We note that the saturation point of the number of defaults in the first round does not coincide exactly with the *plateau* of the total number of defaults: the explanation is that the largest banks in the first shell need more than one hit to fail, and so they populate the failures of higher rounds. The reason for this is that for larger banks the overall number of credit relationships to other banks is larger too (by assumption, following observed empirical regularities), and so for them the failure of the largest bank will lead to a proportionally smaller loss than for the smaller client banks of the defaulted entity. When the percentage of net worth decreases, these defaults occur already in earlier rounds, up to a point in which all banks of the first shell are affected in the first round of defaults.

It is worthwhile to highlight here the ability of the system to confine the shock in the first shell if the value of γ is higher than some benchmark (approximately 0.018 in our example). Even if contagion defaults occur after the first failure these are limited to banks inside the first shell, i.e. to those banks with direct exposure towards the source of the disruption.

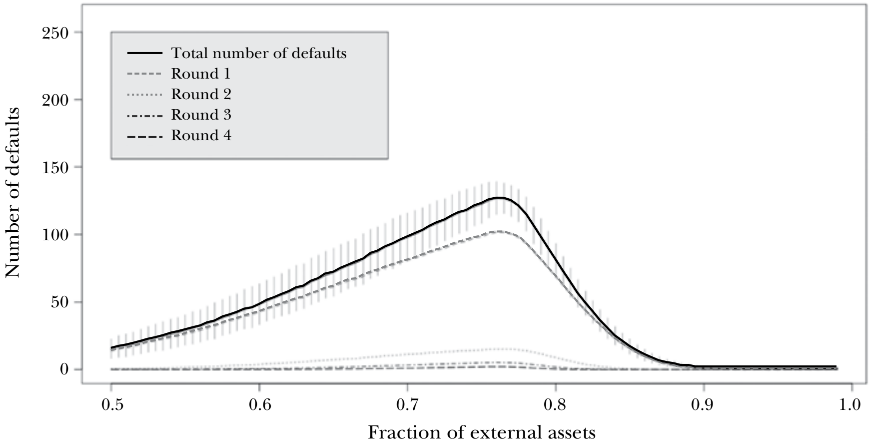
5.4.3. Interbank exposure

In this section we are going to explore how the number of defaults is affected by the percentage of interbank exposure as a function of total assets, namely how the parameter θ affects the resilience of the system. An increase in interbank assets produces, as an immediate result, an increase in the weight of each edge and therefore an increase of the channels through which the shock can propagate. This effect can potentially increase the number of defaults in the system, as the amount of losses transmitted to creditor banks will increase as well. On the other hand, an increase in interbank exposure implies a reduced relative exposure to external markets, and since here we are considering, as initial source of the shock, the external assets, this second effects could cushion banks against systemic risk.

The design of the simulations will remain the same as in the first experiment: we generate a realization of the system and we shock the biggest bank, wiping out all its external assets. Subsequently we count the number of defaults. We will show the mean value of those numbers for each round, and the standard deviation for the total number of defaults. In this section, the percentage of net worth γ is fixed at 0.025, while the percentage of external assets on total assets, θ, varies from 0.5 to 1 (when θ is equal to one no interbank assets are present in the bank balance sheets). Figure 5.4 shows the result.

First, we note that when θ tends to 1 the number of defaults tends to 0: in this case the banks' balance sheet contains only external assets, and so the channels for the propagation of the shock become smaller and smaller, until θ assumes the value 1 and there are no more links in the network, and no domino effects are possible. In figure 5.4 we can also note a threshold value at $\theta \cong 0.78$: at this value, the contagion effects reach their maximum while both more or less intense interbank linkages reduce the number of knock-on defaults (due to a higher degree of risk sharing on the left and fewer links for contagion on the right). At the other extreme, when θ tends to 0, the banks become completely isolated from any external market, and so in our model, where the initial source of the shock comes from

FIGURE 5.4: Interbank exposures and contagion effects



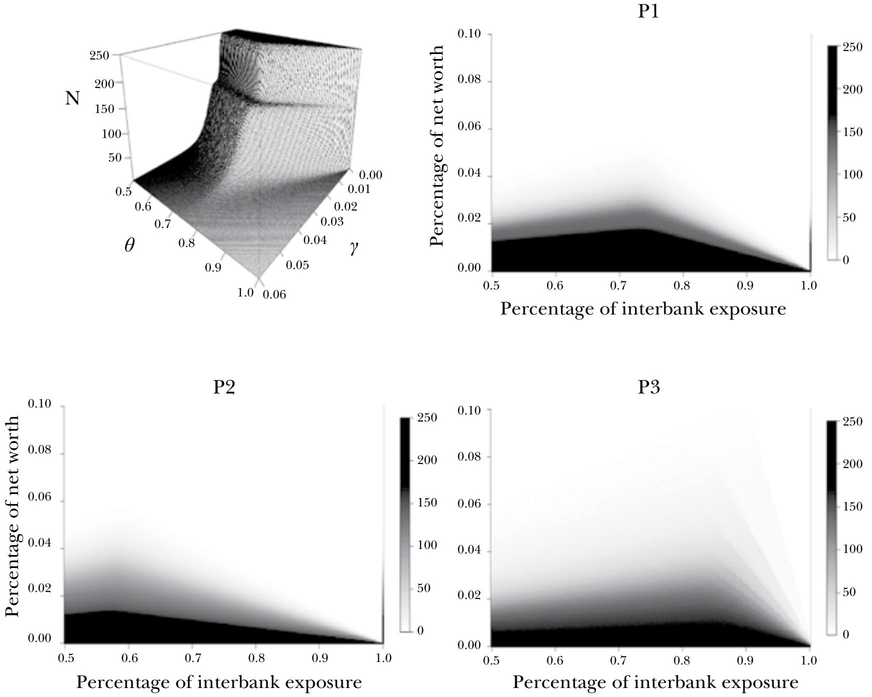
Note: Number of defaults as a function of the percentage of external assets θ, i.e. 1 – the percentage of interbank exposure θ, for probability function (5.7). The other parameters are fixed at: $\gamma = 0.025$, $a = 5$, $b = 100$. The picture shows both the total number of defaults (bold black line) together with the standard deviation of the mean value (thin vertical bars), and the number of defaults occurring during the first four phases of the propagation of the shock. Dashed and dotted lines represent subsequent rounds.

the external assets of the largest bank of the system, the number of defaults tends to 0 as well. Note that this exercise does not leave the size of the internal shock unaffected. Clearly, when external assets decline in their absolute size (from right to left) there should be a decrease of contagious defaults. Nevertheless, despite this lack of normalization of the shock, the behavior of the system is distinctly non-monotonic.

5.4.4. Results with other network generators

So far we have always used equation (5.7) as the probability function generating the networks. Although equation (5.7) correctly reproduces the disassortative behavior and power law degree distributions, it is interesting to see in how far other functional forms generating systems with the same qualitative features reproduce the above results or not. We are going to present, therefore, also the results obtained for the other two functions, namely equations (5.8) and (5.9). In this section we display results in the bidimensional space (γ, θ), and for each pair of these two parameters we use a grayscale to indicate the number of defaults. Figure 5.5

FIGURE 5.5: Probability matrices and resilience



Note: In the top left, a 3*D* plot shows the total number of defaults as a function of the two parameters γ and θ for probability function P_1: in the figure one again detects the *plateau* that already appeared in figure 5.3. The other three panels represent the same information for the three probability functions P_1, P_2 and P_3. In all these maps one observes a non-monotonic behavior of defaults in the percentage of interbank exposure. The grayscale indicates the number of banks in default.

shows the results for the three probability functions discussed in section 5.3.

As one can see from the figure, the behavior of the systems in the presence of a perturbation is qualitatively the same in all the three cases. In particular, it is again possible to observe a threshold value for the percentage of interbank exposure θ, beyond which the trend in the total number of defaults reverts itself. Different versions of our generating mechanisms for interbank connections do, however, affect the location of the level of interbank exposure leading to the largest level of fragility of the system as well as the quantitative importance of defaults in higher rounds.

As we had already highlighted in the introduction of this chapter, most empirical and simulation-based approaches of interbank markets use as topology for the underlying bank network a random network or a maximum entropy principle. Random networks are characterized by a constant probability p for each edge to exist in the network. The maximum entropy principle, on the other hand, assumes a maximum of dispersion of interbank loans (see Upper and Worms [2004] for more details on this kind of networks). We want to compare here the differences in term of contagion effects when the same set of banks is connected through different underlying network structures.

In the following, we will compare the number of defaults in scale free networks, random networks and networks generated via maximum entropy principles, for varying capitalization of the system. For the scale free network case, we use as benchmark case the system generated through function (5.7): again, the *limits (a, b)* are set to (5, 100) and the parameter θ is fixed to 0.8.

For the random network case, we will simply use the probability function:

$$P\left(A_i, A_j\right) = \begin{cases} p, & \text{if } i \neq j \\ 0, & \text{if } i = j \end{cases} \tag{5.22}$$

with p equal to 0.1, 0.2 and 0.3.[7] We note here that with the value $p = 0.1$, the (mean) number of edges in the system generated with function (5.22) is equal to the (mean) number of edges in system generated with function (5.7): this is equivalent to random reshuffling the links (and their weights) among all the banks.

We cannot define a probability function that generates networks according to the maximum entropy principle. For a consistent comparison with the scale free scenario, we proceed in the following way: first we generate a weight matrix W using the fitness algorithm described in section 5.2 (with probability function given by equation [5.7]), then we compute the sum of the rows and the sum of the columns of that matrix: they are, respectively, the total amount of interbank borrowing and the

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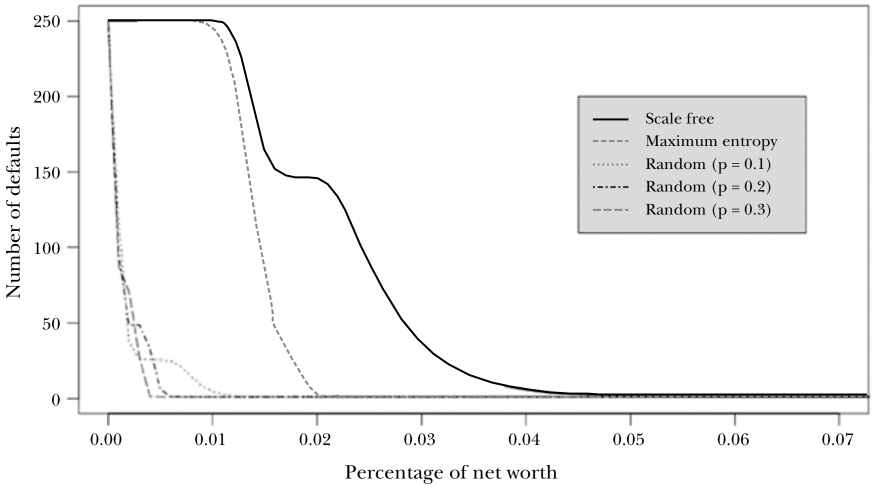
[7] This will simply generate random networks with different densities.

total amount of interbank lending for each bank. The problem is then to determine a new weight matrix W^* such that (i) the sum of the rows and the columns are the same as for W, and (ii) the dispersion of the new bilateral exposures w^*_{ij} is maximized. This problem can be easily solved numerically using the RAS algorithm (see Censor and Zenios [1997] for technical details). The result is a banking system populated by banks having exactly the same balance sheets as in the scale free network case, but now connected in a way that maximizes the entropy of the new weighted matrix W^*.

Figure 5.6 shows the results. As in the previous simulations, we again shock the largest bank in the system by wiping out all its external assets. The figure shows the total number of defaults after the propagation of the shock terminates (for better visibility, we do not report in this graph the standard deviations). We note immediately from the figure that the scale free scenario is the most critical in terms of number of defaults. The random network scenario (no matter what the probability p is) always underestimates the effect of a targeted attack: the large pool of small and

FIGURE 5.6: Contagion effects under different network topologies



Note: Number of defaults as a function of the percentage of net worth for different kinds of network topologies: scale-free networks, networks designed according to the maximum entropy scenario and three random network scenarios with different probability for the existence of links (the random networks generated with $p = 0.1$ have the same mean and density as in the scale free case).

medium-sized banks now has a larger number of outcoming links randomly directed to all the other banks in the system, and, for each bank, the weight on those links is the same (in contrast to the scale free scenario, where the larger the peculiarity of the node, the larger the weight on the links pointing to it). This effect dramatically reduces the threshold value for the percentage of net worth necessary for triggering chains of defaults.

We note moreover that also the maximum entropy scenario underestimates the effects of a targeted attack, albeit to a smaller extent in comparison to the random networks. We see that the classical *plateau* that we have seen in all the other cases now disappears: the reason is that the systems built via the maximum entropy principle are fully connected,[8] and so the distinction between different shells is not applicable here, i.e. all banks belong to the first shell.

5.4.5. The size of the hubs

In this section, we analyze the behavior of the networks when changing the size of the largest bank in the system. Using our simulation engine, this can be achieved simply by expanding the interval from which we draw the fitness parameters of nodes. In particular, we leave the lower boundary a of that interval constant (in our experiments it will be—and it was—fixed to 5), and increase the upper limit b. Since the fitness parameters are drawn from a power law distribution most of the sampled values will be located in a short subset at the left end of the interval. As an example, we can imagine to sample the fitness parameters from a power law on the interval [5, 1000]. If the exponent is 2 it easy to see that more than 95% of the draws will lie in the interval [5, 100], and that 99.5% of the values will lie in the interval [5, 500]. So the result of increasing the upper limit of the interval $[a, b]$ is the introduction of a very small number of very big banks. The presence of those banks has some intuitively plausible effects on the resistance of the system to shocks. Consider,

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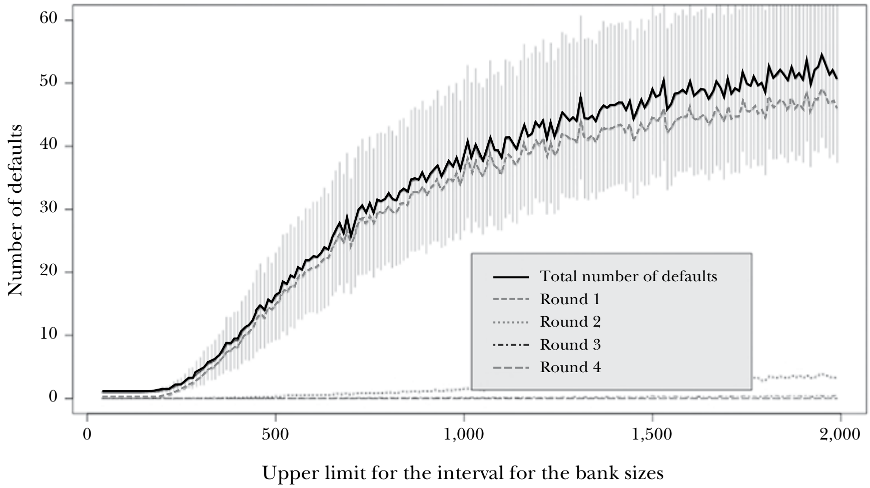
[8] Note that the result is not equivalent to use a random network with probability $p = 1$, since the weights on the links are significantly different, affecting so the way a shock can propagate in the system.

for example, the probability function of equation (5.7), with $\alpha = 0.25$ and $\beta = 1$. When A_{max} increases, the probability of a link involving two small banks or two medium-sized banks decreases: hence, more edges will point to the few hubs of the network. Furthermore, since the edges in our model are weighted by the same probability function (see equation [5.10]), most of the interbank loans will be loaded on the edges pointing to these hubs.

After these preliminary considerations, we now investigate the behavior of the network when bigger hubs are introduced in the interbank system. We will show results for two particular values for the percentage of (excess) net worth γ, namely $\gamma = 0.1$ and $\gamma = 0.01$. These choices permit us to study the system in two limiting cases: in the first case, as demonstrated in the previous sections, the system is relatively well cushioned against systemic risk, while in the second case the system is very *weak*. The parameter θ will be fixed at the value 0.8. Furthermore, for each realization of the system, we will again shock the largest bank by wiping out all its external assets from its balance sheet.

Figure 5.7 shows the results for the case $\gamma = 0.1$. As a first observation, we note that as the value of the upper limit b exceeds

FIGURE 5.7: Size of hubs and resilience. Robust system case

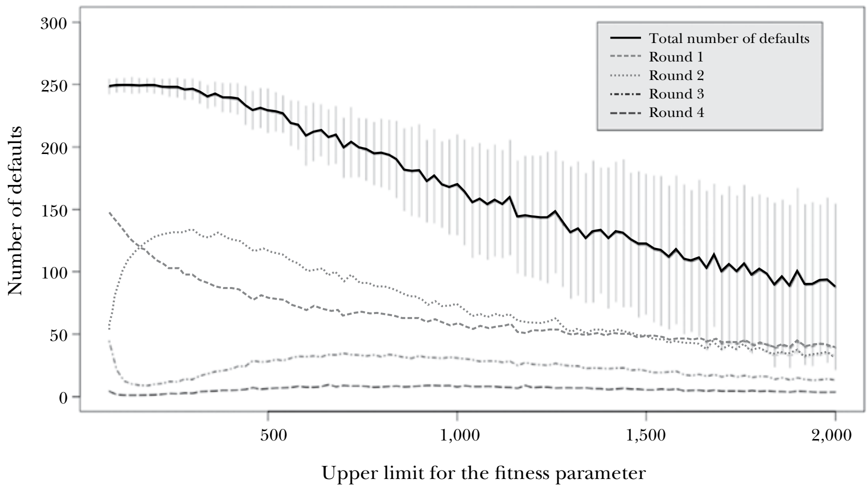


Note: Number of defaults as function of the upper limit of the interval for banks' sizes used in the Monte Carlo simulations. The black bold line denotes the total number of defaults, together with its standard deviation (thin vertical bars). Dashed and dotted lines represent the next rounds. ($\gamma = 0.1$, $\theta = 0.8$).

the threshold value $b \cong 230$, first round effects start. We should emphasize that, in the previous experiments, at $(\gamma, \theta) = (0.1, 0.8)$ no defaults were reported in our system. Figure 5.7 shows that occurrence or not of contagious defaults also depends on the parameter b. In particular, we can see that the number of defaults in the first round sharply increases in the range [230, 700]. That happens because most of the banks are now linked to the hubs and moreover these links become increasingly more loaded (higher in volume) as the parameter b increases. As a consequence, when the largest bank defaults, the first shell is no longer able to absorb the resulting losses.

Figure 5.8 shows the result in the case $\gamma = 0.01$, $\theta = 0.8$. For this pair of parameters we know that the system is extremely vulnerable against systemic risk, and in particular in a few rounds the whole IbM usually had failed after a shock. As one can see from figure 5.8, these results change as well if larger hubs are present in the system: as the size of the biggest bank becomes larger, the pool of small and medium-sized banks effectively stops dealing among themselves, and so the channels through which a shock can propagate beyond the (relatively large) pool

FIGURE 5.8: Size of hubs and resilience. Weak system case



Note: Number of defaults as function of the upper limit of the interval for banks' sizes used in the Monte Carlo simulations. The black bold line denotes the total number of defaults, together with its standard deviation (thin vertical bars). Dashed and dotted lines represent subsequent rounds. ($\gamma = 0.01$, $\theta = 0.8$).

of trading partners of the largest hub do vanish. We can see moreover that as the upper limit b increases, the second round (dotted line in figure 5.8) assumes basically the same importance as the first round. At this point in the system, there are few big hubs (strongly) interconnected, and when the biggest of them fails (producing the default of all banks in its first shell) the other hubs will be failing in due course. When these secondary hubs fail, their first shells will fail as well, and the result is a high number of defaults in the second round. As the upper limit b increases further, networks will become very sparse, and the number of defaults decreases due to lower overall connectivity of the system.

5.5. Conclusion

This chapter has investigated the behavior of a scale-free interbank market, characterized by a disassortative structure, in case of targeted attacks. The networks have been constructed according to a *fitness algorithm,* where the size of each node is used as a kind of peculiarity index for the bank itself: the higher the index, the higher the probability that other banks will lend money to it. For appropriate choices of the probability function, the networks are described by a decreasing mean neighbor degree distribution, i.e. disassortative mixing. The results are networks composed of a large pool of small and medium-sized banks which invest money in interbank loans to the biggest banks, which in turn invest this liquidity into non-financial assets and also redistribute part of it in the interbank market.

In this framework, we have investigated how the percentage of net worth (γ) and the percentage of interbank assets (θ)—on total assets—affect the spread of an idiosyncratic shock. The results show a shell structure in the propagation of losses: banks belonging to the first shell (i.e. creditor banks of the defaulted entity) fail mostly before the others, and it is possible to distinguish between defaults of the different shells in the cascade of events. Moreover, in all three types of probability functions we investigated, a hump-shaped dependency of the number of defaults on

θ was observed, indicating higher robustness of networks with too few and too many links. The intuitive explanation is that if banks invest more money in the interbank market than in other external markets, the risk for endogenous shocks decreases and, therefore, banks are more able to absorb potential losses.

As it turns out, the role of the hubs is ambiguous in these networks: when the size of the hubs increases, the pool of small and medium-sized banks tends to withdraw from dealing among themselves, and to start lending and borrowing mostly from and to the hubs. Given our probability functions, the hubs are also highly connected among themselves. The results of this change in the network structure on the resilience of the system are linked to two antagonistic phenomena: on one hand, the number of channels for the shock propagation decreases as the hub sizes increase. On the other hand, due to the smaller number of connections in the pool of small and medium sized banks, the same pool of banks concentrates their bilateral links in few very big banks, which assume a central position in the entire system. In our model, the results from an endogenous shock are ambiguous and depend on the state of the system in terms of its capital base: for a *strong* system ($\gamma = 0.1$) the total number of defaults increases if the biggest bank meets insolvency problems, for a *weak* capitalized system ($\gamma = 0.01$), the number of defaults decreases with the size of the largest unit.

We also found that random networks or networks constructed on the base of a maximum entropy principle lead to fewer contagious defaults than our scale-free networks, under otherwise identical conditions. It is important to note that this implies a potentially tremendous underestimation of contagion risk, if due to a lack of detailed knowledge, stress tests are conducted with the simple algorithms for random network creation or maximum entropy allocation of interbank credit.

References

ALLEN, Franklin, and Douglas GALE. "Financial contagion." *Journal of Political Economy* 108, no. 1 (2000): 1-33.

BATTISTON, Stefano, Domenico DELLI GATTI, Mauro GALLEGATI, Bruce GREENWALD, and Joseph STIGLITZ. "Liaisons dangereuses: increasing connectivity, risk sharing, and systemic risk." NBER Working Paper no. 15611, Cambridge, MA: National Bureau of Economic Research, January 2009.

BENITO, Enrique "Size, Growth and Bank Dynamics." Working Paper no. 0801, Madrid: Bank of Spain, 2008.

BOSS, Michael, Helmut ELSINGER, Martin SUMMER, and Stefan THURNER. "Network topology of the interbank market." *Quantitative Finance* 4, no. 6 (2004): 677-684.

CALDARELLI, Guido. *Scale-Free Networks: Complex Webs in Nature and Technology*. Oxford University Press, 2007.

CENSOR, Yair, and Stravos A. ZENIOS. *Parallel Optimization: Theory, Algorithms, and Applications*. Oxford University Press, 1997.

COCCO, Joao F., Francisco J. GOMES, and Nuno C. MARTINS. "Lending relationships in the interbank market." *Journal of Financial Intermediation* 18, no. 1 (2009): 24-48.

DE MASI, Giulia, Giulia IORI, and Guido CALDARELLI. "Fitness model for the Italian interbank money market." *Physical Review E Statistical, Nonlinear, and Soft Matter Physics* 74, no. 6 (2006): 066112.

ENNIS, Humberto M. "On the size distribution of banks." *Economic Quarterly* 87, Federal Reserve Bank of Richmond (2001): 1-25.

FINGER, Karl, Daniel FRICKE, and Thomas LUX. "Network analysis of the e-MID overnight money market: the informational value of different aggregation levels for intrinsic dynamic processes." *Computational Management Science* 10, n.º 2, (2013): 187-211.

GAI, Prasanna, and Sujit KAPADIA. "Contagion in Financial Networks." Working paper no 383/2010, London: Bank of England, 2010.

GAI, Prasanna, Andrew G. HALDANE, and Sujit KAPADIA. "Complexity, concentration and contagion." *Journal of Monetary Economics* 58, no. 5 (2011): 453-470.

HALDANE, Andrew G., and Robert R. MAY. "Systemic risk in banking ecosystems." *Nature* 469 (2011): 351-355.

IMAKUBO, Kei, and Yutaka SOEJIMA. "The Transaction Network in Japan's Interbank Money Market." In *Financial System Report*. Tokio: Financial market department, Bank of Japan, 2006.

INAOKA, Hajime, Takuto NINOMIYA, Ken TANIGUCHI, Tokiko SHIMIZU, and Hideki TAKAYASU. "Fractal Network Derived from Banking Transaction: An Analysis of Network Structures Formed by Financial Institutions." Bank of Japan Working Paper no. 04-E-4, Tokio: Bank of Japan, April 2004.

IORI, Giulia, Giulia DE MASI, Ovidiu V. PRECUP, Giampaolo GABBI, and Guido CALDARELLI. "A Network Analysis of the Italian Overnight Money Market." *Journal of Economics Dynamics and Control* 32, no. 1 (2008) 259-278.

JANICKI, Hubert P., and Edward C. PRESCOTT. "Changes in the size distribution of U.S. banks: 1960-2005." Federal Reserve Bank of Richmond *Economic Quarterly* 92 (Fall 2006): 291-316.

LUX, Thomas, and Daniel FRICKE. "Core-Periphery Structure in the Overnight Money Market: Evidence from the e-MID Trading Platform." Working Paper no. 1759, Kiel (Germany): Kiel Institute for the World Economy, 2012.

MAY, Robert M., and Nimalan ARINAMINPATHY. "Systemic Risk: The Dynamics of Model Banking Systems." *Journal of the Royal Society Interface* 7, no. 46 (2010): 823-838.

MEMMEL, Christoph, and Angelika SACHS. "Contagion in the interbank market and its determinants." Series 2: Banking and Financial Studies Discussion Paper no. 17/2011, Frankfurt am Main: Deutsche Bundesbank, 2011.

MISTRULLI, Paolo Emilio. "Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns." Temi di discussion (Economic working papers), Working Paper no. 641, Rome: Bank of Italy, September 2007.

NIER, Erlend W., Jing YANG, Tanju YORULMAZER, and Amadeo ALENTORN. "Network models and financial stability." *Journal of Economic Dynamics and Control* 31, no 6 (2007): 2033-2060.

SORAMÄKI, Kimmo, Morten L. BECH, Jeffrey ARNOLD, Robert J. GLASS, and Walter E. BEYELER. *The topology of Interbank Payment Flows.* Staff Report no. 243, Federal Reserve Bank of New York, March 2006.

UPPER, Christian. "Simulation methods to assess the danger of contagion in interbank markets." *Journal of Financial Stability* 7, no. 3 (2011): 111-125.

UPPER, Christian, and Andreas WORMS. "Estimating Bilateral Exposures in the German Interbank Market: Is there a Danger of Contagion?" *European Economic Review* 48, no. 4 (2004): 827-849.

Appendix 5.1. Computation of the degree distribution via the probability function

We provide here the derivation of equations (5.13) and (5.14). Starting from a particular probability function $P_S(Ai, Aj)$, and a distribution for the *size* parameter $r(Ai)$, we can write the mean in-degree of a vertex as:

$$k_{in}(A_i) = n\int_a^b P_s(t, A_i)\rho(t)dt = n \cdot F_{in}(A_i) \qquad \text{(A.5.1)}$$

and, similarly, for the out-degree we can write:

$$k_{out}(A_i) = n\int_a^b P_s(A_i, t)\rho(t)dt = n \cdot F_{out}(A_i) \qquad \text{(A.5.2)}$$

where n is the number of nodes of the network. Assuming the function $F_{in}(A_i)$ and $F_{out}(A_i)$ to be monotonous in A_i, and for n large enough, we can invert the functions F_{in} and F_{out} in order to find the relationships between the size parameter A_i and the out-and in-degree of the node:

$$A_i = F_{in}^{-1}\left(\frac{k_{in}}{n}\right) \qquad \text{(A.5.3)}$$

$$A_i = F_{out}^{-1}\left(\frac{k_{out}}{n}\right) \tag{A.5.4}$$

The transformation of the parameter in the size-distribution $\rho(A_i)$, from A_i to $k_{in/out}$, bring us to:

$$P(k_{in}) = \rho\left[F_{in}^{-1}\left(\frac{k_{in}}{n}\right)\right] \cdot \frac{d}{dk_{in}} F_{in}^{-1}\left(\frac{k_{in}}{n}\right) \tag{A.5.5}$$

$$P(k_{out}) = \rho\left[F_{out}^{-1}\left(\frac{k_{out}}{n}\right)\right] \cdot \frac{d}{dk_{out}} F_{out}^{-1}\left(\frac{k_{out}}{n}\right) \tag{A.5.6}$$

List of Figures

List of Tables

Index

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