Systemic Risk and the Financial System

Background Paper

NAS-FRBNY Conference on New Directions in Understanding Systemic Risk

Federal Reserve Bank of New York

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Introduction

This paper is intended as background material for a cross-disciplinary conference, sponsored by the Board of Mathematical Sciences (BMSA) of the National Academy of Sciences (NAS) and the Federal Reserve Bank of New York (FRBNY), on new approaches to evaluating systemic risks and managing systemic events in the global financial system. A key objective of the conference is to bring together a diverse group of leading researchers who have developed analytical tools for the study of complex systems in a range of fields of inquiry.

The stability of the financial system and the potential for systemic risks to alter the functioning of that system have long been important topics for central banks and for the related research community. However, recent experiences, including the market disruption following the attacks of September 11, 2001, suggest that existing models of systemic shocks in the financial system may no longer adequately capture the propagation of major disturbances. For example, current models do not fully reflect the increasing complexity of the financial system's structure, the complete range of financial and information flows, and the diverse nature of the endogenous behavior of different agents in the system. Fresh thinking about systemic risk is, therefore, desirable.

This document describes the broad features of the global financial system and the models with which researchers and central bankers have typically approached the issues of financial stability and systemic risk—information that can serve as a shared reference for conference participants. The conference itself will provide an opportunity for participants to discuss related research in other fields and to draw out potential connections to financial system mechanisms and models, with the ultimate goal of stimulating new ways of thinking about systemic risk in the financial system.

Systemic risk is a difficult concept to define precisely. A recent report by the Group of Ten countries (2001) on financial sector consolidation defined systemic risk as "the risk that an event will trigger a loss of economic value or confidence in, and attendant increases in uncertainty about, a substantial portion of the financial system that is serious enough to quite probably have significant adverse effects on the real economy." This definition is broad enough to permit different views on whether certain recent episodes within the financial system constituted true systemic risk or only threatened to become systemic by having a significant adverse impact on the real economy.

Some argue that even damage to the real economy is not sufficient grounds to classify an episode as systemic; rather, the key characteristic of systemic risk is the movement from one stable (positive) equilibrium to another stable (negative) equilibrium for the economy and financial system. In this view, research on systemic risk should focus on the potential causes and propagation mechanisms for the "phase transition" to a new but much less desirable equilibrium as well as the "reinforcing feedbacks" that tend to keep the economy and financial system trapped in that equilibrium.

While differences in the definition of systemic risk are clearly important from a policymaking perspective, this paper includes discussions of episodes that not everyone would agree were systemic in nature. This is because our primary interest is in stimulating further research on the types of propagation or feedback mechanisms that might cause a small financial shock to become a major disturbance, allow a financial shock to have a material impact on the real economy, or mire the financial system in a sub-optimal equilibrium. In this regard, the dynamics of nonsystemic episodes may still be very relevant to the modeling of financial market behavior. Moreover, as a recent private sector report on risk management practices (Counterparty Risk Management Policy Group 2005) noted, "Unfortunately, in real time it is virtually impossible to draw such distinctions."

The remainder of this document is organized in three sections. The first describes the classical case of systemic risk in a banking-dominated financial system and provides some background information on the current workings of the international banking system. The second section focuses on issues that arise in market-oriented "panics" (for example, the October 1987 stock market crash) and again seeks to provide some relevant background information. The third section discusses the challenges in understanding the full nature of systemic risk posed by events of the last decade (for example, the Asian currency crises and 9/11 gridlock) as well as key ongoing trends in the financial markets generally. Significantly, this document is meant primarily to stimulate discussion of relevant issues at the conference; it is not intended to provide a comprehensive overview of the substantial economic literature on systemic risk and financial instability.

Systemic Risk in Banking Systems

Banks have long been at the center of financial activity. They remain so today, even though their share of financial intermediation has been reduced by the growth of capital markets and mutual funds and other developments of the last few decades. The largest commercial banks have balance sheets in the $1 trillion range, engage in extensive international operations, and maintain a presence in a wide variety of retail and wholesale financial business activities. These activities include making loans to corporations and individuals; underwriting debt and equity securities offerings; acting as dealers in foreign exchange, securities, and derivatives markets; providing asset management services; providing payments, settlement, and custodial services; and taking deposits.

The classical model of a commercial bank is a firm that makes loans on the asset side of its balance sheet and takes demand deposits (checking and savings accounts) on the liability side.[1] The loans are typically perceived as being long-term "illiquid" assets in the sense that efforts to liquidate them prior to maturity will yield a reduced value relative to their intrinsic worth if held to maturity. However, the bank is obligated to pay back demand deposits at any time the depositor requests. Thus, banks are seen as providing a fundamental maturity and liquidity transformation that is both beneficial and inherently unstable.

[1] The following discussion draws heavily on Diamond and Dybvig (1983).

This instability is seen by considering a case in which each depositor at a particular bank would be willing to leave his or her funds on deposit, but believes that other depositors are likely to withdraw their funds, thus making it necessary for the bank to call in its loans and suffer the associated losses. In this case, all rational depositors will seek to withdraw their funds as quickly as possible, producing a "run" on the bank. In this simplified model, bank runs can be caused by concerns over liquidity even if the bank's assets are fundamentally sound on a going-concern basis (that is, the bank is solvent). The distinction between illiquidity and insolvency is one that occurs repeatedly in discussions of systemic risk.

Moreover, in this model, bank runs can be contagious. The contagion can arise simply as the result of a self-fulfilling prophecy if depositors believe that other depositors will regard a run at one bank as an indication that runs are now more likely at other banks. Somewhat more concretely, contagion may be more likely to occur if the issue that sparked the original run—excessive loan exposure to real estate or the oil industry, for example—is perceived to potentially affect other banks, or as the result of concerns about significant interbank exposures (that is, runs at banks seen as having large exposures to the bank subject to the original run). Naturally, in this model, runs are more likely at banks perceived to have a smaller equity capital cushion to absorb declines in asset values and at banks whose financial condition is difficult to assess in the first place.

Although the model just described is highly simplified, it nevertheless captures the essence of past bank runs, which occurred with some frequency before the 1930s. The primary approaches to dealing with the risks inherent in banking activity have included (1) controlling the relative risk of the loans extended—for example, through regulation, (2) requiring that bank balance sheets contain a larger share of equity capital and a smaller share of demand deposits, and (3) ensuring that government provides a "lender of last resort" function and/or deposit insurance.

The lender of last resort role is one of the most distinctive functions of central banks. In this role, central banks such as the Federal Reserve typically have the authority to provide short-term liquidity to banks against collateral. For example, a bank could pledge some of its loans to the central bank and obtain cash on a short-term basis. In determining whether to provide liquidity, the central bank must make a judgment about the bank seeking funds. The conventional wisdom that emerged in the nineteenth century was that central banks should "lend freely at a penalty rate" when they believe that the bank needing funds is illiquid but not insolvent, but should not lend at all to a bank that is truly insolvent. Of course, there is often substantial practical difficulty in distinguishing illiquidity from insolvency.

The provision of deposit insurance in the United States followed the bank runs of the early 1930s. Deposit insurance aims to eliminate the threat of a bank run directly, by assuring depositors that they will be paid regardless of whether the bank ultimately fails. While clearly effective in discouraging bank runs, deposit insurance further reinforced the need for bank regulation to limit the extent of banks' risk taking. Economists refer to the incentive problems created by the presence of deposit insurance as an instance of "moral hazard." That is, bank managers will want to take on risk to increase their upside

potential, but insured depositors will have no incentive to monitor or constrain their behavior. Thus, the bank runs of the Great Depression served to shape the institutional framework in which banks operate today—a framework that emphasizes official regulation and supervision of banks.

In considering the systemic risk associated with banking crises, one should also bear in mind the social costs of such episodes. On balance, the economic literature on the Great Depression concludes that much of the social cost of this episode stemmed from the interruption to credit allocation that occurred when vast numbers of loans had to be called in as a result of the bank runs. That is, the broader, nonfinancial portion of the economy was seriously hurt by the interruption in the financing of its activities and by the reluctance of banks to extend new financing amid a series of bank runs. Concern that financial sector crises may adversely affect the functioning of many other parts of the economy is a recurrent theme in discussions of systemic risk.

Although the overall importance of banks within the financial system has declined in the last few decades, the largest banks in the key financial centers remain sufficiently important that their failure to function normally would raise questions of a systemic nature. Significantly, these institutions exhibit several of the characteristics discussed above.

- They are highly leveraged, with equity-to-total-asset ratios ranging between 5 percent and 10 percent.

- While banks are less reliant on short-term-deposit funding than the stylized model just outlined would imply, such funding remains a material part of the liability structure for the largest institutions.

- The scope and complexity of their activities and legal/organizational structures make assessments of their true financial condition by outsiders difficult, while also posing significant management challenges for the banks themselves.

- The largest banks typically have very significant exposures to one another, for example through interbank deposit markets, interdealer transactions in over-the-counter (OTC) derivatives, and wholesale payment and settlement arrangements.

- According to some commentators, banks remain particularly prone to cyclicality and myopia in their credit processes, tending to forget the last cycle of bad lending too rapidly when economic conditions brighten. The old saying that “bad loans are made in good times” captures the essence of this concern.

- Finally, the largest banks appear to be increasingly subject to legal and regulatory risks stemming from actions of their employees, risks that in some cases could result in sudden adverse impacts.

Nevertheless, despite the vulnerabilities just outlined, the financial system today does not seem highly prone to contagious runs on very large banks. This reflects the relative profitability and health of banks in many countries as well as the perception that

the largest banks would benefit from liquidity provision or other forms of official assistance should runs appear imminent. In Japan, for example, official intervention following the emergence of significant banking sector problems in the 1990s largely forestalled major bank runs. Interestingly, however, Japan's policies to prevent runs did not prevent economic weakness associated with a banking sector too fragile to play a full and vibrant role in financing broader economic activity. In the United States, policymakers have sought to discourage the assumption that large banks are "too big to fail" and instead have worked to ensure that such banks maintain a strong financial condition and adopt rigorous risk management policies and procedures.

This last point reflects a concern that ineffective public policy choices can serve to generate systemic risk. For example, many observers note that the U.S. savings and loan crisis of the late 1980s largely resulted from policies that paid insufficient attention to "moral hazard" concerns. The expansion of deposit insurance effectively left even the largest depositors with little incentive to monitor firm risk. In addition, supervisors failed to deal with insolvent firms promptly, creating strong incentives for the management of such firms to invest in high-risk projects in an effort to restore solvency. The downside risks of these (frequently sub-optimal) investments ended up being borne by society at large, both in the form of increased government deficits stemming from the bailouts of depositors and in the form of numerous investments yielding little or no return.

While the liquidity-based contagious run model of systemic risk applies very directly to banks, it also has relevance to other kinds of institutions. The largest securities firms rely on debt rather than bank deposits as a significant funding source and hold a greater share of their assets in the form of marketable securities than do banks. Nevertheless, some analysts have argued that securities firms may be vulnerable to contagious runs because of their reliance on short-term funding sources such as commercial paper, the complexity of their transactions in less liquid securities markets, and their derivatives businesses. As leveraged institutions, hedge funds that do not effectively manage their liquidity risks could also be subject to runs by their investors and creditors. Indeed, liquidity risk management failures contributed to the problems experienced by the Long-Term Capital Management (LTCM) hedge fund in 1998. The case of LTCM is discussed further in this paper's final section, as it raises other issues about the sources and propagation of systemic risk.

Significantly, a run on an individual firm alone might not be enough to create systemic risk according to the definition outlined above unless the liquidation of assets by the firm or an associated reduction in the firm's underwriting activities were to have a material impact on economic growth. For example, in 2001, Enron suffered what amounted to a run on its short-term liabilities in the period immediately preceding its bankruptcy filing, but there appeared to be very limited systemic contagion to other energy-trading firms and very little impact on the broader economy.

Systemic Risk in Financial Asset Markets

While the bank run model of systemic risk has been fairly widely studied in the financial economics literature, more recent examples of systemic financial crises have

often been associated with disruptions to financial markets, rather than runs on particular financial institutions. For example, the 1987 stock market crash was not precipitated by concerns at an individual institution, nor was it the proximate cause of the failure of any large financial firm. Nevertheless, it was clearly viewed—at the time and since—as an event with potentially systemic consequences that warranted official sector intervention.

A market-oriented systemic crisis typically manifests itself as a breakdown in the functioning of financial markets for traded assets such as stocks and bonds, and it may develop in response to a sharp decline in the value of one particular type of asset. In addition to the 1987 stock market crash, examples of such crises might include the widening of interest rate spreads and decline in liquidity following the near-collapse of LTCM in 1998 and the collapse of the junk bond market in 1989-90. In the more distant past, the Dutch tulip mania of the 1630s and similar episodes could, in their end-stage, be viewed as additional examples of this type of crisis.

Consider first the characteristics of the 1987 stock market crash. Two aspects of this systemic market episode are particularly important to highlight. First, the episode suggests that asset price declines can in some circumstances become self-reinforcing and even feed into a reduced willingness on the part of major financial institutions to bear risk across the full range of their activities. Second, the episode underscores the potential importance of not only the specific institutional arrangements that are in place for clearance and settlement of transactions but also the credit and liquidity exposures arising from those arrangements.

Market-Based Financial Crises, Liquidity, and Self-reinforcing Price Movements

The need to shift emphasis from bank runs to "market gridlock" as a source of systemic risk has arisen from a number of factors, not least the success of policies aimed at preventing runs mentioned earlier. In addition, financial crises now manifest themselves in markets rather than in institutions because financial intermediation has moved into markets and away from institutions. This "disintermediation" in financial activity has been particularly pronounced in the United States in the last thirty years. For example, in 1975, commercial banks and thrifts held 56 percent of total credit to households and businesses; by 2005, this figure had dropped to 33 percent. A large fraction of financial assets—both equity and debt—are sold directly by issuers/borrowers to investors, especially institutional investors, via stock and bond markets, effectively bypassing traditional banking.

The shift from a bank-based to a market-based financial system has expanded the types of activities that banks and other financial intermediaries engage in and the assets that they invest in. The large financial institutions at the core of the system have expanded their activities to intermediate the movement of capital among the various other participants in multiple ways. They assist businesses in the issuance of new stocks and bonds directly into the market (investment banking), intermediate to buy and sell stocks and bonds (market making) after issuance on behalf of clients (broker dealers/trading desks), manage asset portfolios on behalf of individuals and institutions (asset management), and lend directly to households and businesses (traditional commercial

banking). The consolidation of financial activity has produced a general trend toward the formation of large, complex institutions at the core of the financial system. At the same time, however, disintermediation has increased the importance of "end-user" financial institutions that invest in securities on behalf of households and firms. These include mostly unleveraged institutional investors (mutual funds, pension funds) as vehicles for household savings as well as more lightly regulated and more leveraged risk-bearing entities (hedge funds).[2]

Market-based financial intermediation has a number of advantages over a banking-oriented financial system. One important advantage is that the investment risk in holding securities is dispersed broadly among investors instead of being concentrated in financial intermediaries. For example, debt instruments issued by ultimate borrowers are held directly by savers/investors to a greater degree than in a banking-oriented financial system. Another feature of today's financial system that works to reduce systemic risk is the replacement of bank deposits by mutual fund shares as an investment vehicle for households. While the fixed face-value of a bank deposit is inherently fragile, the value of a mutual fund share fluctuates with market prices daily. As a result, the mutual fund model is better able to absorb and disperse shocks across a wide set of investors.[3]

Although superior to a banking-oriented financial system in some respects, market-based financial intermediation carries its own vulnerabilities. The capital markets work best when key markets are liquid. In this context, the term *liquidity* refers to tradability. When a market is liquid, any single trade to buy or sell a particular asset is unlikely to have a major effect on the price of the asset because of the large number of willing transactors on both sides of the market. Market liquidity also ensures that investors can buy and sell securities without undue delay or loss in value from the price impact of the transaction. Almost by definition then, a market-gridlock systemic crisis is a period when market liquidity is absent.

In normal circumstances, market liquidity rests on a number of foundations. Foremost among them are market making, trading, and arbitrage. Market makers buy and sell out of inventory they maintain to meet customer demand. They smooth out short-run imbalances in market supply and demand, and profit from the bid/ask spread. Arbitrageurs also contribute to market liquidity by trading on bets that prices will converge to long-run fundamental levels. These traders typically take positions that they hold for potentially long periods of time until prices converge to their long-run norms. Arbitrageurs play an important role in maintaining the stability of markets and speeding up the convergence of prices to their fundamental values.

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[2] Note too that any large market participant itself consists of a very large number of separate legal entities, with many different charters, incentive structures, constraints, and regulations.

[3] Money market mutual funds raise some of the same issues as bank deposits because of their limited ability to bear credit losses; historically, parents of such funds have absorbed impaired money market instruments rather than allow a credit loss to reduce the fund's share value below $1.

Modern market-oriented crises tend to begin with a large change—usually a decline—in the price of a particular asset; the change then becomes self-sustaining over time. When asset prices drop sharply, there are generally some participants (arbitrageurs) willing to "swoop in" and buy assets that have declined sufficiently in price—an action that largely prevents the stress from becoming worse. In systemic crises, however, arbitrageurs are either unable or unwilling to step in, perhaps because their own losses have limited their market-making capacity or because a structural failure in, say, payments or settlement systems has made such a step difficult. As prices decline, more and more market participants sell, pushing prices lower. Eventually the price declines become so large and persistent that no buyers emerge, market liquidity dries up, market participants reduce their intermediation activities and their risk taking, and market gridlock takes hold. This sequence of events is in some measure self-reinforcing: if price declines are sufficiently large to create losses for arbitrageurs, these participants may cease providing liquidity to the market, thereby exacerbating the price declines.

Market-based crises are often characterized by a coordination failure in which a wide cross section of participants in financial markets, including market makers and arbitrageurs, simultaneously decide to reduce risk taking and effectively pull back from financing activities (trading stocks, issuing new stocks and bonds, lending, and so forth). While no one institution is necessarily insolvent or illiquid, each firm reduces its activity and risk to protect capital and profits. In aggregate, however, the firms' actions combine to slow down or stop financial market activity. In severe cases, the financial system could become almost paralyzed and unable to perform its core functions of channeling capital to investment opportunities. The period immediately following the 1987 stock market crash is a classic example of this type of coordination failure, although its consequences were contained.

The potential for self-sustaining dynamics in financial price movements has been studied extensively in the finance and economics literature. Minsky (1977) and Kindleberger (1978) have advanced theoretical explanations for many varieties of financial crisis in which an exogenous change in the economic environment leads to the creation of new profit opportunities that attract capital fed by an expansion in credit.[4] For a time, these investments give rise to even more profit opportunities, leading to a speculative euphoria that, by involving segments of the population typically not involved in such ventures, becomes a "mania" or a "bubble." However, at a certain point, knowledgeable insiders begin to take profits and sell out. Prices begin to level off and some financial distress may ensue. A crisis occurs when a specific event precipitates the equivalent of a run on the asset class that was the subject of the speculative frenzy. Revulsion develops toward that asset class by banks and others that had previously lent against it, and with this revulsion arises a desire to obtain liquidity at nearly any cost. The resulting panic culminates when (1) asset prices fall so low that investors are tempted back, (2) trading is cut off, perhaps by the closing of the relevant exchange, or (3) a lender of last resort succeeds in convincing the market that sufficient liquidity will be available to meet demand if necessary.

[4] The discussion in this paragraph draws heavily on Kindleberger (1978).

Although not all economists would subscribe to this broad theory of speculative financial crises, it is useful to keep in mind, especially in relation to those features of the financial system that could make the system particularly vulnerable to large, self-sustaining changes in asset prices, and thus to market gridlock.

In modern financial systems, debt and leverage are necessary and pervasive. Many market participants, including the largest intermediaries, borrow funds in order to expand their balance sheets and thus increase their ability to invest and trade in financial assets. They adopt this strategy to increase their return on equity capital invested (that is, by holding assets expected to yield returns exceeding the cost of the funds borrowed). As noted earlier, the largest banks are nearly all leveraged more than ten to one, implying that such institutions cannot afford to realize losses greater than 10 percent of the value of their assets if they are to remain solvent.

The obvious implication of leverage is the need for financial institutions to carefully control their losses and to take steps to reduce their risk taking in the face of declining asset values. In other words, leverage creates an incentive to sell assets whose prices are declining, particularly if further price declines are expected in the future. For example, if a firm is leveraged ten to one, then even a 1 percent realized loss in asset value translates to a 10 percent loss in the firm's capital value. Collectively, of course, widespread selling after an asset price decline will likely push prices even lower and losses higher. This scenario raises the obvious concern that such liquidations would further amplify the underlying price movements.

Moreover, in some markets, liquidations after losses can be automatic. For example, when an investor trades stocks on margin accounts (by borrowing a percentage of the stock value), a subsequent decline in the value of the stock requires that the investor post (add) collateral—usually cash—in order to bring the margin account back into compliance with the margin rule of the stock exchange.

In the 1987 stock market crash, large margin calls required investors to sell stock, thus putting further downward pressure on stock prices. The sudden and large fall in stock prices created large debits in the accounts of investors that had purchased stock on margin at brokers or held long positions in equity-linked derivatives contracts on futures exchanges. These margin account debits created a need to transfer large sums of cash that many investors were not able to provide within the time frames required by brokers and the futures exchanges.

An additional feature of contemporary financial markets that can create self-reinforcing asset price dynamics relates to financial products that exhibit convexity in their price behavior. Assets (or derivatives) with convexity are those that become more or less sensitive to changes in an underlying asset price (or other variable) as that price or variable changes.

The classic example of convexity is an option. An option is a right, but not an obligation, to buy (or sell) a particular asset (for example, 100 shares of IBM) at a particular price at some point in the future. Those who have sold options to others are

exposed to what market participants call negative convexity: as the underlying asset price falls, the value of the sold option position becomes increasingly sensitive to further declines in the price of the underlying asset. If the option seller should try to compensate for this increased sensitivity by selling the underlying asset, it will put additional downward pressure on the underlying asset price. But a further decline in the underlying asset price simply increases the option sensitivity again, prompting even more selling. Thus what appears to be a risk-mitigation strategy by the options seller is, in fact, a strategy that can reinforce adverse asset price dynamics.

This phenomenon was evident in the 1987 stock market crash. At that time, many institutional investors had purchased portfolio insurance from intermediaries or were attempting to replicate such insurance through dynamic hedging strategies. Portfolio insurance is nothing more than a put option on the underlying asset; it exhibits exactly the characteristics outlined above. The seller of the insurance (or the firm trying to replicate it) must hedge its position by selling in greater amounts as prices decline, creating even further downward price pressure. Although the extent to which such activity was responsible for stock price declines in October 1987 is heavily debated, there is little doubt that such strategies—if widespread—have the potential to create self-reinforcing market movements.

Importance of Clearance and Settlement Arrangements

Clearance and settlement mechanisms contributed greatly to the liquidity strains created by the large price declines across cash, futures, and options markets and the resulting margin calls in the 1987 stock market crash. The different settlement arrangements and time frames for different products (that is, T+5 for stocks traded on the exchanges at that time in contrast to same-day settlement for stock index futures) meant that even investors that were hedged across the different markets could face large cash demands during the interim period.

This sudden need for large cash transfers threatened to create gridlock in the payments system and in the stock and futures markets. Securities firms did not have the funds to make margin payments at futures exchanges because their customers had not made margin payments to them. The futures exchanges' credit risk management practices required that positions be closed out when margin payments were not made. This unwinding of futures positions would likely have triggered further massive selling pressures in the stock market, exacerbating what had already occurred. However, the concentration of risk in the clearinghouses used to guarantee settlement of both securities and futures transactions meant that if positions were not closed out and markets fell further, the integrity of the clearinghouses themselves could be threatened. Since these clearinghouses form a core part of the infrastructure supporting the relevant trading activities, such an outcome could have significantly impaired market functioning for a sustained period of time.

In the end, large commercial banks were persuaded of the need to supply liquidity to those firms most heavily exposed to equities (that is, by lending against the value of those portfolios), and the most severe consequences were averted. However, the banks'

action was due in part to official sector appeals to their collective desire to avert a further deepening of the crisis, as well as a stated willingness by the Federal Reserve to make more liquidity generally available to the banking sector.

This example shows that arrangements for wholesale market payments, clearance, and settlement can be a significant source of systemic risk, owing to the very sizable credit and liquidity exposures that typically characterize such arrangements, particularly on an intraday basis. In normal circumstances, the extension of such large amounts of intraday credit and liquidity between the major participants in these mechanisms facilitates more rapid settlement of the transactions. During a crisis, however, the reluctance of participants to continue doing business in this fashion can potentially lead to gridlock.

A case in point is the 1974 failure of Herstatt Bank, a midsize German bank whose U.S. bank correspondent had received payment on the foreign currency leg of Herstatt's foreign exchange transactions but subsequently refused to make payment of the U.S. dollar legs that were to settle later the same day in New York. This created a short-term gridlock in the foreign exchange market that remained a source of systemic concern until the mid 1990s, when central banks made clear that the amounts of such "payment vs. payment mismatch" were too large to be tolerated indefinitely and the large commercial banks invested in the CLS Bank, a system for simultaneously settling both sides of foreign exchange transactions.

Broadly speaking, central banks and others in the official sector have been pushing for continuing improvements in the robustness of payments, clearance, and settlement mechanisms. These improvements provide greater assurance to investors that their transactions will settle, and that the mechanisms for payment and settlement will not themselves become a channel for propagating systemic disturbances. Nevertheless, these arrangements remain highly complex and are increasingly concentrated. For example, most market participants effectively outsource payments, clearance, and custodial functions associated with their transactions to an increasingly small number of global banks that specialize in those activities.

In turn, these banks at the core of the financial system interact with a relatively small number of specialized organizations that actually provide the central settlement functions for specific assets. For example, the Federal Reserve provides settlement services for U.S. dollar wholesale payments through its Fedwire service while the European Central Bank does the same for euro-denominated payments. The Federal Reserve provides settlement services for U.S. government bonds, while the Depository Trust and Clearing Corporation (DTCC) provides clearance and settlement services for a wide range of securities, including all equities traded on U.S. stock exchanges. Significantly, all of these systems continue in one form or another to provide large amounts of intraday credit to their major participants.

Many financial markets (especially securities and futures markets) have, in addition to the settlement mechanism, a clearinghouse that provides further assurance that transactions will settle by interposing itself as the legal counterparty to both sides of the

original transaction. The clearinghouse typically imposes margin requirements or other controls on member transactions while also maintaining its own financial resources and/or the ability to call on its members' resources. Although clearinghouses have the ability to contain financial distress, they can also magnify it—as the 1987 stock market crash vividly illustrates—if problems are severe enough to call the integrity of the clearinghouse into question.

Role of Central Banks

Central banks have historically played a key role in ensuring that financial markets have sufficient liquidity to function effectively. They have several tools that can be used in this regard. First, they control the aggregate supply of bank reserves—the ultimate unit of account. By increasing the supply of reserves, central banks can increase the aggregate amount of liquidity in the financial system. Second, central banks function as the lender of last resort, a role that gives them the ability to lend directly to individual commercial banks. In extraordinary circumstances, the Federal Reserve System also has the power to lend directly to any individual or corporation, although this power has not been exercised since the 1930s. Third, the central bank typically possesses sufficient influence to persuade market participants that a collective decision to make liquidity available in particular circumstances will produce a better outcome than if individual market participants all seek to "free ride" on the actions of others. Largely because these tools are so effective, the central bank can often forestall liquidity pressures simply by announcing its willingness to make liquidity available should the need arise. Such announcements were made by the Federal Reserve in the wake of the 1987 crash as well as after the events of September 11, 2001. Elaborate assurances of this kind were also given in advance of the Y2K rollover.

Of course, central bank actions to forestall financial crises may themselves have a cost. In line with the moral hazard argument discussed in the section on banking-oriented crises, it is important that market participants not become so complacent that they count on the central bank to defuse any potential market-oriented financial crisis and thus under-invest in their own management of market and liquidity risks.

New Sources of Systemic Risk

In the last ten to twenty years, financial markets have evolved significantly. They are more global and involve a wider range of more complex products than ever before. In some areas, market activities have become increasingly concentrated in a handful of very large firms. In other areas, the role of smaller, more specialized entities has grown significantly. From a policy perspective, there does not seem to be a clear consensus on whether the financial system today is more or less vulnerable to systemic disturbances than it was in, say, 1990.

Moreover, several of the most significant financial market disturbances of the last decade manifested features that, though present in earlier financial crises, have become more prominent. As the "supply chain" has evolved from the simplicity of a bank's making and servicing a loan over its life to the complexity of securitization (involving

originators, holders, servicers, trustees, and hedging markets), the focus on core banks and securities firms and major markets must expand to include other potential single points of failure. In addition, the economic forces leading to consolidation have included economies of scale in risk and liquidity management. The liquidity needed in key market-risk-management markets and in the processing of high-value dollar payments derives in substantial part from the natural offsetting of risks or payments when volumes are high. Finally, the global scale of large banks and securities firms and some major investors has expanded the channels that can transmit systemic risk.

These new features raise interesting questions about whether the kinds of conceptual models outlined in the preceding two sections fully capture the range of possible causes and propagation channels for systemic risk. The discussion below addresses two cases: (1) the events of 1997 and 1998 that involved currency crises in several Asian countries, the Russian debt default, and the collapse of the Long-Term Capital Management hedge fund, and (2) the disturbances in payment and settlement arrangements following operational disruptions resulting from the terrorist attacks of September 11, 2001.

Asia, Russia, and LTCM

This sequence of events began in the summer of 1997 as certain Asian countries faced a substantial change in market sentiment that exposed relatively fragile macroeconomic conditions. In particular, several countries had short-term foreign currency debts that far exceeded their international reserves. The countries were thus susceptible to a run on their currencies, with generally negative consequences from a macroeconomic point of view. While currency crises are an extremely well-studied subset of economic crises, the Asian episode was notable in several respects.

First, the Asian crisis was characterized by a significant interplay between macroeconomic and financial sector factors. This interplay reflected weakness in the banking sectors of some countries that, while not the root cause of the crisis in all cases, clearly affected how the crisis played out and how well each country absorbed the macroeconomic impact of the crisis.

Second, consistent with the model of bank runs outlined earlier, contagion figured very prominently in the Asian crisis. Indeed, the events demonstrated a new mode of contagion. Various trading and risk management strategies now commonly used by market participants created linkages between different assets and activities that may not have previously existed, in some cases requiring positions in one currency to be adjusted largely as the result of movements in another. In some instances, a problem triggered by a currency or maturity mismatch in one country or market would lead global investors seeking to reduce risk to identify similar vulnerabilities in other markets.

A year later, contagion figured in the relationships between Russian debt and the debt of Brazil and other emerging economies. Although the economies of Russia and Brazil are not themselves closely integrated, the prices of their debt fluctuated largely in tandem. In part, these parallel fluctuations reflected the fact that many of the holders of

this debt specialized in holding the debt of emerging market countries, regarded these countries as proxies for each other, and needed to maintain some stability in their overall risk profile. Thus, when Russian debt began to be perceived as increasingly risky and to lose liquidity, some of these participants began to sell their Brazilian debt to reduce their risk profile and to take advantage of the Brazilian debt's greater liquidity. Ultimately, of course, the correlation between these two assets broke down as Russia defaulted while Brazil did not.

The Russian government default of August 1998 occurred against the backdrop of the Asian crisis that had been playing out over the preceding year, but otherwise took place in a period that was characterized both by the strong macroeconomic performance of the United States and by the strong financial condition of the major financial intermediaries. Nevertheless, the Russian default set in motion a chain of events that created significant fear among the leadership of those same intermediaries and served to reduce liquidity across most of the world's capital markets for some months.

Long-Term Capital Management was a hedge fund that conducted leveraged trades involving both securities and derivatives on a large scale and used highly sophisticated mathematical approaches to manage its risk. The firm suffered a severe loss of capital when prices moved against its positions following the Russian default. While LTCM's uniquely high leverage made it a fragile enterprise, it may not have been the only leveraged investor to be vulnerable, and this broader vulnerability may have played a role in amplifying the price shocks that occurred in a number of markets following the Russian default. For a year or two before the crisis, the liabilities of financial intermediaries had increased substantially relative to the liabilities of the nonfinancial sector, suggesting that others besides LTCM had also leveraged up and were similarly vulnerable to price volatility and liquidity shocks. At the onset of the crisis, however, signs of an abrupt scaling back of leverage in trading activity emerged. For example, the repurchase contracts that securities dealers use to finance their own and customers' trading positions showed a sharp and unusually sustained decline in volume. An implication of the deleveraging was that other traders that might have speculated against the fall in asset prices and thereby stabilized the markets were no longer a support in the markets.

As the ensuing market liquidity crisis unfolded during August and September 1998, growing risk aversion made ever larger numbers of investors seek out low-risk assets and retire to the sidelines, and credit spreads widened sharply beyond what had already occurred following the Russian default. To avoid a disorderly default, and the potentially adverse consequences of the further selling pressures this might have incited, a consortium of LTCM's trading counterparties undertook a recapitalization of the hedge fund in what was essentially an informal bankruptcy procedure conducted by the creditors with the cooperation of the fund's management.

Even after the LTCM recapitalization, however, spreads in many markets continued to widen as participants showed an ongoing aversion to risk. Other hedge funds in particular saw dramatic changes in the willingness of major intermediaries to finance their activities—a development that prompted further selling and spread

widening. By mid-October, reports had grown that the situation was hindering the ability of nonfinancial businesses to raise capital and that risk aversion was beginning to manifest itself in payment and settlement procedures. Only after the Federal Reserve surprised markets with an intermeeting rate cut did the markets gradually return to normal.

While analysts differ in their views on whether the disorderly collapse of LTCM would have been a systemically significant event, the hedge fund episode nevertheless signals the need to think broadly about the potential sources of systemic risk. In particular, how has the growing emphasis on trading activities—which are increasingly conducted through hedge funds—affected the potential for systemic risk? Does this emphasis create mechanisms for propagation that did not exist previously? Can these mechanisms be fully captured by the classical models associated with bank runs or market gridlock or do they introduce fundamentally new elements?

Several recent trends in the financial markets bear on these questions. One trend relates to the blurring of distinctions between types of financial firms. Commercial banks that have traditionally focused on making loans have increasingly removed loans from their balance sheets through securitization (pooling loans such as mortgages into securities) or outright trading of loans and securities; at the same time, they have increased their investment banking and trading activities. Conversely, some of the largest investment banks and trading houses now lend directly to businesses and households.

One result of this broadening of activities has been an increased volume of trading in asset types that have in the past been regarded as illiquid. Traditionally, financial assets have been separated into liquid and illiquid assets: liquid assets (such as stocks and government bonds) are priced and traded regularly after issue on exchanges or in large interdealer markets, while illiquid assets (such as bank loans) are held by financial institutions, particularly commercial banks, over long periods of time and rarely traded or priced after origination. In recent years, however, the sharp distinction between liquid and illiquid assets has eroded, and liquidity, or tradability, has become a continuum. While some types of assets still trade very little after issuance, there is a trend toward trading asset types that have traditionally been regarded as illiquid—for example, bank loans, debt and equity of small firms, and debt of bankrupt or distressed firms.

Moreover, financial institutions now securitize many previously illiquid assets. Securitization involves pooling together collections of illiquid assets such as mortgages, auto loans, or credit card loans and creating a relatively standardized security that pays investors the cash flows from these assets. As a result of these changes, market participants today trade and price a much wider array of risky assets—at least when markets are functioning normally. During times of financial market distress, however, the liquidity of many assets can drop sharply, and differences in liquidity across asset types can widen dramatically.

Similarly, the tremendous growth in use of financial derivatives reflects the increased tradability of financial risk. A substantial amount of current financial market activity involves the repackaging of claims on underlying assets and the redistribution of

the underlying risks. This last activity has spawned enormous growth in the trading of derivatives, which are contingent claims in which payoffs are conditioned on the behavior of underlying variables such as interest rates or equity prices. The institutions at the core of the financial markets not only participate in these various activities, but also frequently serve as market-making intermediaries as well.

Derivatives offer a number of advantages in the trading and hedging of the price risks in underlying assets. First, because they are equivalent to a leveraged trading position, they can often be entered into with very little capital up front. Thus, they are an ideal hedging instrument because the underlying risk can be hedged without the cost of committing a substantial amount of capital. At the same time, however, the leveraged nature of derivatives contracts makes them risky trading instruments, and traders that use these instruments to speculate can lose large sums very quickly. Second, the ability to structure and specify the particular underlying risk that a derivatives contract is exposed to enables users to unbundle a collection of risks embodied in an asset and trade the components separately. This precision also makes derivatives an ideal hedging and trading tool, since a hedger can choose which risk to hedge and which to leave uncovered.

An important consequence of the widespread use of derivatives contracts is the parsing and dispersal of the risks embodied in underlying assets. Overall, this has provided a net benefit to the economy, because risks that would have remained locked up and concentrated in underlying assets are now spread out and allocated to those more willing to bear them. This ability to transfer unbundled risks through derivatives contracts separately from the aggregates in underlying assets enables investors to better select which risks they are exposed to, providing two important benefits: lower risk premia in asset prices because investors are no longer locked into bearing unwanted risks, and the potential for a better allocation of risks to those more able to bear them.

Accompanying the growth of trading in less liquid assets and derivatives has been the general trend toward fair value accounting for more types of instruments and positions. Fair value accounting imposes a discipline that can force institutions to take action to address emerging problems that might not occur under historical cost accounting. By contrast, historical cost accounting is more likely to allow serious problems to go undetected and unaddressed for longer periods of time.

A second significant trend, alluded to earlier, is the increasing role played by a broader range of market participants—not only hedge funds but also other forms of specialized vehicles such as private equity firms and CDO managers. These new agents for risk bearing have the potential to alter the dynamics of how the financial system as a whole manages risk. By allowing risk to be spread more widely, they have the potential to help insulate the financial system against external shocks. In the view of some analysts, however, a greater capacity for risk bearing may lead the system to become even more inclined to cyclical behavior. The extent to which these new entrants are stabilizing or destabilizing depends in part on whether the extent of aggregate leverage in the financial system is greater today than in the past, since more highly leveraged institutions are more susceptible to large shocks that erode capital. Another critical

question relates to the linkages between these new entrants and the traditional financial intermediaries. For example, in a financial crisis, it may not be sufficient for banks to have transferred risks to hedge funds if the ultimate source of financing and liquidity for those hedge funds remains the banks themselves. Again, the overall impact will likely depend on whether the new arrangements increase or decrease the amount of total equity capital at stake (including both bank equity and hedge fund investors' equity) relative to the size of the risks being taken.

A third trend is the strong emphasis that leveraged institutions—not only the large banking and securities intermediaries but also the majority of hedge funds—put on quantitative models for the pricing and risk management of their activities. Risk management practices at such organizations owe a significant debt to the efforts over the past fifty years of many academics and practitioners to apply statistical and mathematical techniques to the problem of analyzing movements and co-movements in market prices and other relevant variables. Such analysis, leavened in most cases by market experience, is used to help assess a firm's ability to operate safely with different combinations of assets and leverage. Risk management strategies are also obviously critical in influencing how financial market participants will react to changes in market conditions. To the extent that there is commonality in risk management models and strategies, there is potential for a broad cross section of market participants to react similarly to changes in asset prices.

In valuing complex derivatives transactions, it is often necessary to interpolate or extrapolate the fair value of such instruments using mathematical models calibrated to the observed market values of other, simpler instruments. In some cases, these models are very difficult to test against an objective reality beyond the fact that other participants are using similar models. It is no accident that models are most commonly used to price relatively illiquid assets; thus, during periods of financial distress, actual prices are most likely to differ substantially from modeled prices. A related issue is the degree to which the positions and strategies of the diverse participants in various markets are correlated. To the extent that many participants are pursuing very similar strategies and will behave very similarly in response to market shocks, the value of diversification to the system as a whole may be less than it appears during more benign periods.

All of these trends—a substantial emphasis on trading, risk transfer, and derivatives; greater market involvement by hedge funds; and a heavy reliance on quantitative risk management models—were at work to some extent in the LTCM episode. While the classical models of bank runs and market gridlock were undoubtedly also relevant to LTCM, the episode highlights the need to expand these models to incorporate more fully the potential endogeneities and feedback effects generated by the trends discussed here.

September 11, 2001, and the Reliance on Critical Infrastructure

While the growth of hedge funds underscores how financial market activities have expanded beyond the major commercial and investment banks, the financial sector events following 9/11 emphasize the reliance of the financial sector on certain core elements of

infrastructure and on a relatively small number of organizations. Two related aspects of the post-9/11 period merit discussion in this regard.

First, the terrorist attacks of that day did widespread damage to both property and communications systems in lower Manhattan.[5] Because many of the largest commercial banks had operating facilities in this area (or had electronic communications routed through hubs in the area), they were unable to make payments as they normally would—that is, they could not send wire instructions to the Federal Reserve's Fedwire system. Since most large banks normally both send and receive a large volume of Fedwire payments every day, relying heavily on incoming payments for the liquidity to make their own payments, the normal coordination of payments broke down and liquidity shortages developed at many banks.

From a systemic perspective, the Federal Reserve attaches extreme importance to keeping the Fedwire system open, since otherwise this central aspect of the financial system nationwide would not be able to function at all. Indeed, in the wake of 9/11, the Federal Reserve extended the operating hours of the system to help provide more time for banks to execute their transactions. In addition, the Federal Reserve made more liquidity available, both to individual banks through its discount window operations and to the system generally through open market operations. These measures, along with the willingness of the Federal Reserve to permit sizable intraday overdrafts, helped restore normal functioning to the payments system.

A second set of issues arose in the market for U.S. government securities. The clearance and settlement of these securities (as well as a number of other fixed-income securities) are concentrated in two commercial banks. These same two banks provide the primary mechanism through which the securities portfolios of the major securities firms are financed on a daily basis (the "tri-party repo market"). The financing itself is provided by money market mutual funds and pension funds primarily, but the two banks provide the systems, services, and intraday credit on which this nearly $1.5 trillion market critically depends.

Following the 9/11 attacks in New York City, one of these two clearing banks suffered very significant operational disruptions, reflecting the proximity of both its primary and backup operating sites to downtown Manhattan. Although these disruptions did not completely obstruct the processing of securities transactions, the processing slowed considerably, and trade records were not fully reconciled for several weeks. In the meantime, the uncertainty arising from the disruptions contributed to a significant increase in the number of trades that failed to settle. This "fails" problem became so serious that the U.S. Treasury conducted an unprecedented reopening of the auction for the ten-year note in order to increase the supply of that security in the marketplace.

Although the systemic financial consequences of the events of 9/11 are probably best described as a "near miss," they do demonstrate the global financial system's vulnerability. Investigation of the possible outcomes of the attacks indicates that if one

[5] This discussion draws heavily on McAndrews and Potter (2002).

of the two clearing banks had not, in fact, been capable of operating for a sustained period of time, the task of replicating such functionality elsewhere would have taken considerable time, possibly as much as a year or more. In the meantime, the underlying securities markets that are supported by the financing activities that clear through these banks would be disrupted. In particular, the U.S. government securities market that forms the basis for the implementation of U.S. monetary policy and the financing of U.S. government activities and that is used as "riskless" collateral in countless financial transactions worldwide could be impaired.

While this particular vulnerability was highlighted by the events following the 9/11 attacks, it is almost certainly not the only critical "choke point" in the global financial system today. That is, the operational disruption of other relatively modest organizations or physical facilities could significantly damage the functioning of the overall financial system. Indeed, the last decade has seen increased concentration in the provision of critical infrastructure services such as payments, settlement, and custody activities. Not surprisingly, the potential systemic risk associated with threats to such critical infrastructure has since 9/11 spurred a significant amount of effort by both the public and the private sector to increase the resiliency of that infrastructure.

Clearly, traditional financial models of systemic risk cannot readily capture the type of systemic risk that arises from the potential for critical points of failure to lead to broader disruptions in the system. For one, the proximate cause is more operational than financial in nature. Nevertheless, the financial aspects cannot be ignored. As the example of the breakdown in payments flows illustrates, even if the initial disruption stems from physical damage or computer malfunction, the methods of propagation may still be financial. Thus, there is a strong need for models more capable of capturing the complex interactions between operational infrastructure and the financial flows that the infrastructure supports. Similar models would be helpful in understanding the consequences of a pandemic event that made it impossible for large numbers of urban employees to work from their offices. Is the existing financial system capable of a smooth transition to a temporarily reduced level of activity? Current models cannot readily even frame such a question.

Implications for Systemic Risk

Three interesting themes emerge from the events discussed in this section. First, the number of relevant points of failure has increased with the growing complexity of the financial system. Large financial institutions such as banks and major financial markets such as the U.S. equity market continue to be focal points in any assessment of systemic risk. But new sources of risk have arisen with the growth of risk transfer through securitization and derivatives as well as the increasing use of central counterparties and other specialist financial institutions that fill specific roles in the financial market infrastructure. One further implication is that when individual institutions have problems, the number of business relationships and elements of risk has expanded dramatically.

Second, as the volume of transactions—payments, derivatives, and secondary market trading—has increased, the apparently strong economies of scale in risk and liquidity pooling have led to consolidation, typically into a subset of the larger financial institutions. The high velocity of transactions creates substantial efficiencies that are reflected in timing and pricing. However, sharp slowdowns in transaction volume, such as those occurring in the payment system after 9/11, can reverse these efficiencies and potentially impair the performance of the financial system when key parts of the system are under stress. Similarly, a key institution's loss of credit standing can diminish the flow of business substantially and increase the cost of managing its derivatives or payments books.

Third, in the information-rich global environment that has emerged over the last few decades, the potential for contagion has changed. That potential continues to include direct linkages among large institutions through common credit and market exposures or exposures to one another, although many policy changes and enhancements to private risk management have sought to reduce that potential. Now, however, the potential for contagion has expanded to include associations between risk dimensions created through common investors, similarities in risk profile and risk appetites, and common exposure to macro-level risk factors such as geopolitical risk. In periods of distress, such as the Asian currency crises, the Russian debt default, or the LTCM collapse, such associations may lead to the propagation of market disturbances in hard-to-predict and probabilistic ways, and therefore make crises more difficult to anticipate and manage.

Questions for Discussion

This background paper covers many different subjects at a relatively high level. Some key questions that conference participants might pursue are as follows:

- What types of models of systemic failure or collapse have proved useful in other disciplines? How applicable are these models to the kinds of issues discussed above?

- Which aspects of the financial system seem most important and/or challenging to capture in considering the potential for systemic risk in the financial sector?

- What potential avenues for future cross-disciplinary collaboration on systemic risk issues seem most promising?

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