Outline of the Research Project

Network Effects and Systemic Risk in the Banking Sector

funded under the Leibniz Community Initiative "Innovative and Risky Research Projects"

1. The Current Crisis in the Financial Sector and Deficits in Economic Research

The field of economics was caught completely unprepared for the current financial crisis. It thus seems to many that it has obviously ignored many important factors and relationships relevant to financial markets. The inability of economic models to recognize developments that exacerbate crises and to capture developments observed in the real world has led to a heated debate about methodological deficits in this field. Paul Krugman, a 2008 Nobel Prize winner, has stated for example that the last 30 years of macroeconomic and financial market research have been "spectacularly useless at best, and positively harmful at worst" (cf., *The Economist*, July 16th, 2009). Others have emphasized that economists are partially responsible for negligence of the distortions in the financial sector, since their prevailing models paint an illusionist picture of a financial sector that is perfectly frictionless. It has also been argued that their axiomatic approaches served, without being validated empirically, as the intellectual basis for the thoroughgoing liberalization of financial markets that has finally led to the current crisis (see, for example, Colander 2009 et al.).

In the prevailing macroeconomic models, the financial sector indeed plays only a very rudimentary role: the central bank sets the interest rate, which in turn affects the consumption and savings decisions of households. The actual actors in the financial sector and the many types of transactions made there do not really play a role in these models. Phenomena such as speculative bubbles, overinvestment, the effects of balance sheet changes and liquidity, and the domino effects of bank bankruptcies are excluded a priori. The origination of distortions in the financial sector and their spread to the real economy is not compatible with the basic structure of these models. The way the financial crisis has played out thus demands that macroeconomic research be given a new direction in many respects. On the one hand, the internal structure of the much differentiated global financial sector and its intrinsic destabilization potential need to be studied. On the other hand, the spread of the crisis from the banking sector to the business sector needs to be studied.

The former will be the primary object of study in the project proposed here, since the network structure of the financial sector is not well researched. Understanding these networks appears to be of central importance in analyzing systemic instabilities. It provides the scientific background for the much emphasized macroprudential approach to regulating the banking sector, an approach that is supposed to take into account not only bank-specific risks but also the system-wide risk factors currently ignored.

2. Network Structures and Systemic Risk in the Banking Sector

The current crisis seemed to many to spread like a contagious disease. It spread rapidly from its initial source, the U.S. real estate market, to far-flung financial institutions because they were holding securities whose yield depended on the default rates for U.S. mortgage loans. After these securities turned “toxic”, they forced their holders to adjust their balances by selling other securities, whereby these subsequently fell in value, causing losses for other security holders and triggering the further spread of the disease. Attempts by financial institutions to protect themselves actually exacerbated the spread of the disease: they stopped giving short-term loans on the interbank market after Lehman Brothers collapsed, but this only caused a further spiral of liquidity problems. Since almost every financial institution depends on a well-functioning interbank market, pulling back from the market, which can be a sensible reaction from a microeconomic perspective, engendered a liquidity crisis that threatened the whole financial system. Governments and central banks had to intervene to prevent the whole system from collapsing.

Most economists will agree with this description of the chain of causes and effects leading to the current crisis. However, our historical understanding of the situational logic of the crisis needs to be complemented and supported by quantitative research. This is especially the case as concerns the linkages and network structures in the global financial sector. Pure situational logic cannot explain why the real estate crash in the United States almost led to the collapse of the complete global financial system, whereas the real estate crash in Japan in the early 1990s basically had only regional effects. Only by understanding the topology of the financial sector will we be able to explain why similar shocks can have such different effects. Similarly, only the quantitative survey of this topology will allow us to derive well-founded knowledge about the fragility of the system, its particular weaknesses, the patterns with which disruptions spread through the system, and the speed with which they spread. A macroprudential approach to regulating the financial sector requires that we have such knowledge. Otherwise, policy makers would have no basis to devise effective measures to increase the absorptive capacity of the financial system.

The current crisis differs from previous crises in particular ways that indicate that the network structure of the system has become increasingly complex. The preceding boom phase saw a sharp increase in investment in new kinds of financial derivatives that allowed various financial institutions throughout the world to participate in the U.S. real estate bubble. The most important of these products are asset-backed securities (ABSs), collateralized debt obligations (CDOs), and credit default swaps (CDSs). The first two kinds are securities whose value and income payments are derived from and collateralized by a specified pool of underlying assets (the most well-known of which are the subprime mortgage loans for debtors with poor credit ratings). The third kind is an agreement to pay the holder a certain amount if a borrower defaults on a loan. Like most derivatives, these derivatives were originally designed to secure risks, but they increasingly turned into independent financial products that are traded by parties that are not exposed themselves to the underlying risks. Because of this, they can have the opposite of their intended effect. A financial institution that otherwise has no ties to the bankrupt Lehman Brothers, can nevertheless go bankrupt merely by being a counterparty in CDS contracts on Lehman Brothers. Holding CDSs creates new ties between market participants that otherwise would have had no ties. This is also the case for various tranches of CDO portfolios that are held by different parties, whereby even those market participants who are directly involved apparently cannot easily determine how strong the ties or correlations to other participants are that such derivatives engender or even who the other participants are. With the current regulatory system, the particular network structures they create are virtually indiscernible to outsiders (or even to those directly involved) because the links are created via a system of “shadow banks” (hedge funds, so-called special investments vehicles, and other special purpose entities) that are not included in the balance sheets of their mother institutions.

The robustness and fragility of network structures is a topic that has been dealt with extensively in the natural sciences in recent years. Economics, however, which has been strongly microeconomically oriented in recent decades, lacks such a perspective on system-wide structures and connections between micro units. One did certainly already express fears of the threat of systemic risk (i.e., expected domino effects) when the hedge fund Long Term Capital Management collapsed in 1998. But even in the current crisis, this term, although commonly used by economic policy experts, is still more of a catchword than a precisely defined category.

3. Network Research in Economics and the Natural Sciences

In the economics literature network structures are mostly studied from a game-theoretic perspective. The starting point in this literature is a decision problem of the simplest possible structure where an individual's utility or benefit depends on interactions with other individuals, but where creating communication structures incurs costs. This literature typically deals with the existence and stability of efficient equilibria of strategic network formation (Jackson and Wolinsky, 1996; Jackson and Watts, 2002). A closely related question is whether an evolutionary dynamics leads to uniform patterns of activity within the network structure (Bala and Goyal, 1998). Often the resulting equilibrium configurations are very simple structures, for example, a star-shaped structure with a common center. However, mechanical models of social network formation often generate structures that are similarly simple without any game-theoretic considerations (Liggett and Rolles, 2004).

Of more relevance to our subject, a second less abstract type of game-theoretic models that is studied in the economics literature is concerned with stylized models of interbank credit. The starting point here is a paper by Allen and Gale (2000), which studies interbank lending intended to provide insurance against liquidity shocks. Within a set-up with four banks they study the properties of all possible permutations of network structures in such a framework. This study, like others on this topic (Lagunoff and Schreft, 2001; Leitner, 2005), looks at stylized networks in a quasi-static model (i.e., in a model with two or three periods for planned and realized transactions). Such models are, however, far removed from empirical structures and quantitative applications. Extant research in this area is also confined primarily to the strategic aspects of microeconomic decisions.

Whereas the literature in economics concentrates on the microscopic aspects of networks, the network literature in the natural sciences concentrates for the most part on their macroscopic characteristics (Schweitzer et al., 2009). The latter is very empirically oriented and attempts to discover regularities in the formation of networks in such varied areas as the internet, the co-authorship of scientific publications, and metabolic structures in living organisms. In this literature, various statistics have been developed to characterize network properties like the average connectivity (the average number of connections), the centrality of nodes, and the average path length between two nodes. Different configurations of such statistics characterize the important classes of random networks, small-world networks, and scale-free networks. Further, this literature has also revealed simple microstructural mechanisms that can generate various types of networks. The mechanism of preferential attachment (meaning that the more connected a node already is, the higher its probability to receive additional links), for example, can generate scale-free networks. An important research topic in this literature is the robustness and vulnerability of various network topologies to the random failure or deliberate elimination of individual network components (Boesch et al., 1981; Criado et al., 2005). Scale-free networks are more robust to random failure than random networks, but they are more vulnerable when the central nodes, or hubs, are deliberately attacked (Solé and Mantoya, 2001).

The applications for such models in the financial sector are obvious: loans and other payment obligations can be seen as links between financial institutions. The current crisis, with its global contagion effects, credit defaults, and liquidity problems, has demonstrated how fragile the whole financial system is. The parallels between the financial system and other complex networked systems have indeed been noticed already before the crisis. The Federal Reserve held a symposium in 2006 that was devoted to network research and its possible applications to the financial sector (Kambhu et al., 2007). More recently, Andrew Haldane, a member of the board of directors at the Bank of England, has repeatedly compared the course of events in the ongoing crisis with the collapse of an ecosystem (Haldane, 2009) and has emphasized the importance of having information on network topology for reforming financial sector regulations.

Pertinent research is, however, still very scarce. Available studies on network structures in the financial sector have been conducted mainly by two groups of researchers: physicists and researchers in central banks. Physicists have applied the instruments used in network research to available data on short-term interbank lending in various countries (see Boss et al., 2004, as regards Austria, Iori et al., 2008, as regards Italy, and Soramäki et al., 2007, as regards the United States). These studies have mostly found that the structures of the interbank market are very similar to those in scale-free networks, i.e., that they have short path lengths on average, and that they are very sensitive to the failure of the highly connected hubs. The critical components of such a network can be characterized as “systemically relevant” institutions, whose failure would engender domino effects endangering the entire system. Scientists at central banks have developed network models for stress tests (often basing their models on the studies conducted by the physicists). The models developed by the Austrian National Bank (Elsinger et al., 2006) and the Bank of England (Aikman et al., 2009) count as the most advanced models for the network structure of the banking sector. Studies conducted at the Deutsche Bundesbank (Upper and Worms, 2004; Memmel and Stein, 2008) have also found that the German banking sector could suffer from systemic risk in the presence of the failure of one or more large banks.

However, in retrospect, many of these studies seem to have underestimated the magnitude of the downstream effects. The reason for this is undoubtedly the fact that a lack of data allows only some of the links between financial institutions to be discerned. Iori et al. (2008) and Soramäki et al. (2007) use only the available data on short-term interbank trading. Boss et al. (2004) and Upper and Worms (2004) use the aggregated data of the German banking sector and construct a linkage matrix using an entropy approach. Other network components, such as the implicit links (mentioned above) that credit derivatives create between numerous market participants, have received little attention. A study using the data available on CDS positions in the U.S. financial sector shows, however, that when a large bank fails solely because of its CDS positions, most of the other large market actors are also affected. Especially the three largest banks in this study were so dependent on one another that if any one of the banks failed the other two would also fail. Thus, they were “too interconnected to fail”. If one of the banks ran into trouble, the government would have no choice but to bail the bank out (Markose et al, 2009).

4. Agent-Based Modeling of the Network Structure of the Financial Sector

Although the available contributions have provided important insights into the linkages within the financial sector, they do not provide a complete picture of the potential dangers engendered by contagion effects within the global financial network. These approaches also suffer from their static design and their lack of a behavioral micro-foundation. The project proposed here aims to push ahead the “mapping of the financial sector” and to expand the current phenomenological literature into an agent-based, dynamic model of the financial sector.

4.1 Comprehensive Modeling of the Network Structure

The first goal of the project is to use all available data sources (aggregated bank statistics, balance sheet data from individual institutions, data from electronic payment systems) to piece together as complete a picture as possible of the important components of the network structure in the financial sector, whereby especially the interactions between “simple” links (generated by loans over various time horizons) and higher-order links (via derivative positions) and the characteristics of the system of “shadow banks” are to be captured. The project will develop a micro-simulation model that maps the structural characteristics of the financial sector in the most important economies (rather than mapping an actual financial system in a particular economy). To do so, empirical knowledge of bank activities derived will be used where possible. This concerns the size distribution of individual institutions (measured by their balance sheet total) and the various types of business they engage in (Boot and Marinc, 2008), as well as the structure of the obligations between the institutions.

Exemplary data on the distribution of interbank obligations can be extracted from data sets that capture complete market segments (e.g., from data from the Italian payment system E-MID). Further information about the structure of linkages can be inferred indirectly from various amply available market data. A large spectrum of econometric methods can be used to draw inferences one the “market’s” assessment of risks of contagion between two (or more) institutions. As underlying data one could use, for example, correlations between the stock prices of two banks (Gropp et al., 2008), or conditional default probabilities based on multivariate models of the determinants of risk premia on default insurance (Azizpour and Gieseke, 2008).

A “calibrated” model that is as complete as possible is to be used for stress tests and to test possible regulatory measures. These tests will then allow inferences to be made about systemic risk and the ability to contain this risk. An important aim in this context is to identify meaningful indices of vulnerability for the complete system and for the links between individual institutions, which provides crucial information for any approach to system-wide regulation. To accomplish this, insights derived in the natural sciences can be used (Kitsak et al., 2010), but will have to be adapted to this new area of application.

4.2 Behavioral Micro-Foundation

In the second stage of our project, our aim is to move beyond an empirically calibrated structure and to develop an evolutionary system of interacting market participants that is based on behavioral components. To accomplish this, behavioral regularities for the stylized business policies of the banking sector will first have to be developed. Whereas most of the components can be derived from the microeconomic theory of bank behavior (Freixas and Rochet, 1997), there is a complete lack of behavioral foundations for interbank trading. Some of the findings in an unpublished paper by Iori et al. that is based on Iori et al. (2008) indicate that links do not develop randomly, but rather that long-term business relations obtain that are taken advantage of when there is not enough or too much liquidity. By using the complete data sets on the Italian overnight interbank market, it should be possible to rigorously analyze this phenomenon and explicitly estimate the behavioral parameters for the development and maintenance of links. Various methods developed in the social sciences of estimating the parameters of dynamic processes in the formation of networks can be used for this purpose (Koskinen and Snijders, 2007; Snijders et al., 2009). Estimates from this market could serve as benchmarks for the behavioral parameters of our stylized model.

A behavioral model would make it possible to generate endogenous adjustments of market participants that go beyond the mechanical transmission of shocks, and thus would provide a more flexible picture of possible contagion effects. Instead of producing momentary pictures of prevailing links in the banking network, a “pulsating” system could be produced whose structure is continually changing. It would then be possible not only to determine domino effects by using stress tests, but also to analyze the emergence of fragile structures. An agent-based model would be able to show whether endogenous mechanisms exist that make the system tend towards critical states, for example, to develop increasingly high levels of leverage (degrees of indebtedness) and stronger linkages. The object of the analysis would then be the long-term statistical characteristics of the system (e.g., the frequency and the determinants of insolvencies) and the temporal variation in network statistics. Such a model would be a suitable instrument with which to analyze the interactions between the financial sector and the real economy, since it would provide a basis with which to model lending in a fragile banking sector.

A plausible model could serve as laboratory for regulatory or structural measures, and thus as a test bed for the system-wide supervision of the financial sector. Thus, it could be used to analyze the stability or fragility of different architectures of the banking sector, the effects of differentiated capital requirements in various economic situations, the role of a particular institution in the system (measured, for example, by its centrality or the intensity of its linkages), and the effects of rating conventions and the regulation of derivatives markets. When structures change (e.g., because banks merge), it could be used to determine whether the change tends to stabilize the system or make it more fragile. It could also be used to answer broader questions about the basic structure of the banking sector: Does separating traditional banking from investment banking increase the ability of the system to absorb shocks? Could a public banking sector with limited areas of business provide a “backup” for a fragile private system? Finally, should the legal options for banks to offshore loans in special purpose entities be revised?

5. Innovation and Risk Content

In summarizing the Fed’s network symposium, its organizers wrote:

> *An effort to model an entire system, with the aim of learning how to control it better, is a very large-scale project and one that academic economists will not readily take on because of the way the profession is organized and financed.* (Kambhu et al., 2007, p. 379)

International organizations and economic policy makers have also emphasized the importance of network modeling for the financial sector (International Monetary Fund, 2009; Financial Stability Board, 2009; European Central Bank, 2010). Nevertheless, applied research on network models has hitherto been conducted almost exclusively by physicists and scientists at central banks. Because the traditional methods used in economics are so conceptionally different from the methods used to study networks, it is not very probable that research on the network structures in the financial sector will intensify any time in the near future. Since untried methods would have to be adapted and new concepts would have to be developed, it does not seem too promising for economists under an individual career perspective to conduct research on the societally urgent problems addressed here. Further, such research would require interdisciplinary teams of researchers that are normally not found in the staff of an economics department. Given the dimension and the riskiness of such a research project, an effort like this seems better placed in a larger research center, such as the Kiel Institute for the World Economy. The Kiel Institute also has a great deal of experience in conducting interdisciplinary research, for example, environmental, development, and transformation research, and maintains close ties with central banks and international organizations as regards macroeconomic issues that are closely related to the research proposal presented here.

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