

The Network Challenge

*Strategy, Profit, and Risk in an
Interlinked World*

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**with
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Networks in Finance¹

Franklin Allen
Ana Babus

Abstract

Modern financial systems exhibit a high degree of interdependence, with connections between financial institutions stemming from both the asset and the liability sides of their balance sheets. Networks—broadly understood as a collection of nodes and links between nodes—can be a useful representation of financial systems. By modeling economic interactions, network analyses can better explain certain economic phenomena. In this chapter, Allen and Babus argue that the use of network theories can enrich our understanding of financial systems. They explore several critical issues. First, they address the issue of systemic risk, by studying two questions: how resilient financial networks are to contagion, and how financial institutions form connections when exposed to the risk of contagion. Second, they consider how network theory can be used to explain freezes in the interbank market. Third, they examine how social networks can improve investment decisions and corporate governance, based on recent empirical results. Fourth, they examine the role of networks in distributing primary issues of securities. Finally, they consider the role of networks as a form of mutual monitoring, as in microfinance.

¹ We are grateful to the editors and to participants at the Wharton INSEAD conference on November 8-9, 2007, where the book's papers were presented for their helpful comments.

The turmoil in financial markets in August 2007, and the following months has revealed, once again, the intertwined nature of financial systems. While the events unfolded, it became clear that the consequences of such an interconnected system are hard to predict. What initially was seen as difficulties in the U.S. subprime mortgage market rapidly escalated and spilled over to debt markets all over the world. As markets plunged, investors' risk appetite was reduced. Banks became less willing to lend money as freely. Interbank lending rates started to rise, and soon the market for short-term lending dried up. The credit crunch ultimately triggered a bank run at the British mortgage lender Northern Rock—something not seen in the UK for over 140 years and in Western Europe for the past 15 years.

Connections in the financial world are varied. The dependencies between financial institutions stem from both the asset and the liability sides of their balance sheets. For instance, direct asset linkages result from exposures between banks acquired through the interbank market. Financial institutions are indirectly connected by holding similar portfolio exposures. When they share the same mass of depositors, banks are connected in a network through the liability side of the balance sheet.

The intricate structure of linkages between financial institutions can be naturally captured by using a network representation of financial systems. The general concept of a network is quite intuitive: A network describes a collection of nodes and the links between them. The notion of nodes is fairly general; they may be individuals or firms or countries, or even collections of such entities. A link between two nodes represents a direct relationship between them; for instance, in a social context, a link could be a friendship tie, and in the context of countries, a link could be a free trade agreement or a mutual defense pact. In the context of financial systems, the nodes of the network represent financial institutions, and the links are created through mutual exposures between banks, acquired on the interbank market by holding similar portfolio exposures or by sharing the same mass of depositors. In this chapter, we argue that network theory may provide a conceptual framework within which the various patterns of connections can be described and analyzed in a meaningful way.

A network approach to financial systems is particularly important for assessing financial stability and can be instrumental in capturing the externalities that the risk associated with a single institution may create for the entire system. A better understanding of network externalities may facilitate the adoption of a macroprudential framework for financial supervision. Regulations that target individual institutions, as well as take into account vulnerabilities that emerge from network interdependencies in the financial system, may prevent a local crisis from becoming global.

More generally, network analysis may help address two types of questions: the effect of the network structure and the process of network formation. Whereas the first type of question captures aspects related to social efficiency, the second type highlights the tension between socially desirable outcomes and the outcomes that arise as a result of the self-interested action of individuals. The first type of question, on network effects, studies processes that take place on fixed networks. For instance, we can study what is the impact of the financial network structure on the way the banking system responds to contagion. We can show not only that network structures respond differently to the propagation of a shock, but also that the fragility of the system depends on the location in the network of the institution that was initially affected. At the same time, financial institutions may gain significant payoff advantages from bridging otherwise disconnected parts of the financial network. Hence, certain network structures may provide additional benefits for those financial institutions that are able to exploit their position as intermediaries between other institutions. Network structure can also play a role in how effective mutual monitoring is for the enforcement of risk-sharing agreements, as in microfinance.

The second type of question, on network formation, studies how financial institutions form connections. We can gain new insights on the issue of systemic risk if we understand how financial institutions form connections when exposed to the risk of contagion. Risk sharing can be an important driving force that explains how financial institutions form connections. Moreover, theories of network formation may help explain freezes in the interbank market of the type we have observed in August 2007, and subsequent months. When the risk associated with lending funds on the interbank market is too high, links become too costly relative to the benefits they bring. In this case, a network formation game would predict an empty network, where no two banks agree to form a link.

This chapter is organized as follows: The following section considers the limited literature in finance that uses network theory and suggests areas for future research where such an approach is likely to be fruitful. The final section contains concluding remarks.

Applications to Finance

Economic research on networks offers insights into how network analyses might be applied to financial systems. Although there would appear to be many applications of network analyses to financial systems, the literature on financial networks is still at an

early stage. Most of the existing research using network theory concentrates on issues such as *financial stability and contagion*. Moreover, most of the research done in financial networks studies *network effects* rather than *network formation*. The literature primarily investigates how different financial network structures respond to the breakdown of a single bank to identify which structures are more fragile. In the first subsection that follows, we discuss this literature on contagion. In the second subsection, we consider whether network theory can be used to understand how interbank markets can freeze, as they did in the months after August 2007. The third considers the role of social networks in investment decisions and corporate governance, among other areas. The fourth subsection considers how network theory can be used to analyze investment banking. Finally, we look at how networks can help understand microfinance and other types of network-based relationships.

Contagion

More connections between banks may reduce the risk of contagion. Although the risk of contagion might be expected to be larger in highly interconnected banking system, research indicates that shocks may have complex effects, to the extent that the more complete the set of links between banks is, the lower the risk of contagion in the system.

The literature on contagion takes two approaches: examining direct linkages and examining indirect balance-sheet linkages. In looking for contagious effects via direct linkages, early research by Allen and Gale (2000) studied how the banking system responds to contagion when banks are connected under different network structures. In a setting where consumers have the liquidity preferences introduced by Diamond and Dybvig (1983) and have random liquidity needs, banks perfectly insure against liquidity shocks by exchanging interbank deposits. The connections created by swapping deposits, however, expose the system to contagion. The authors showed that incomplete networks are more prone to contagion than complete structures. Better-connected networks are more resilient because the proportion of the losses in one bank's portfolio is transferred to more banks through interbank agreements. To show this, they take the case of an incomplete network in which the failure of a bank may trigger the failure of the entire banking system. They prove that, for the same set of parameters, if banks are connected in a complete structure, then the system is more resilient in response to contagion effects.

The research that followed, although using stylized models, captured well the network externalities created from individual bank risk. Freixas, Parigi, and Rochet (2000)

considered the case of banks that face liquidity shocks due to uncertainty about where consumers will withdraw funds. In their model, the connections between banks are realized through interbank credit lines that enable these institutions to hedge regional liquidity shocks. As in Allen and Gale's study, more interbank connections enhance the resilience of the system to the insolvency of a particular bank. One drawback is that this weakens the incentives to close inefficient banks. Moreover, the authors find that the stability of the banking system depends crucially on whether many depositors choose to consume at the location of a bank that functions as a money center.

Concerned with the optimal financial network, Leitner (2005) constructs a model in which the success of an agent's investment in a project depends on the investments of other agents she is linked to. Because endowments are randomly distributed across agents, an agent may not have enough cash to make the necessary investment. In this case, agents may be willing to bail out other agents to prevent the collapse of the whole network. Leitner examines the design of optimal financial networks that minimize the trade-off between risk sharing and the potential for collapse. Vivier-Lirimont (2004) addresses the issue of optimal networks from a different perspective: He is interested in those network architectures in which transfers between banks improve depositors' utility. He finds that only very dense networks, in which banks are only a few links away from one another, are compatible with a Pareto optimal allocation. Dasgupta (2004) also explores how linkages between banks, represented by cross-holding of deposits, can be a source of contagious breakdowns. The study examined how depositors who receive a private signal about banks' fundamentals may want to withdraw their deposits if they believe that enough other depositors will do the same. To eliminate the multiplicity of equilibria, the author uses the concept of global games. Dasgupta isolated a unique equilibrium, depending on the value of the fundamentals.

Other researchers studied contagion in other industries beyond banking. Cummins, Doherty, and Lo (2002) show how the structure of catastrophe insurance markets can lead to contagion. State guarantee funds, such as the one in Florida, are based explicitly on allocating defaulted policy claims to other solvent insurers, typically in proportion to the net premiums written by these insurers. This network structure limits the capacity of the insurance industry to absorb the effects of a major catastrophic event to well below the total amount of equity capital in the industry.

Parallel to this literature, other researchers applied network techniques developed in mathematics and theoretical physics to study contagion. For instance, Eisenberg and Noe (2001) investigate default by firms that are part of a single clearing mechanism. Similarly, Mínguez-Afonso and Shin (2007) use lattice-theoretic methods to study

liquidity and systemic risk in high-value payment systems, such as for the settlement of accounts receivable and payable among industrial firms, and interbank payment systems. Gai and Kapadia (2007) develop a model of contagion in financial networks and use similar techniques as the epidemiological literature on spread of disease in networks to assess the fragility of the financial system, depending on the banks' capital buffers, the degree of connectivity, and the liquidity of the market for failed banking assets. As with Allen and Gale, they find that greater connectivity reduces the likelihood of widespread default. However, shocks may have a significantly larger impact on the financial system when they occur.

The impact of indirect linkages on contagion is considered as well in another set of studies. These studies share the same finding with the previous stream of research that financial systems are inherently fragile. Fragility not only arises exogenously, from financial institutions' exposure to common macro risk factors such as economic downturns but also evolves endogenously, through forced sales of assets by some banks that depress the market price, inducing further distress to other institutions.

Lagunoff and Schreft (2001) construct a model in which agents are linked in the sense that the return on an agent's portfolio depends on the portfolio allocations of other agents. In their model, agents that are subject to shocks reallocate their portfolios, thus breaking some linkages. Two related types of financial crisis can occur in response. One occurs gradually as losses spread, breaking more links. The other type occurs instantaneously when forward-looking agents preemptively shift to safer portfolios to avoid future losses from contagion. Similarly, de Vries (2005) shows that there is dependency between banks' portfolios, given the fat tail property of the underlying assets, and this carries the potential for systemic breakdown. Cifuentes, Ferrucci, and Shin (2005) present a model in which financial institutions are connected via portfolio holdings. The network is complete as everyone holds the same asset. Although the authors incorporate in their model direct linkages through mutual credit exposures as well, contagion is driven mainly by changes in asset prices.

The issue of network formation is considered in two studies. Babus (2007) proposes a model in which banks form links with each other as an insurance mechanism to reduce the risk of contagion. At the base of the link formation process lies the same intuition developed in Allen and Gale (2000): Better connected networks are more resilient to contagion. The model predicts a connectivity threshold above which contagion does not occur, and banks form links to reach this threshold. However, an implicit cost associated with being involved in a link prevents banks from forming more connections than are required by the connectivity threshold. Banks manage to form networks in which

contagion rarely occurs. Castiglionesi and Navarro (2007) are also interested in decentralizing the network of banks that is optimal from a social planner perspective. In a setting in which banks invest on behalf of depositors and there are positive network externalities on the investment returns, fragility arises when banks that are not sufficiently capitalized gamble with depositors' money. When the probability of bankruptcy is low, the decentralized solution approximates the first best.

Besides the theoretical investigations, *empirical studies* of national banking systems have looked for evidence of contagious failures of financial institutions resulting from the mutual claims they have on one another. Most of these papers use balance sheet information to estimate bilateral credit relationships for different banking systems. Subsequently, the stability of the interbank market is tested by simulating the breakdown of a single bank. Upper and Worms (2004) analyze the banking system in Germany; Sheldon and Maurer (1998), Switzerland; Cocco, Gomes, and Martins (2009), Portugal; Furfine (2003), the United States; Wells (2004), the UK; Boss et al. (2004), Austria; and Degryse and Nguyen (2007), Belgium. These papers find that the banking systems demonstrate high resilience, even to large shocks. Simulations of the worst-case scenarios show that banks representing less than 5% of total balance sheet assets would be affected by contagion on the Belgian interbank market, whereas for the German system, the failure of a single bank could lead to the breakdown of up to 15% of the banking sector based on assets.

These results depend heavily on how the linkages between banks, represented by credit exposures in the interbank market, are estimated (Upper 2006). For most countries, data is extracted from banks' balance sheets, which can provide information on the aggregate exposure of the reporting institution vis-à-vis all other banks. To estimate bank-to-bank exposures, it is generally assumed that banks spread their lending as evenly as possible (that is, the maximum entropy method). In effect, this assumption requires that banks be connected in a complete network. Hence, the assumption might bias the results, in the light of the theoretical findings that better connected networks are more resilient to the propagation of shocks. This is confirmed by Mistrulli (2007), who analyses how contagion propagates within the Italian interbank market using actual bilateral exposures. He also applies the maximum entropy method to the same dataset, and he finds that it tends to generally underrate the extent of contagion.

Other researchers have examined the impact of specific bank failures. Iyer and Pedro-Alcalde (2007) test for financial contagion using data about interbank exposures at the time of the failure of a large Indian bank. They find that banks with higher interbank exposure to the failed bank experience higher deposit withdrawals, and that the impact of exposure on deposit withdrawals is higher for banks with weaker fundamentals.

Freezes in Interbank Markets

Although researchers have devoted a great deal of time to analyzing possible forms of contagion in interbank markets, the actual type of contagion that occurred following August 2007, came as something of a surprise. The interbank markets simply dried up. Even though interest rates were high and in many cases outside the ranges specified by central banks, it was not possible for many institutions to borrow at a range of short-term maturities. An important issue is whether existing contagion theories can be adapted to understand this phenomenon or whether new ones need to be developed.

Freixas, Parigi, and Rochet (2000) do consider the possibility of gridlocks, primarily due to payment systems' breakdowns. The authors analyze different market structures and find that a system of credit lines, while reducing the cost of holding liquidity, makes the banking sector prone to gridlocks, even when all banks are solvent. However, payment systems functioned well during the 2007 crisis and could have smoothly ensured the flow of money. We need an alternative explanation for the freeze in the interbank market.

One way to understand market freezes is through a network formation game, in which the empty network emerges as an equilibrium, using the kind of analysis in Babus (2007). In her model, the endogenous formation of networks worked well and led to efficiency. However, by including frictions it may be possible for exogenous changes in risk that are small to have large effects by causing agents to withdraw from the network. This may help explain what happened in August 2007.

In a study of social networks, Karlan, Mobius, Rosenblat and Szeidl (2009) propose a model of lending and borrowing in which relationships between individuals are used as social collateral. They find that the maximum amount that can be borrowed in a connected network at most equals the lowest value of a link between any two agents. Although the model focuses on trust in social networks, it can be relevant to describe interactions in the interbank market. In interbank markets, links, representing loans between banks, evolve over time. The current network between banks may serve as collateral to form a network in a future period. In this setting, a decrease in the value of the collateral may trigger an adverse effect on how links will be formed in the next period. A small perturbation can, thus, result in a significant drop in lending and borrowing activities across the network.

Social Networks and Investment Decisions

A recent trend of empirical research advances a new important set of questions about the effects of social networks on investment decisions. Cohen, Frazzini, and Malloy (2008) use social networks to identify information transfers in security markets. They use connections between mutual fund managers and corporate board members via shared educational institutions as a proxy for the social network. They find that portfolio managers place larger bets on firms they are connected to through their network, and perform significantly better on these holdings relative to their nonconnected holdings. These results suggest that social networks may be an important mechanism for information flow into asset prices. However, it is less clear whether there are network externalities. In other words, it is less clear how far information travels through the network and whether it affects asset prices across more than two links. Hochberg, Ljungqvist, and Lu (2007) look at venture capital (VC) firms that are connected through a network of syndicated portfolio company investments. They also find that better-networked VC firms experience significantly better fund performance, as measured by the proportion of investments that are successfully exited through an IPO or a sale to another company. This implies that one's network position should be an important strategic consideration for incumbent VCs, while presenting a potential barrier to entry for new VCs.

Another set of studies investigates problems related to corporate governance. Nguyen-Dang (2007) is concerned with the impact of social ties between CEOs and directors within a board of directors on the effectiveness of board monitoring. The paper investigates whether CEOs are less accountable for poor performance depending on their position in the social network. To map the social network, the author uses data on educational background of CEOs from the largest French quoted corporations. Social ties are also formed through interlocking directorships. He finds that when some of the board members and the CEO belong to the same social circles, the CEO is provided with a double protection. She is less likely to be punished for poor performance and more likely to find a new and good job after a forced departure. In later work, Kramarz and Thesmar (2007) ran a similar analysis and found evidence to support that social networks may strongly affect board composition and may be detrimental to corporate governance. Braggion (2008) considers another proxy for social networks between firms' managers: the affiliation with Freemasonry. He finds that social networks help to resolve agency problems between lenders and borrowers in firms that have difficulties in obtaining debt finance. However, in large publicly quoted corporations that were managed by Freemasons, social connections give rise to agency conflicts between managers and shareholders and worsen economic performance.

In related work, Gaspar and Massa (2007) find that personal connections between divisional managers and the CEO within a firm increase the bargaining power of the connected managers and decrease the efficiency of decisions within the organization. Further studies confirm that firms whose directors are better connected and whose connections are with better connected directors exhibit weaker firm governance. In particular, in firms where members of the board are highly connected, CEO pay is higher, CEO pay is less sensitive to firm performance, and poorly performing CEOs are less likely to be fired (Barnea and Guedj 2008). Similarly, in the mutual fund industry, directors tend to hire advisory firms that they have worked with in the past, and, when creating new funds, advisory firms tend to offer board seats to directors they have had business relationships with in the past (Kuhnen 2008).

Pistor (2007) provides a more integrated approach, looking at the financial system from a global perspective. She argues that network-finance is a critical institutional arrangement, allowing the combination of features of different governance systems and leading to innovation when there is great uncertainty about financing choices.

Investment Banking and Networks

Although there is a very large literature that explains the emergence of *commercial* banks, there has been very little work done on why *investment* banks exist. In an important contribution, Morrison and Wilhelm (2007) argue that investment banks exist because they create networks. The researchers suggest that the central role of investment banks is to issue and underwrite securities. This requires that they develop two networks. The first is an information network, which allows them to acquire information about the demand for an issue. This network consists of large-scale investors such as pension funds and insurance companies. When an investment bank is trying to sell an issue, this network provides information on how much investors are willing to pay, helping to set a fair price. In addition to this information network, the bank needs a liquidity network to provide the funds to purchase the securities. This network may overlap to some extent with the information network. These networks are compensated by the average underpricing that has been well documented in the literature. Morrison and Wilhelm argue that the role of trust and reputation is crucial for these networks to function. Contracting technology is insufficient to provide the correct incentives.

Schnabel and Shin (2004) document how in the eighteenth century, networks of merchant banks allowed capital accumulated in one part of Europe to be invested in far distant parts. For example, Amsterdam banks were networked with Hamburg banks that

were, in turn, networked with Berlin banks. This allowed savings to flow from Amsterdam to be invested in Berlin and other parts of Prussia. In this case, these networks compensated for asymmetric information due to distance.

Formal network theory has not been used extensively in these studies of investment banks. This is an important and interesting area with many phenomena that are only partially understood, such as long-run underperformance of new issues. Network theory potentially provides a new approach to explain such phenomena and also to provide a basis for normative models to analyze regulation.

Microfinance

Microfinance has emerged as a powerful way for people in the developing world to mitigate risk. Households in developing countries often are faced with unpredictable income streams and expenditures. The uncertainty related to health, weather, crop pests, and job opportunities creates large income variation over time. Medical bills and funeral costs are large expenditures, not always foreseeable (Coudouel, Hentschel, and Wodon 2002). Microfinance may help smoothing fluctuations in consumption that are triggered by shocks in income.

Social interactions play a crucial role in the success of microfinance. For example, in India, Self-Help Groups (SHGs) form the basic constituent unit of microfinance (see, for example, Chakrabarti 2005). An SHG consists of 5 to 20 people, usually poor women from different families. Members pool their savings into a fund that they deposit with the bank. After the bank has observed the accumulation in the fund for a while, it starts to lend to the group, without asking for collateral. Instead, the bank relies on peer pressure and self-monitoring within the group to ensure that loans are repaid.

The success of microfinance in the developing world can be traced to two main factors: (1) a significant decrease in the default rate of loans issued under microfinance terms, and (2) group sanctions that are exercised within the microfinance group to reinforce cooperation. In other words, the social network helps make this financial model work.

Although institutions such as the Grameen bank became widely known, formal microcredit markets are a fairly recent innovation in developing countries. When access to credit is limited, substantial evidence points out that risk sharing occurs through informal bilateral agreements.

While microfinance often depends on local personal networks, such networks have their weaknesses. Group-based models such as microfinance SHGs are often fraught with free-riding and moral hazard problems. These issues and the lack of enforceability of agreements have been identified as the main deterrents for efficient risk sharing (Udry 1994). Inefficiencies arise from the trade-off between the benefits these arrangements provide and the risks involved. Localization is also an issue. Households that live far apart or rely on different occupations are more likely to have different income streams or to be exposed to different sources of risk. Thus, the gains from risk sharing are maximized at large social and geographical distances. However, larger distances make the enforceability of risk-sharing agreements increasingly difficult. For this reason, as has been documented empirically, individuals tend to insure suboptimally, foregoing benefits from risk sharing for better enforceable contracts. For instance, Fafchamps and Gubert (2006) show that the major determinants for the formation of risk-sharing agreements are geographic proximity, as well as age and wealth differences, and not occupation or income correlation. In other words, risk-sharing arrangements are primarily established depending on the enforceability of contracts, proxied by short distances, rather than the diversification of income risk. Understanding the role of networks in this group incentive problem is one potential way of understanding the success of microfinance. We reviewed a few models previously that explore the mechanisms behind cooperation in risk-sharing networks.

Further evidence points out the importance of social networks in emerging economies. Bunkanwanicha, Fan, and Wiwattanakantang (2008) show that marriage might be used to strengthen business alliances. It appears that in Thailand, between 1991 and 2006, more than two-thirds of marriages of big-business owners' offspring were beneficial to the family's firms. This is reflected in the positive reaction the stock market has to the wedding news when the partner is from an economically or politically powerful family.

Most of the work on risk-sharing networks has focused on monitoring and enforceability problems. Other aspects are worth considering as well. For instance, it would be interesting to study the effect that the structure of a preexistent social network has on the formation of a risk-sharing network.

A further question is how introducing a formal institution (that is, a bank) that reduces the need for informal risk-sharing agreements in one region of the network affects the efficiency of risk sharing in the overall network. A closely related issue is to understand the effects of changes in the underlying social network, for example due to migration, on the overall efficiency of the network of risk-sharing agreements.

Conclusion

Our financial systems are networks, and today these networks have grown increasingly complex and interlinked. In this paper, we have argued that network analyses can potentially play a crucial role in understanding many important phenomena in finance. At the moment, this type of approach has mostly been restricted to analyzing contagion in interbank markets. More recent work has focused on the effects of social networks in various contexts, including investment and corporate governance. It seems clear that networks are also crucial in understanding investment banks and microfinance. Another issue to be explored is how some financial institutions exploit their position as intermediaries between other institutions. Financial institutions that bridge otherwise disconnected parts of the network might gain significant payoff advantages. Financial networks will thus be shaped by incentives that drive institutions to acquire the intermediation gains. These are just some of the topics in finance that a network analysis could be useful for, going forward.

Moreover, recent events have made clear that there is a strong need for sound empirical work in this area. Mapping the networks between financial institutions is a first step toward gaining a better understanding of modern financial systems. A network perspective not only would account for the various connections within the financial sector or between the financial sector and other sectors, but also would consider the quality of these links. We need this work to guide the development of new theories that can help us understand events such as the August 2007 crisis, as well as design new regulations that better meet the challenge of an increasingly networked world.

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