The crisis of 1998 and the role of the central bank

David A. Marshall

Introduction and summary

A key mission of the U.S. Federal Reserve System is to safeguard the economy against systemic financial crises. This concern with financial crises stems from a long-held belief that they are associated with declines in economic activity. In the U.S., there is clear evidence that financial panics and recessions are somehow related (Mishkin, 1991). In the case of the Great Depression, Bernanke (1983) argues that the disruption in financial intermediation transformed a severe downturn into a "protracted depression." More recently, the Asian financial crisis in 1997 was followed by sharp declines in economic activity. (Indonesia, Korea, Thailand, and Malaysia all experienced two-quarter declines in gross domestic product [GDP] of over 12 percent.) This historical record has led to a pervasive belief that systemic crises in the financial sector have consequences that are far more than sectoral. Rather, they appear to affect the entire economy, perhaps through the unique role played by financial intermediation.

The most recent financial crisis in the U.S. occurred in late summer and fall of 1998. On August 17, the Russian government devalued the rouble, defaulted on its rouble-denominated debt, and imposed a moratorium on payments to foreign creditors of Russian financial institutions. Following these actions, asset values fell precipitously in all Group of Seven (G-7) countries, and there is evidence of widespread withdrawal of liquidity from financial markets. Particularly dramatic was the near collapse and eleventh-hour recapitalization in late September of Long-Term Capital Management (LTCM), a large hedge fund.

From a U.S. perspective, these events might be described as an "incipient" crisis, because there is little evidence of damage to western economies. Arguably, this is because of the decisive action by the Federal Reserve in cutting the target federal funds rate in three successive 25 basis-point moves. The second of these moves, on October 15, was particularly noteworthy, since it occurred between regularly scheduled meetings of the Federal Open Market Committee (FOMC). Intermeeting rate cuts of this type are rare; the October 15 action was the first such action since April 1994. In the next section, I provide evidence that the end of this incipient crisis coincided almost exactly with the October 15 rate cut. In particular, credit spreads abruptly narrowed on October 16 (one day after the Federal Reserve move), and stock markets in all G-7 countries started to recover a week to ten days prior to the October 15 move. (That stock markets anticipated the rate cut is no surprise. For at least a week prior to the move the financial press reported rumors of a possible intermeeting rate cut.)

The way this incipient crisis ended is somewhat puzzling. The crisis had a clear trigger: the Russian default and devaluation in mid-August. Western financial institutions were directly affected by the default if they held Russian liabilities. Furthermore, the Russian default may have signaled higher default risk for sovereign debt from other emerging or transition economies. So it is not surprising that uncertainty grew about institutions' solvency (with attendant increases in asset price volatility and credit spreads). What is puzzling is the way the crisis appears to have abated with the Fed's second rate cut. Why would the problems (both direct and informational) associated with the Russian default be reduced by a mere 50 basis-point cumulative cut in the overnight interest

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rate? If the crisis was associated with higher default risk of emerging-economy debt, why would the Fed's rate cut have dramatically reduced this default risk? Similarly, if the crisis was associated with an increased informational asymmetry among financial institutions, why would the 50 basis-point cut in the federal funds rate have reduced this asymmetry?

In this article, I argue that the crisis can be characterized as an episode of potential *coordination failure*, triggered by—but ultimately distinct from—the events in Russia. I propose a simple model of financial crises as coordination failure. The model qualitatively matches the following features typically associated with financial crises:

1. Abrupt shifts between a state of adequate liquidity provision and a state of aggregate illiquidity (the latter being a case where institutions with liquidity refuse to lend to those needing liquidity);
2. A "flight to quality," whereby institutions with funds to invest preferentially choose a low-risk, low-return asset;
3. Fear among lenders that credit quality among potential borrowers has deteriorated;
4. Real costs in economic output;
5. Sudden declines in asset values; and
6. A role for the central bank's open market operations in containing the crisis.

In particular, the model provides one potential explanation for why the Federal Reserve action on October 15, 1998, eliminated the danger of a full-blown crisis. This model contributes to the growing literature developing formal models of financial crises and financial fragility. Notable examples of these include Chang and Velasco (1998), Louganoff and Schreft (1998), DenHaan, Ramey, and Watson (1999), and Chari and Kehoe (1998, 2000).

Coordination failure can emerge in any economy where the profitability of a given agent's investment depends on the decisions of the other agents in the economy. In the model of this article, the possibility of coordination failure arises from the essential function of financial markets: to match potential users of capital (borrowers) with potential providers of capital (lenders) in an environment of asymmetric information. Borrowers and lenders match via a search procedure. In this model, multiple equilibria are possible. A *high-coordination equilibrium* can occur in which all lenders and all borrowers enter the match, maximizing the expected output of the economy. However, there are times when a *low-coordination equilibrium* is possible in which all good quality (that is, highly creditworthy) borrowers refrain from entering the match. Knowing that only poor quality borrowers seek loans, potential lenders refuse to lend. I identify this low-coordination equilibrium with a financial crisis.

In the model, the low-coordination equilibrium cannot exist if the risk-free real interest rate is sufficiently low. This suggests a potential role for the central bank. If monetary policy can affect real interest rates, the central bank can extinguish the low-coordination equilibrium if it reduces the real interest rate sufficiently via an aggressive monetary expansion. That the Federal Reserve has the power to do so is suggested by the events of 1991–93. As I discuss in a later section, there is evidence that banks cut back on lending activity in the early 1990s. Following a shift to a more expansionary monetary policy in mid-1991, in which the real federal funds rate fell from 2.5 percent to 0.5 percent, lending activity moved back to normal levels.

Unlike the Federal Reserve action of 1991–93, the monetary expansion in fall 1998 was too small, and the consequent effect on real interest rates too marginal, to have a substantial direct effect on lender incentives. Rather, I interpret the intermeeting rate cut of October 15 as a signal that the Federal Reserve's *policy rule* had changed. Before the intermeeting move, market participants were uncertain whether the Federal Reserve would compromise its focus on price stability (and the associated tight money policy) even in the face of severe financial market strains. I argue that the intermeeting move was interpreted by market participants as signaling a shift to a *state-contingent* policy: focus on price stability *unless* a financial crisis becomes imminent; temporarily abandon that focus if the threat of financial crisis becomes severe. In this article, I formally model such a policy, and I show that, in principle, such a policy can extinguish the low-coordination equilibrium. Furthermore, if this policy is credible, it never has to be implemented: The policy itself removes the possibility of coordination failure. That is, monetary expansion is an "off-equilibrium path" that enforces the high-coordination equilibrium.

Below, I review the facts of the crisis of fall 1998, highlighting key features that I will seek to replicate in the theoretical model. Then, I describe the basic coordination failure model. Finally, I show how the central bank can avert coordination failure by implementing an appropriate and credible state-contingent monetary policy.

Brief review of the events of fall 1998

Here, I review the crisis and provide evidence for the following assertions:

1. The crisis was associated with large declines in equity values, increased volatility in financial markets, widening credit spreads, and an increased demand for U.S. Treasury securities.
2. During the crisis, there was a reduction in available liquidity, as institutions with loanable funds reduced the volume of funds available to the market.
3. The crisis rapidly abated following the Federal Reserve's intermeeting cut in the federal funds rate on October 15, 1998.

Financial markets showed evidence of potential problems starting around mid-July 1998. However, the onset of the crisis is usually associated with the Russian devaluation and default in August 1998. This denouement was in large part forced by declining hard currency inflows over the preceding several months as oil prices fell. On August 17, Russia defaulted on its rouble-denominated public debt. At that time, this stock of debt represented $61 billion, 17 percent of Russian GDP. At the same time, Russia declared a 90-day moratorium on all foreign obligations of Russian financial institutions. Finally, the rouble exchange rate zone was substantially widened, amounting to a de facto devaluation of 25 percent. The exchange rate zone was completely abandoned ten days later.[1] As I discuss below, western financial markets reacted negatively to these developments. In response, the FOMC cut the federal funds rate by 25 basis points at its next regular meeting on September 29. This move by the Federal Reserve did not calm the financial markets.[2] On October 15, in an unusual intermeeting move, the FOMC made an additional 25 basis-point rate cut. Observers point to this intermeeting move as marking the end of the crisis.

The data in figure 1 characterize more fully the impact of these events on western financial markets. As shown in figure 1, panel A, the U.S. S&P 500 index peaks in mid-July 1998, with a small local peak in mid-August 1998 (vertical dashed line) following the Russian default. Thereafter, there is a sharp decline in stock values, amounting to more than 18 percent over the three months from peak to trough. The S&P 500 index bottomed out on October 8, one week before the FOMC's intermeeting rate cut on October 15 (vertical solid line). The biggest close-to-close rise of this period was from October 14 to October 15. It is no surprise that the market trough occurred one week before the Fed intermeeting action, since there was speculation prior to the Fed's action that an intermeeting rate cut was likely.[3] The behavior of the federal funds futures market supports this interpretation. Through October 7, futures prices implied an expected federal funds rate through the end of October of 5.22 percent to 5.24 percent, implying little probability of a rate cut. On October 8, this expected federal funds rate dropped to 5.18 percent, which is consistent with a 50 percent probability of a quarter-point rate cut around mid-October.[4]

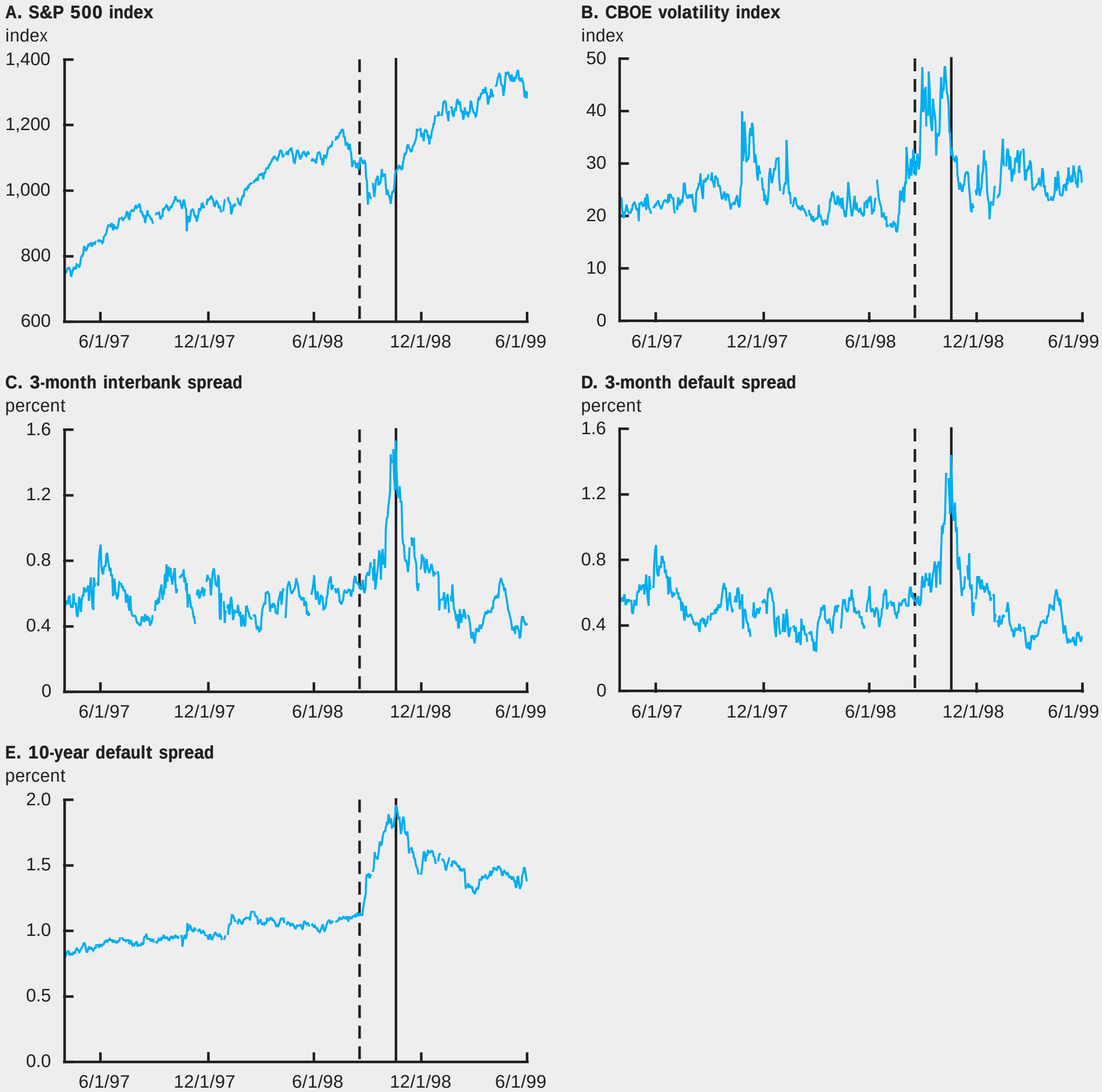
The behavior of stock indexes for the other six countries in the G-7 is roughly comparable to that of the U.S. indexes. In all cases, the market peaks in mid-July, falls steeply, and starts to turn up about one week before the October 15 rate cut. The total market declines over this three-month period were quite pronounced, ranging from 18 percent in Japan to over 28 percent in Canada, Italy, and France.[5]

Figure 1, panel B displays the value of the Chicago Board Options Exchange (CBOE) volatility index (a measure computed by the CBOE from implied volatility on a number of option contracts).[6] These data show that uncertainty (and associated risk) in financial markets rose steeply in mid-August 1998. The date of the first pronounced jump was actually August 27, when the closing value of this index rose to 39.16 (compared with the previous day's close of 30.66). This date corresponds to the Russian government's announcement that it was abandoning its trading band for the rouble. In trading during August 27, the rouble fell 40 percent against the deutschemark. In addition, on that date Deutsche Bank lost its AAA rating from Standard and Poor's when it revealed that it had unsecured Russian credit risk amounting to almost $750 million. For the next seven weeks the volatility index stayed at a level that was unprecedented, except for the period around the 1987 stock market crash. The index remained at or near 40 until October 15 (the date of the intermeeting rate cut),[7] when it fell to 35.95 (compared with the previous day's close of 41.31). Within two trading days the index had fallen to around 30, remaining between 20 and 30 through the end of 1999.

Figure 1, panels C, D, and E display three U.S. credit spreads: the interbank spread (three-month interbank yield minus three-month T-bill yield), the short-term credit spread (three-month commercial paper yield minus three-month T-bill yield), and the long-term credit spread (ten-year AAA corporate bond yield minus ten-year T-bond yield). These credit spreads confirm the inference from figure 1, panel B that there was an abrupt increase in perceived credit risk from mid-August to mid-October. In particular, they show a pronounced spike starting in late September 1998 (around the time of the LTCM rescue) and continuing until October 16, one day after the FOMC's intermeeting rate cut. The peak in the long-term credit

FIGURE 1

U.S. financial market indicators, March 1997–June 1999



Notes: The vertical dashed lines indicate August 17, 1997, the date of the Russian default. The vertical solid lines indicate October 15, 1997, the date of the Federal Reserve's intermeeting cut in the federal funds rate. Panels C, D, and E display three U.S. credit spreads: the interbank spread (panel C) is the three-month interbank yield minus three-month Treasury bill yield. The three-month default spread (panel D) is the three-month commercial paper yield minus three-month Treasury bill yield. The ten-year default spread is the ten-year AAA corporate bond yield minus ten-year Treasury bond yield.

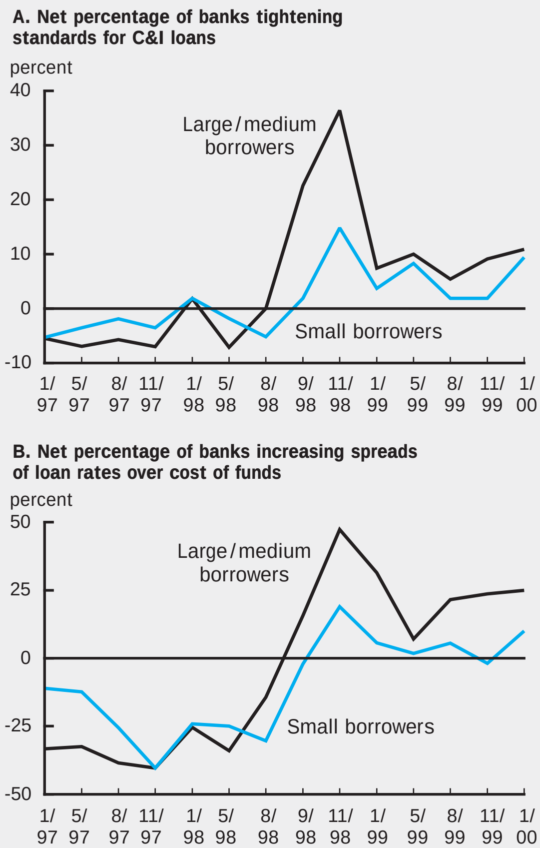
Sources: Board of Governors of the Federal Reserve System (panels A, C, D, E); Chicago Board Options Exchange (panel B).

spread during this period is the highest in the 1990s, and the peak in the other two credit spreads is only exceeded during this decade by that observed during the 1990–91 recession.[8]

There is evidence that the increase in perceived credit risk was associated with a substantial drying-up of liquidity. That is, institutions with loanable funds became more reluctant to extend unsecured loans. The Federal Reserve Board of Governors' Senior Loan Officers Survey in September[9] revealed a marked increase over the August survey in the number of banks tightening loan standards and raising loan rates. (See figure 2, panels A and B.) A principal reason reported by banks for these actions was "a

FIGURE 2

Measures of credit market tightness



Notes: This figure plots data from the Federal Reserve Board's Senior Loan Officers Surveys from January 1997 through January 2000. Responses to the January, March, August, and November surveys report bank credit policies over the preceding three months. The September 1998 survey reports bank credit policies over the preceding month only.
Source: Board of Governors of the Federal Reserve System, Senior Loan Officers Survey.

reduced tolerance for risk." Interestingly, there was a substantial increase in the number of banks reporting *decreased* loan demand. The respondents generally attributed this reduced demand to reductions in both merger and acquisition activity and fixed investment. This suggests that the reduction in loan activity was due to both a reduced willingness of lenders to bear default risk *and* a reduced interest of borrowers in expanding economic activity. While reports of tightened loan standards continue through the November survey, the reduction in loan demand appears to have reversed by November.

The Bank for International Settlements (BIS, 1999) surveyed a number of market participants about the events of fall 1998. The survey results confirm the perception that risk levels were elevated and liquidity provision diminished in the period from mid-August through mid-October 1998. They point to an "unprecedented" widening in bid/ask spreads and even to "one-sided markets," where sellers of risky securities could not find a buyer at any price. On numerous occasions, market makers in government securities simply withdrew from trading and refrained from posting quotes.[10] The BIS interviewees report a flight to the most liquid, "on-the-run" (that is, most recently issued) Treasury securities. For example, by early October, the yield spread between 28-year and 30-year Treasury bonds had widened to 29 basis points from just 7 basis points in mid-August (although the 28-year issues are just as free from default risk as the 30-year on-the-run bonds). Salomon Smith Barney reported that this spread was the widest it had ever recorded.[11] Continued ability to trade Treasury securities in any desired quantity was assured only for the on-the-run issues. The flight to quality even devolved, "for a brutal but short-lived period"[12] to a flight to cash. A number of participants reported reductions in credit lines to other financial institutions. This drying-up of liquidity exacerbated price volatility and increased credit risk associated with institutions that relied on market funding. Interestingly, the infusion of funds to LTCM, facilitated by the Federal Reserve Bank of New York in late September 1998,[13] seemed to *exacerbate* the liquidity crisis. Participants in the BIS survey interpreted the Federal Reserve's role as a signal that the Federal Reserve believed that the crisis was far worse than previously thought. Finally, the BIS interviewees perceived the October 15 rate cut as the turning point of the crisis. In its summary of interviews with market participants, the BIS states, "The second monetary easing by the Federal Reserve (15 October) signaled the beginning of the abatement of financial strains. At that time, traders clearly understood the commitment of the Federal Reserve to fix the problems."

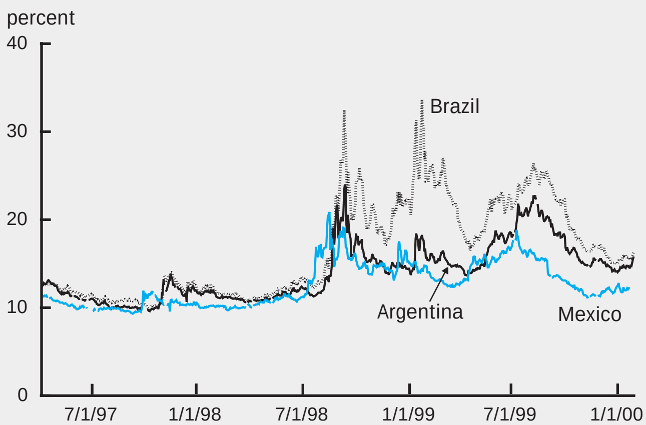
To summarize, the period from mid-August to mid-October 1998 was characterized by rapid declines in stock values, rapid increases in uncertainty, and a reluctance of institutions with loanable funds to provide loans. The crisis appears to have abated in U.S. financial markets with the Fed's intermeeting rate cut of October 15. In particular, the stock market recovery, the narrowing of credit spreads in fixed income markets, and the decline in the CBOE volatility index all commenced around October 15. Other more qualitative measures of the crisis, such as the Board of Governor's Senior Loan Officers Survey, the BIS interviews with market participants, and reports in the financial press, are also consistent with this interpretation.

What generated the crisis?

It is perhaps no surprise that the Russian default and devaluation triggered turmoil in western financial markets. There was a good deal of uncertainty about the direct exposure of western financial institutions to the Russian default. Furthermore, western investors may have interpreted the Russian default as evidence against the creditworthiness of other emerging economies. Investors were particularly concerned about Argentina, Brazil, and Mexico, which are far more important than Russia for U.S. trade.[14] (In fact, Brazil devalued its currency in mid-January 1999.) Figure 3, which plots Brady bond yields,[15] shows how the Russian default triggered an increase in perceived credit risk for these three Latin American countries that eclipsed the increase following the 1997 Asian crisis. In all three countries, the yields more than doubled following the Russian default in mid-August 1998. (The yield spike for Brazil was particularly pronounced.) However, this explanation for the crisis does not fully account for the way it ended. It is hard to imagine that the exposure of western institutions to emerging and transitional economies or the informational asymmetry about these exposures would have been reduced by a 50 basis-point reduction in the federal funds rate. Similarly, the creditworthiness of borrowers in these economies would not have been affected substantially by the Federal Reserve's action. Thus, while the Russian default clearly triggered the financial crisis, the crisis appears to have taken on a self-fulfilling aspect over and above the damage attributable to the actions of the Russian government.

FIGURE 3

Brady bond yields for Argentina, Brazil, and Mexico
(April 1997–January 2000)



Note: This figure plots yields from dollar-denominated sovereign debt ("Brady bonds") issued by Argentina, Brazil, and Mexico.
Source: Bloomberg.

Other financial crises have also involved sudden shifts between crisis and non-crisis states without a commensurate change in fundamentals. The Asian crisis of 1997 provides an example, although in that case the sudden shift occurred at the beginning of the crisis. The Asian crisis was completely unforeseen by financial markets. In particular, in none of the Asian crisis countries do interest rates or forward exchange rates move prior to the speculative attacks leading to the initial Thai devaluation.[16] Furthermore, the Asian crisis was not triggered by any shock to fundamentals commensurate with the magnitude of the subsequent debacle. While there were clear problems with market fundamentals in these countries (in particular, the poor state of their banking sectors), these problems were well known months or even years prior to the crisis.[17] It appears that any theory of systemic financial crisis must incorporate the possibility of sudden, untriggered shifts between crisis and non-crisis states.

Modeling financial crisis as coordination failure[18]

As described earlier, the financial crisis of fall 1998 had a number of characteristics that have been associated with crises more generally. There was a sudden shift between crisis and non-crisis states without a commensurate change in fundamentals. The crisis state was characterized by a sharp reduction in liquidity provision with a corresponding flight to quality. The crisis was associated with a decline in asset values, as reflected in stock market indexes.[19] In addition, the crisis of 1998 shows clear evidence of an increase in perceived default risk. Finally, the end of the 1998 crisis was associated with an unusual action by the central bank (a change in the target federal funds rate between regularly scheduled FOMC meetings).

In this section, I propose a simple model of financial crisis that, in principle, can accommodate these patterns. My approach focuses on the possibility of coordination failure. In coordination models, an investor benefits if he chooses the same strategy as other investors. Thus, investors will tend to "coordinate" on a particular strategy. A multiplicity of equilibria can emerge, each associated with a different pattern of coordination. Suboptimal equilibria are then associated with coordination failure: the failure to coordinate on the socially optimal choices. In a familiar example, known as *external increasing* *returns to scale*, the productivity of a particular firm's capital investment is high only if there is a high level of aggregate economic activity. Therefore, a firm may only want to choose a high level of investment if enough *other* firms also choose a high level of investment (thereby assuring a high level of aggregate activity). If other firms choose low investment, aggregate activity will be low, and an individual firm's investment productivity may be too low to justify a high investment level. In this example, there are two equilibria: one where all firms "coordinate" on high investment, the other where all firms have low investment.[20]

In the model I present here, the possibility of coordination failure arises from the essential nature of financial relationships—the need to match potential borrowers with potential lenders in an environment of asymmetric information. In particular, lenders must search for borrowers and vice versa. As the total number of borrowers and lenders rises, this search process becomes more productive. That is, the rate at which borrowers and lenders match goes up. In other words, the matching process exhibits a *thick markets externality*: Everyone benefits as the number of participants in the market rises.[21]

This thick markets externality gives rise to the possibility of a coordination failure equilibrium: If lenders believe that there are few high-quality borrowers searching for loans, and simultaneously the high-quality borrowers believe that there are few lenders willing to extend credit, an equilibrium can emerge where both lenders and borrowers forsake the loan market in favor of alternative investments. In effect, all parties have "coordinated" on nonparticipation, so the optimal strategy for any individual agent is not to participate.

Basic structure of the model

The basic model is completely static. There are two types of risk-neutral agents: borrowers (N_{borr} in number), who are endowed with a project but no liquidity; and lenders (N_{lend} in number), who are endowed with one unit of liquidity but no project. A borrower can operate his project in two mutually exclusive ways: *autarkically*, without any liquidity inflow from outside; or *with investment*, which requires borrowing one unit of liquidity from a lender. A borrower must decide at the beginning of the period whether to operate the project autarkically or whether to seek a loan. In other words, once the borrower has decided to seek a loan, the possibility of autarkic production is precluded.

Borrowers are randomly assigned one of two types of projects, *bad* (assigned with probability p^b), and *good* (assigned with probability $(1 - p^b)$). The quality of the project is private information to the borrower. Good projects pay $R^{autarky}$ with certainty if operated autarkically; they pay R with certainty if operated with investment, *provided* the borrower has found a lender willing to lend. Bad projects pay 0 if operated autarkically; if operated with investment, bad projects pay R with probability θ and $R^{salvage}$ with probability $(1 - \theta)$, again provided borrower has found a lender willing to lend. Informally, a bad borrower defaults on his loan with probability $(1 - \theta)$; $R^{salvage}$ represents the salvage value of the project that is available to satisfy the lender's claim. Finally, if a borrower seeks a loan but fails to match with a lender, he receives zero.

An interpretation[22] of these two types of borrowers is that bad borrowers are in severe financial distress. If they do not get an immediate liquidity infusion, they will be forced into bankruptcy. Even if they do receive liquidity, financial distress may impair their productivity with probability $(1 - \theta)$. In contrast, good borrowers can stay in operation without liquidity, albeit at a lower output. However, there is an up-front cost to structuring the project to utilize liquidity. My assumption that a good borrower who tries to obtain a loan and fails receives zero is equivalent to a specification where the up-front cost equals $R^{autarky}$ and the output with liquidity (before the up front cost is paid) equals $R + R^{autarky}$.

Lenders have one unit of liquidity, which they can use in two mutually exclusive ways. First, they can invest it at a gross risk-free rate R^f. Second, they can attempt to find a borrower to whom to lend. If a borrower and a lender match, the loan contract takes the following exogenous specification:[23] If R is produced, the lender receives R_{lend} (where R_{lend} is an exogenous parameter satisfying $R_{lend} \geq R^{salvage}$) and the borrower receives $R_{borr} \equiv R - R_{lend}$; if $R^{salvage}$ is produced, the borrower is in default, so the lender receives the full salvage value $R^{salvage}$ and the borrower receives nothing. Finally, if a lender does not find a borrower, she simply ends up with her unit of liquidity.[24] To summarize, the payoffs are as follows:

1) Payoff to good borrower =

R_{borr}	if borrower matches with lender
0	if borrower attempts to match with lender and fails
$R^{autarky}$	if borrower operates project autarkically.

2) Payoff to bad borrower =

R_{borr}	if borrower matches with lender and project produces R

0 if borrower attempts to match with lender and fails *or* if borrower matches with lender and project produces $R^{salvage}$ *or* if borrower operates project autarkically.

3) Payoff to lender =

R_{lend} if lender matches with borrower and project produces R

$R^{salvage}$ if lender matches with borrower and project produces $R^{salvage}$

1 if lender attempts to match with a borrower and fails

R^f if lender uses the risk-free investment and does not attempt to match with a borrower.

The matching procedure

According to equations 1, 2, and 3, the expected payoff to an agent who attempts to match depends on the probability of consummating the match. Suppose that there are a total of B borrowers seeking loans and L lenders seeking to match with borrowers. I denote the probability that a given borrower matches with a lender by $prob_{borr}(B,L)$. Similarly, the probability that a given lender matches with a borrower is denoted $prob_{lend}(B,L)$. (In equilibrium, the expected number of matches equals $B \times prob_{borr}(B,L) = L \times prob_{lend}(B,L)$.)

If either B or L equals zero, both $prob_{borr}$ and $prob_{lend} = 0$. (That is, if there are no borrowers or lenders, there can be no matches.) It is also natural to assume, in the language of Mortensen and Pissarides (1998), that borrowers and lenders are *complements*. That is, it is easier for a borrower to find a match if there are more lenders, and vice versa. (Formally, $\frac{\partial prob_{borr}}{\partial L} > 0$ and $\frac{\partial prob_{lend}}{\partial B} > 0.$) In addition, following Mortensen and Pissarides (1998), I assume that there is a *congestion effect*. An increase in the number of borrowers decreases the probability that a given borrower will match, and vice versa. (Formally, $\frac{\partial prob_{borr}}{\partial B} < 0$ and $\frac{\partial prob_{lend}}{\partial L} < 0.$)

Finally, I assume that the expected number of matches displays *increasing returns to scale*. This is equivalent to the condition that as the number of borrowers and lenders increases equiproportionally, both $prob_{lend}$ and $prob_{borr}$ increase. This is a natural assumption to make for many types of matching problems. Consider the problem of finding a taxi cab in a medium-sized city. If there were only one rider looking for a cab and one cab looking for a fare (as might be the case at 2:00 am), the probability of a match would be very low. If there were 10,000 riders and 10,000 cabs, the probability that a given rider would find a cab would be much higher. (This intuition is formalized in the model developed in appendix A.)[25]

Increasing returns is implied by a number of search models that have been proposed in the literature. In appendix A, I discuss a number of these and I develop one model in detail. Diamond (1982) and others note that increasing returns in the matching technology can give rise to multiple search equilibria. I exploit this feature below.[26]

High-coordination and low-coordination equilibria

The matching technology implies that the decision of borrowers whether to enter the match affects the probability that a given lender will match and, therefore, affects the expected payoff to the lender from entering the match. Similarly, the decisions of lenders affect the expected payoff of the borrower. This implies the possibility of coordination failure between borrowers and lenders and, thus, the possibility of multiple equilibria. I define a *high-coordination equilibrium* as one in which all lenders enter the match and all borrowers enter the match. Of course, a lender will enter the match if, and only if, her expected payoff from entering the match equals or exceeds R^f. Using the payoffs given in equation 3, in a conjectured high-coordination equilibrium this condition can be written as

4) $$prob_{lend}(N_{borr}, N_{lend})((p^b\theta + 1 - p^b) R_{lend} + p^b(1-\theta)R^{salvage}) + (1 - prob_{lend}(N_{borr}, N_{lend})) \geq R^f.$$

Similarly, a good borrower will enter the match, if and only if, his expected payoff from entering the match equals or exceeds $R^{autarky}$. In a conjectured high-coordination equilibrium, this condition is

5) $$prob_{borr}(N_{borr}, N_{lend})R_{borr} \geq R^{autarky}).$$

Note from equation 2 that the bad borrowers always enter the match, since the payoff from entering the match dominates the autarkic payoff to the bad borrower of zero. Therefore, equations 4 and 5 are sufficient for the existence of a high-coordination equilibrium.

I define a *low-coordination equilibrium* as one where no lenders enter the match and only bad borrowers enter the match. The payoff to lenders in the low-coordination equilibrium is R^f. The payoff to good borrowers is $R^{autarky}$, and the payoff to bad borrowers is zero. If there are no lenders in the match, there is clearly no incentive for good borrowers to defect from the equilibrium strategy of autarky (since

$prob_{borr}$ (1,0) = 0). However, there may be an alternative strategy for a lender that could break the low-coordination equilibrium. Let the total number of bad borrowers be denoted N_{bad}. (The expected value of N_{bad} is simply $p^b N_{borr}$.) If, starting in a low-coordination equilibrium, a lender decides to defect from the equilibrium strategy by entering the match, her probability of matching with a borrower is $prob_{lend}(N_{bad}, 1)$ (since only bad borrowers are in the match in a low equilibrium). Her expected payoff conditional on a successful match is $\theta R_{lend} + (1 - \theta) R^{salvage}$. Therefore, a low-coordination equilibrium can only be sustained if the expected payoff to this alternative strategy is less than the payoff to a lender in the low-coordination equilibrium:

6) $$prob_{lend}(N_{bad}, 1)(\theta R_{lend} + (1 - \theta)R^{salvage}) + (1 - prob_{lend}(N_{bad}, 1)) \leq R^f.$$

The left-hand sides of equations 4 and 6 give the value to a lender of entering the match in the high-coordination and low-coordination equilibria, respectively. Similarly, the left-hand side of equation 5 gives the value to a good borrower of entering the match in the high-coordination equilibrium. For a particular base line parameterization,[27] figure 4 displays how these values are affected by changes in the model parameters. Specifically, the left-hand column of plots in figure 4 shows how the left-hand sides of equations 4 (black lines) and 6 (colored lines) change as a particular model parameter is varied; the right-hand column does the same for the left-hand side of equation 5 (colored lines). The five parameters that are varied in figure 4 are: number of lenders, as a fraction of total population (first row of plots); R^{lend}, as a fraction of R (second row); R^{salvage}, as a fraction of R (third row); θ (fourth row); and p^b (fifth row).

The behavior of these values is intuitive. The value to lenders of entering the match for both equilibria is strictly decreasing in the ratio of lenders to total population (reflecting the greater competition from other lenders); the corresponding value to good borrowers is strictly increasing in this ratio (reflecting the higher probability of matching with a lender). Not surprisingly, increasing R_{lend}/R, the fraction of output received by lenders, increases the value of the match to lenders, but decreases that value to borrowers. For both equilibria, the value of the match is increasing for lenders in $R^{salvage}$ and θ (the probability that a bad project produces R). Neither of these parameters affects the value of the match for good borrowers. Finally, an increase in p^b, the probability of bad projects, reduces the value of the match for lenders in the high-coordination equilibrium, but increases the value of the match for lenders in the low-coordination equilibrium. In the high-coordination equilibrium, increasing p^b simply increases the probability of borrower default. In the low-coordination equilibrium, however, an increase in p^b increases the number of borrowers seeking loans. (Recall that only bad borrowers seek loans in the low-coordination equilibrium.) This increases the probability of a match for a lender contemplating deviating from the equilibrium strategy.

Suppose the borrower condition for a high-coordination equilibrium (equation 5) holds. That is, suppose $R^{autarky}$ lies below the colored line in any of the plots in the right-hand column of figure 4. Then the existence of the high- or low-coordination equilibrium depends on the level of the risk-free rate R^f relative to the solid and colored lines in the plots in the left-hand column. If R^f is above both lines, then neither equilibrium exists for these parameter values. If R^f is below the solid line but above the colored line, then both low-coordination and high-coordination equilibria exist. If R^f is below both the solid line and the colored line, then a high-coordination equilibrium exists but no low-coordination equilibrium exists. Thus, if equation 5 holds, the high-coordination equilibrium can be enforced by setting R^f sufficiently low.

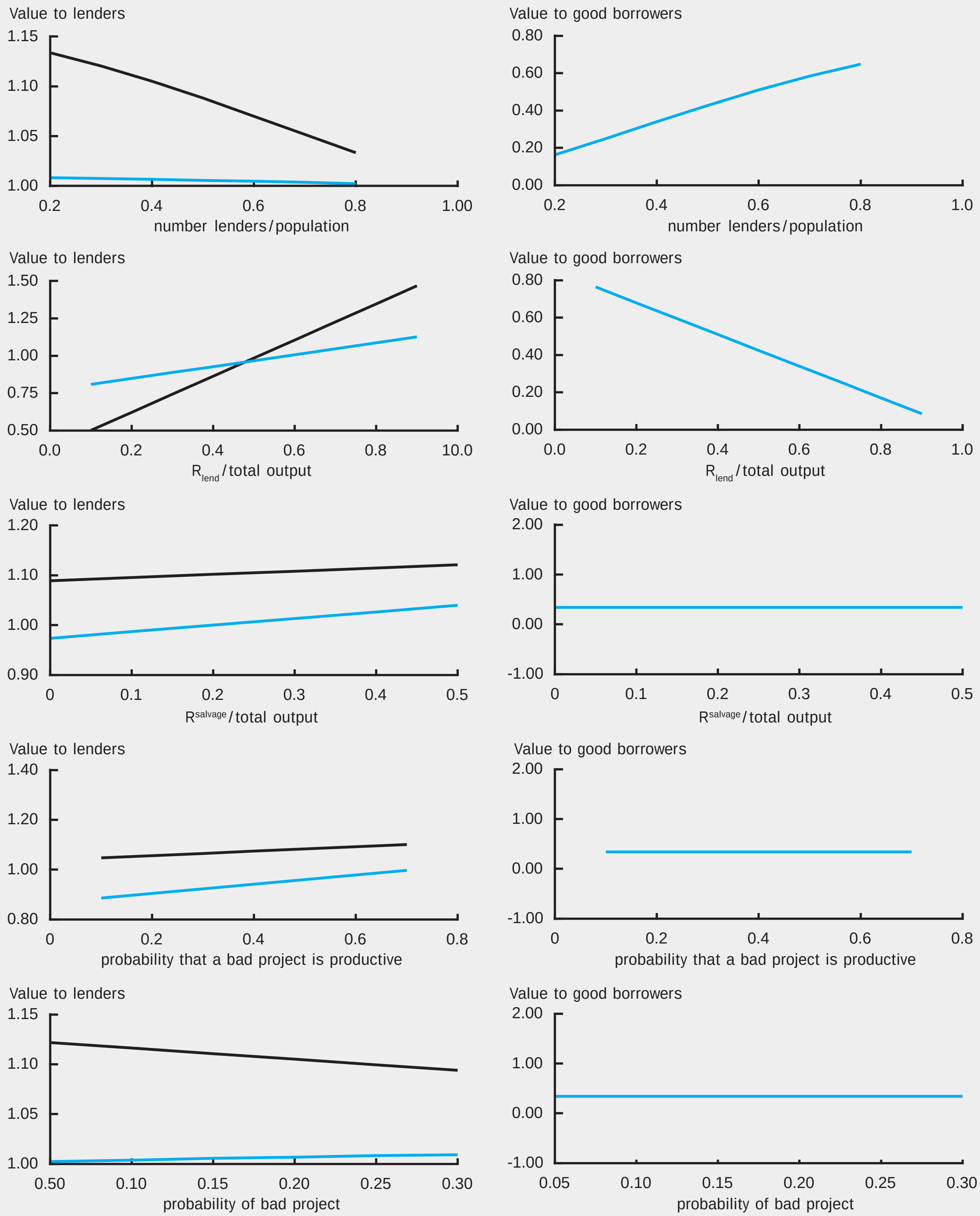
Finally, there may also be additional "mixed" equilibria where a fraction of lenders and/or good borrowers enter the match, while the remaining agents choose the alternative strategies (investing risk-free for lenders, operating the project autarkically for the borrowers.) I discuss the conditions for these mixed equilibria in box 1. The possibility of mixed equilibria complicates the analysis of this model. For the purposes of this article, I assume that these mixed equilibria are never observed. For the remainder of this section, I focus only on the low- and high-coordination equilibria.

Interpreting the model as a theory of financial crises

I associate the low-coordination equilibrium in the model with a financial crisis. This equilibrium captures many characteristics associated with financial crises. In this simple model, asset values and output can both be measured by the expected payoff to a borrower's project; both are clearly lower in the low-coordination equilibrium than in the high-coordination equilibrium.[28] There is a clear flight to quality in the low-coordination equilibrium, coupled with a drying-up of liquidity: Lenders invest in the risk-free asset instead of making loans, so the aggregate quantity of liquidity provided falls to zero. There is a perception of declining credit quality: If we were to ask a lender

FIGURE 4

Effect of changes in model parameters on the value of entering the match



Notes: For a particular set of baseline parameters, this figure illustrates how the value of entering the match implied by the model changes as five parameters of the model are varied. The left-hand column of figures plots the value of a lender entering the match in the high-coordination equilibrium (left-hand side of equation 4, represented by the black lines) and the low-coordination equilibrium (left-hand side of equation 6, represented by the colored lines) changes as the following five parameters change: number of lenders, as fraction of total population (first subplot); payoff to the lender R_{lend}, as a fraction of total output (second subplot); salvage value of a bad borrower's project $R^{salvage}$, as a fraction of total output (third subplot); probability that a bad project is productive θ, (fourth subplot); and the probability that a given project is bad, p^b (fifth subplot). The right-hand column of figures plots the value of a good borrower entering the match in the high-coordination equilibrium (left-hand side of equation 5), as the same five parameters are varied. The baseline parameters are as follows: N_{lend} = 20; N_{borr} = 30; R = 2; R_{lend} = 1.2 (so R_{borr} = 0.8); $R^{salvage}$ = 0.5; p^b = 0.2; θ = 0.75. Parameter N_{bad} is set equal to its expected value of 6. I use the model of $prob_{lend}$ and $prob_{borr}$ described in appendix A, equations 19 and 20, with parameter M = 10.

why she refrained from making loans, she would answer that the risk of default was too high (since all borrowers actually entering the match in the low-coordination equilibrium are bad borrowers). This is the sort of response given by lending institutions in the BIS interviews and the Board of Governors'

BOX 1

Mixed equilibria

In a mixed equilibrium, some lenders and/or good borrowers enter the match, while the remaining agents choose the alternative strategies (investing risk-free for lenders, operating the project autarkically for the borrowers). If there were a continuum of agents, these mixed equilibria would require agents to be indifferent between entering the match and using the alternative strategies. If one takes seriously the constraint that the number of agents of each type be an integer, then the conditions for a mixed equilibrium must take into account the effect on the matching probabilities were an agent to deviate from the equilibrium.

To write down the conditions for a mixed equilibrium, it is convenient to define functions V_{lend} and V_{borr} that measure the value of entering the match for lenders and borrowers, respectively. Let B_{good} denote the number of good borrowers entering the match, and let L denote the number of lenders entering the match. Recall that all bad borrowers enter the match (since the value of autarky for bad borrowers is zero). Therefore, the fraction of bad borrowers in the match is $\frac{N_{bad}}{N_{bad}+B_{good}}$, and (analogously with the left-hand side of equation 4) the value to a lender of entering the match is

$$B1)\ V_{lend}\left(B_{good},L\right) \equiv prob_{lend}(N_{bad}+B_{good},L) \times\left(\left(\frac{\theta N_{bad}}{N_{bad}+B_{good}}+\frac{B_{good}}{N_{bad}+B_{good}}\right)R_{lend} + \frac{(1-\theta)N_{bad}}{N_{bad}+B_{good}}R^{salvage}\right)+(1-prob_{lend}(N_{bad}+B_{good},L)).$$

The value of entering the match for a good borrower is given by the analogue to the left-hand side of equation 5:

$$B2)\ V_{borr}(B_{good}, L) \equiv prob_{borr}(N_{bad} + B_{good}, L)R_{borr}.$$

If there were a continuum of agents, so the defection of a single agent from the equilibrium strategy would not affect the matching probabilities, then a mixed equilibrium would be a pair $\{B_{good}, L\}$ satisfying

$$B3)\ 0 < B_{good} < N_{borr} - N_{bad}$$
$$0 < L < N_{lend}$$

for which

$$B4)\ V_{lend}(B_{good}, L) = R^f$$
$$V_{borr}(B_{good}, L) = R^{autarky}.$$

If (as I assume throughout this article) there are an integer number of agents of each type, then a conjectured defection from the equilibrium strategy changes $prob_{lend}$ or $prob_{borr}$ and, therefore, changes V_{lend} or V_{borr}. To take this explicitly into consideration, I must modify equation B4. Assume that

B5) V_{lend} is decreasing in L.

Since $prob_{lend}(B,L)$ is strictly decreasing in L, a sufficient condition for assumption B5 is

$$B6)\ \left(\frac{\theta N_{bad}}{N_{bad}+B_{good}}+\frac{B_{good}}{N_{bad}+B_{good}}\right)R_{lend} + \frac{(1-\theta)N_{bad}}{N_{bad}+B_{good}}R^{salvage} > 1.$$

In other words, the expected payoff to a lender from a successful match exceeds the payoff from entering the match but failing to match. Note that V_{borr} is decreasing in B_{good}, because $prob_{borr}(B,L)$ is strictly decreasing in B. Under assumption B5, a mixed equilibrium is a pair $\{B_{good}, L\}$ satisfying equation B3 and

$$B7)\ V_{lend}(B_{good}, L+1) \leq R^f \leq V_{lend}(B_{good}, L)$$
$$V_{borr}(B_{good}+1, L) \leq R^{autarky} \leq V_{borr}(B_{good}+1, L).$$

The logic behind equation B7 is straightforward. If the first set of inequalities in equation B7 holds, then a lender in the match has no incentive to switch to the risk-free asset (since the value of being in the match exceeds R^f), and a lender investing risk-free has no incentive to switch to entering the match (since, by entering the match, the total number of lenders in the match will equal $L + 1$, and the value to being a lender in the match when the total number of lenders equals $L + 1$ is dominated by the risk-free rate). A similar logic holds for borrowers if the second set of inequalities in equation B7 holds.

Senior Loan Officers Survey, discussed earlier. It is also consistent with widening credit spreads. Furthermore, there is a reduction in demand for liquidity on the part of borrowers, a pattern that was also reported in the September Senior Loan Officers Survey.

This model is also consistent with sudden switches between normal and crisis states without any change in underlying fundamentals (as represented by the model's parameters). While I do not model dynamics explicitly, a multiple-equilibrium model of this type can be incorporated into a dynamic model in which switches between coordination states are driven solely by changing expectations. If enough lenders in the economy become pessimistic about the aggregate number of borrowers entering the match (or vice versa), then a low-coordination equilibrium will emerge, validating their pessimism ex post. Thus, all that would be needed to model the abrupt switches between crisis and non-crisis states would be to model switching between optimism and pessimism in the economy.[29]

Financial crises and the role of the central bank

Perhaps the most interesting feature of the model presented here is that it suggests a role for the central bank in dealing with financial crises. We can see from equation 6 that a liquidity crisis (that is, a low-coordination equilibrium) is only possible if the real risk-free rate is sufficiently high. If the central bank can affect the real risk-free rate through open market operations, it can extinguish the possibility of a liquidity crisis by reducing the risk-free rate until the left-hand side of equation 6 exceeds the right-hand side. Intuitively, if the risk-free rate is so low that a lender expects a higher return by seeking to match with a borrower *even if all borrowers are believed to be of bad quality*, then the low-coordination equilibrium cannot be sustained.

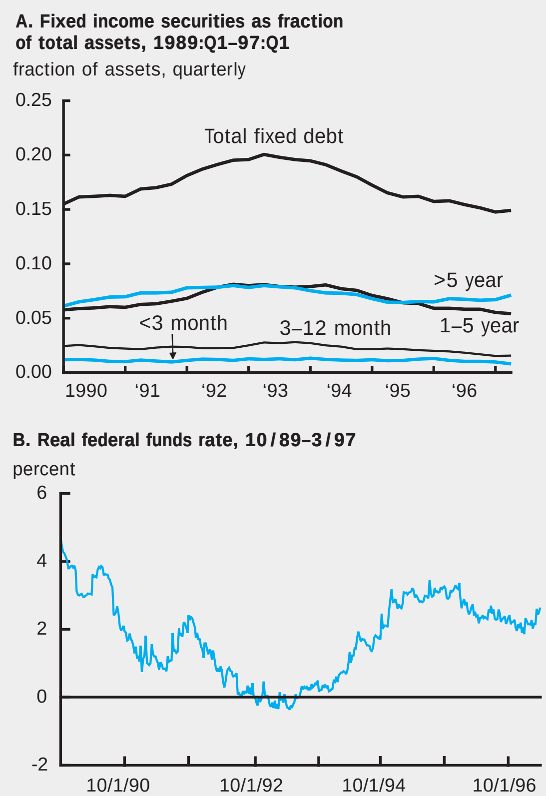
Example of central bank action: The events of 1991–93

One interpretation of monetary policy in the early 1990s is that the Federal Reserve used open market operations in the manner suggested in the preceding paragraph. The recovery from the 1990–91 recession appeared to be impeded by a so-called credit crunch. Responding perhaps to the introduction of risk-based capital requirements, banks reduced their volume of loan provision, investing instead in Treasury securities and other low-risk assets. One can see this process in figure 5, panel A, which displays fixed income securities as a fraction of total banking assets. Note that fixed income securities as a percentage of total assets rose from just over 15 percent at the beginning of 1990 to over 20 percent at the beginning of 1993. While this is far less dramatic than the complete coordination failure in the low-coordination equilibrium of the model, this process can be interpreted as a slow shift away from full coordination.

In mid-1991, the FOMC started reducing the federal funds rate in an effort to encourage more lending. This policy shift is evident in figure 5, panel B, which displays the real federal funds rate (defined here as the difference between the nominal federal funds rate and the ex post monthly CPI inflation rate) from 1989 through 1997. Note that the real funds rate declines to an extremely low level (between 0.5 percent and 0 percent) between late 1992 and February 1994. As in the simple model, the effect is to reduce the return on alternative assets, making even the relatively low risk-adjusted return on loans seem reasonably attractive.[30] As shown in figure 5, panel A, banks did shift

FIGURE 5

Bank portfolios and monetary policy, 1989–97.



Notes: Panel A displays fixed income securities as a faction of total bank assets. The uppermost black line displays total fixed income securities. The other lines in the graph disaggregate the securities by maturity. Panel B displays the real federal funds rate, computed as the nominal federal funds rate minus the one-month CPI inflation rate.
Sources: Call reports (panel A); author's calculations, using data from the Board of Governors of the Federal Reserve System (panel B).

away from non-loan assets to loans following the implementation of this policy. It is possible that the increased loan growth was due to some change in the economic or regulatory environment other than the extremely low real interest rates. However, these patterns in the data are certainly consistent with the intuition that lenders are more willing to lend when the return to alternative investments is low, and that the central bank can influence this alternative return.

Particularly interesting is what happened after the FOMC reversed course starting in February 1994 and allowed the real interest rate to return to its level of early 1990. If banks' willingness to lend depended only on the return on alternative assets, the banks presumably would then have cut back on their loan provision. In fact, figure 5, panel A shows that banks continued to increase their lending. This suggests that there may have been an element of coordination failure in the credit crunch. Once the economy had securely moved to a high-coordination state, it could remain there even after the FOMC raised real interest rates to a higher level.

Policy alternatives implied by the model

According to the model, a central bank can prevent financial crises by keeping interest rates extremely low all the time. However, this strategy conflicts with the central focus of monetary policy: to establish a reputation as a force for price stability. Even if the Fed could act against the possibility of a low-coordination equilibrium by decisively reducing Treasury yields, such an action would be costly, not only in its direct effect on future inflation, but also in eroding the credibility of the Fed's commitment to containing inflationary pressures.

In principle, a central bank could reconcile these two competing imperatives by establishing a credible *state-dependent* policy—enforce a low interest rate *only* when there is clear evidence that a financial crisis is imminent. The advantage of such a policy is that the low interest rate is rarely implemented, yet the possibility that it might be implemented moves the economy to a preferred equilibrium. In fact, when I incorporate such a state-dependent policy into the simple model developed earlier, the low interest rate is *never* implemented. In the language of economic theory, it is an *off-equilibrium path* that enforces the high-coordination equilibrium.

As an example of such a state-dependent policy, consider the aftermath of the October 1987 stock market crash. There is considerable anecdotal evidence that many banks were reluctant to provide the liquidity needed to settle trades made during the day of the crash. This withdrawal of liquidity may have represented a low-coordination equilibrium: If a given bank is likely to be repaid only if the aggregate provision of liquidity is high, it may be individually rational for each bank to withhold liquidity. In response, the Federal Reserve announced a state-contingent policy: "The Federal Reserve ... affirmed today its readiness to serve as a source of liquidity to support the economic and financial system."[31] The operative word is "readiness." With the Fed standing ready to ensure adequate liquidity in the market, it became rational for individual banks to provide liquidity to their clients. In the event, no significant liquidity disruptions were observed,[32] yet the Fed itself did not actively provide the liquidity—discount window borrowing by member banks did not increase significantly, and the increase in non-borrowed reserves was small.

In September 1998, investors were uncertain whether a state-dependent policy was in place.[33] One can interpret the intermeeting rate cut on October 15, 1998, as a credible signal that the Fed had shifted to this sort of state-dependent policy. It seems more plausible to interpret the effect of this rate cut to its role as a signal than to any direct effects. Certainly, the interest rate cuts in fall of 1998 were much smaller than those in 1990–91, clearly not sufficient to substantially change investors' incentives directly. There is evidence that financial markets perceived the intermeeting rate cut as signaling a policy change. According to the *Wall Street Journal,* "the economic indicators that the Fed usually tracks—the unemployment rate, the pace of orders for factory goods and retail sales, among other things—don't explain the Fed's sudden action, since many of those indicators have suggested that the economy is relatively healthy. Rather, officials at the Fed ... have been focused on unusual signs of stress in the financial markets."[34] In the words of analysts at Morgan Stanley Dean Witter, the Fed's "unexpected easing" signaled a "new aggressiveness."[35] Market participants' perception of a change in Fed emphasis is consistent with the minutes of the FOMC's deliberations. In the minutes of the September 29 meeting,[36] the financial market turmoil is noted, but it is seen primarily as one factor among many affecting inflationary pressures through aggregate demand. In particular, "The members did not believe that the tightness in credit markets and strong demand for safety and liquidity were likely to lead to a 'credit crunch.' ..." A 50 basis-point cut is explicitly ruled out because "the risk of rising inflation ... was still present, especially in light of the persistence to date of very tight labor markets and relatively robust economic growth." In contrast, the minutes of the FOMC teleconference preceding the intermeeting rate cut of October 15 do not mention inflationary pressures at all. Rather, an additional rate cut is motivated "to help settle volatile financial markets and cushion the effects of more restrictive financial conditions on the ongoing expansion." Following the October 15 action, members of the FOMC describe the move as a (temporary) shift of focus from price stability to financial stability. For example, the *Wall Street Journal* cited Federal Reserve Bank of St. Louis President William Poole as saying that "[the recent market instability] and the circumstances surrounding it are so unusual in the context of U.S. history that policy makers must concentrate on dealing with this situation for the time being."[37] According to the same article, Governor Roger Ferguson "indicated that the Fed would be willing to cut rates aggressively at any hint of a recession."

In the following section, I incorporate such a state-dependent policy into the simple model outlined earlier. I argue that such a policy, if credible, may have been sufficient to eliminate the possibility of coordination failure without requiring the central bank to actually implement any substantial interest rate reductions. To formalize this idea, I extend the model so that the central bank acts in real time. I then demonstrate that the low-coordination equilibrium can be eliminated if agents believe that the monetary authority will act in the future to eliminate coordination failure should coordination failure become likely.

Modeling a state-dependent central bank policy

To model a central bank interest rate policy that actively responds to a developing liquidity crisis, I need to modify the simple model to make precise the notion of "incipient crisis." I do so in the following (admittedly highly stylized) way. Suppose that there is a preliminary period before the matching of borrowers and lenders. At the beginning of this preliminary period, each lender is assigned at random a mood of *pessimism* or *optimism*. A pessimist believes that the low-coordination equilibrium will prevail *provided* a low-coordination equilibrium could exist (that is, provided equation 6 could hold). An optimist believes that the high-coordination equilibrium will prevail, again provided this equilibrium could exist (that is, equations 4 and 5 could hold). In addition, in the beginning of the preliminary period the N_{lend} lenders are assigned an index $i = 1, ..., N_{lend}$. They then must declare (irrevocably) in order of their index assignment whether they will enter the match or invest in the risk-free technology. After all N_{lend} lenders have declared, the match is held, projects are operated, and payoffs are made, as in the simple model.

Let Q_i denote the number of lenders who have declared that they are in the match through the *i*th lender, so $Q_{N_{lend}}$ denotes the total number of lenders committed to entering the match at the end of the preliminary period. As I show in proposition 1 below, if $Q_{N_{lend}}$ is sufficiently high (that is, if $Q_{N_{lend}}$ is greater than or equal to a particular threshold N^*), a low-coordination equilibrium cannot exist. A pessimist with index *i* will assume that the low-coordination equilibrium will prevail *unless* Q_{i-1} (weakly) exceeds this threshold.

Now, I develop this idea more fully. For simplicity, I consider a case where the central bank can choose one of two interest rates: R^{high} and R^{low}, where R^{high} is consistent with both equilibria. That is, when $R^f = R^{high}$, equations 4, 5, and 6 all hold. (I discuss conditions on R^{low} below.) If $R^f = R^{high}$, the equilibrium that emerges depends on the beliefs of the lenders about $Q_{N_{lend}}$. In particular, there exists an N^* such that, if it is believed that $Q_{N_{lend}} \geq N^*$, it is optimal for *all* good borrowers to enter the match. The smallest such value of N^* is given by

7) $N^* = \min N \text{ s.t. } prob_{borr} (N_{borr}, N)\, R_{borr} \geq R^{autarky}$.

The existence of $N^* \leq N_{lend}$ follows from the assumption that a high-coordination equilibrium exists (that is, equation 5 holds.)

To proceed, I must make an additional assumption. Let V_{lend} denote the value to a lender of entering the match. V_{lend} depends on both the total number of lenders in the match and the number of good borrowers in the match. An explicit expression for V_{lend} is given in equation B1 in box 1. I assume that

8) V_{lend} is strictly decreasing in the total number of lenders in the match.

A sufficient condition for assumption 8 to hold is given in equation B6 in box 1.

Proposition 1

Suppose equations 4 and 8 hold. If all lenders believe that $Q_{N_{lend}}$ will be at least as big as N^*, then all lenders enter the match, so $Q_{N_{lend}} = N_{lend} \geq N^*$. This implies, first, that their beliefs are ratified ex post, and, second, that the high-coordination equilibrium prevails. (The proofs of all propositions are in appendix B.)

Proposition 1 tells us that the central bank can ensure that the high-coordination equilibrium will prevail if it can ensure that at least N^* lenders commit to entering the match. As in the previous model, it can do so by setting R^f sufficiently low. To formalize this possibility, let us assume that

9) $(\theta R_{lend} + (1 - \theta)\, R^{salvage}) > 1$

and let R^{low} satisfy

$$10)\ prob_{lend}(N_{bad}, N^*)(\theta R_{lend} + (1-\theta) R^{salvage}) + (1 - prob_{lend}(N_{bad}, N^*)) \geq R^{low}.$$

Equation 9 means that the expected payoff to a lender conditional on matching with a bad borrower exceeds the payoff from failing to match. It ensures that the left-hand side of equation 10 is increasing in $prob_{lend}$.

Proposition 2

If the central bank sets $R^f = R^{low}$ and equations 9 and 10 hold, the high-coordination equilibrium is enforced.

Proposition 2 tells us that the central bank can eliminate the low-coordination equilibrium by permanently setting the risk-free rate sufficiently low (in particular, low enough so equation 10 holds). In reality, however, this low interest rate policy is a very costly way to deal with the possibility of financial crisis. As I discussed above, the excessively expansionary monetary policy needed to keep interest rates at R^{low} may directly conflict with the central bank's primary mission of price stability. If so, a better central bank rule is to set $R^f = R^{high}$, but commit to switching to R^{low} if there is evidence of an incipient crisis. Informally, the central bank can measure the tone of the market by looking at the ratio Q_i/i. This ratio gives the fraction of the first i lenders who will enter the match, so this ratio measures the "skittishness" of the market. If the central bank observes a low value of Q_i/i (presumably because the random assignment of the first i indexes fell disproportionately on pessimists), it may be concerned that a financial crisis is brewing.

In the formalism of this model, let "incipient crisis" be defined as any point i^* in the declaration sequence such that

$$11)\ Q_{i^*} + (N_{lend} - i^*) = N^*.$$

In words, if such an i^* is reached, then *all* of the remaining lenders must declare themselves in the match to ensure that there are N^* lenders seeking to match with borrowers. Since the goal of the central bank is to ensure that at least N^* lenders enter the match, this is the "last chance" for the central bank to do so.

Central bank rule

The proposed central bank rule is as follows:

- Set $R^f = R^{high}$ as long as no $\{i^*, Q_{i^*}\}$ satisfying equation 11 is reached.
- The first time $\{i^*, Q_{i^*}\}$ satisfying equation 11 is reached, set $R^f = R^{low}$ from that point on.

Proposition 3

If this rule is credible, the only equilibrium is high-coordination with $Q_i = i$, $\forall i$, and $R^f = R^{high}$.

According to proposition 3, the second branch of the rule is an off-equilibrium path that is never observed in equilibrium. Thus, the best of all possible worlds is obtained: Liquidity crises are ruled out without compromising the goal of price stability. Proposition 3 specifies that the rule must be credible. I do not attempt to formalize how "credibility" is to be established. Authors such as Christiano, Chari, and Eichenbaum (1998) and Christiano and Gust (2000) stress the importance of the central bank establishing a credible commitment to price stability if expectations-driven inflationary episodes are to be avoided. Proposition 3 suggests that a credible commitment to financial stability may serve an analogous role in avoiding financial crises.

Discussion

Is this what happened in October 1998?

One interpretation of the FOMC's interest rate cut on October 15, 1998, is that it was an intentional signal that Federal Reserve had shifted from an unequivocal focus on price stability to a policy of "price stability unless there is a pressing need to deter a financial crisis." In the formalism of the model, the former policy sets $R^f = R^{high}$ always, while the latter policy is given by the policy rule described above.

There are clearly other possible explanations for the ending of the fall 1998 crisis. One such explanation is that the reduced interest rates increased the collateral value of firms' fixed income portfolios, thereby increasing their borrowing capacity. But the effect of a 50 basis-point interest rate cut on the value of debt holdings is small, especially for the short-term securities generally used as collateral. In any event, the turmoil in fall of 1998 was associated with a "flight to quality," which raised the value of the Treasury securities that typically collateralize liquidity loans. Another explanation is that the open market operations used to implement these interest rate cuts increased the total supply of reserves in the system, increasing the amount of liquidity available to be borrowed. Again, this explanation seems wanting. In contrast to the period from 1991 to 1993, when there was an extended and pronounced increase in the volume of reserves in circulation, the amount of reserves in fall 1998 was relatively unchanged.

Perhaps a more straightforward explanation for the abrupt reversal of the 1998 crisis is that financial intermediaries believed that the Federal Reserve had implicitly agreed to provide all financial institutions with a guarantee. In particular, the role of the Federal Reserve Bank of New York in the recapitalization of LTCM may have been interpreted as a commitment to provide similar services to other intermediaries with similar problems. I do not believe that the facts support this explanation. Following the announcement of the LTCM rescue plan, *the crisis actually deepened*. Measures of credit spreads and market volatility deteriorated during the two weeks between the LTCM rescue and the Federal Reserve's intermeeting action on October 15. Furthermore, market participants reported that the Federal Reserve's role in the rescue served to exacerbate market fears, not ameliorate them. Thus, the data seem to contradict the hypothesis that the LTCM rescue was interpreted as an extension of the safety net.

Finally, the October 15 rate cut may have signaled a changed policy stance regarding International Monetary Fund (IMF) funding rather than monetary policy. The Russian fiscal crisis virtually assured that a good deal of IMF resources would flow to Russia. Without an increase in funding levels, the IMF's resources to deal with other countries' problems (most importantly, Latin America) would have been substantially reduced. The increase in Brady bond yields, documented in figure 3, may have reflected concerns that less IMF funding would be available to deal with future Latin American problems following the Russian crisis. During 1998 the U.S. Congress was considering an increase in America's IMF funding quota. However, there was considerable congressional opposition to increased funding. Perhaps the October 15 rate cut was interpreted as a signal that the Federal Reserve would work with greater intensity to secure increased IMF funding.

This interpretation is certainly possible. However, it relies on a less direct mechanism than the monetary policy interpretation I put forth in this article. It places a good deal of weight on the Federal Reserve's influence with Congress. Furthermore, the Federal Reserve was already on record supporting the proposal to increase IMF funding (see Chairman Greenspan's testimony to Congress on May 21, 1998), so the October 15 rate cut would have represented at best a strengthening of this position, not a reversal of a previously held position. Finally, the data are not entirely consistent with this explanation. As shown in figure 3, the peak in Latin American Brady bond yields during 1998 happened in mid-August (Mexico) or mid-September (Brazil and Argentina), not in mid-October when the presumed signal occurred.

Costs of a state-contingent policy for financial crises

In the theoretical model described here, the state-contingent policy rule is costless to implement, since the low interest rate is never actually imposed in equilibrium. Of course, the real world is not so simple. In reality, there would doubtless be crises that could not be extinguished by the belief that the central bank's rule specifies a particular off-equilibrium path. As a practical matter, this sort of policy rule would require aggressive monetary expansion from time to time. Actions of this type have costs. Each time such a monetary expansion is implemented, the central bank compromises its primary objective of price stability. Any time it injects liquidity into financial markets in an effort to counter potential liquidity it faces the difficult task of negotiating a "soft landing"—removing the liquidity after the crisis has abated without triggering a recession. Furthermore, if the state-contingent policy rule weakens the commitment to price stability, the resulting instability might even increase the possibility of financial crises. Finally, if private market participants believe that the central bank will always act to successfully counter financial turmoil, they may engage in less vigilant risk management than they would otherwise. This so-called moral hazard problem may actually increase the chances of an incipient crisis. Policymakers must take all of these issues into consideration before adopting a state-contingent rule as a practical policy doctrine.

Conclusion

In this article, I propose a precise characterization of financial crisis. I argue that coordination problems arise generically in financial markets. I associate financial crisis with a condition of coordination failure, in which low levels of financial intermediation become self-justifying. I also argue that the central bank, through its ability to affect real interest rates, may be able to extinguish the low-coordination trap. This argument supports a role for the central bank in countering systemic financial disruptions.

Having said this, there may be circumstances in which the central bank's power to affect real rates is insufficient to stave off a crisis. In particular, if potential lenders are sufficiently pessimistic about returns from lending, crisis aversion may require a real interest rate below that achievable by open market operations. In addition, the use of open market operations to counter financial crises is not without cost. Open market operations can only have a temporary effect on real rates. Prolonged use of this tool to reduce real interest rates would run directly counter to the central bank's primary goal of price stability. In principle, the central bank is better off establishing a credible contingent policy, whereby a liquidity injection is only made when there is evidence that a crisis is forthcoming. In the simple model presented here, a credible policy of this type never has to be implemented in equilibrium. In reality, of course, life is not so simple. There would doubtless be cases where the central bank would have to implement an expansionary monetary policy to counter an incipient crisis. Thus, this article's policy implications have benefits and costs that must be carefully weighed by policymakers when considering practical policy formulation. Nonetheless, this article does provide a formal justification for the central bank as an essential institution in dealing with financial crises.

APPENDIX A

Increasing returns to scale in matching

Increasing returns to scale in matching can be derived from a number of more primitive search models. For example, Mortensen and Pissarides (1998) describe an environment in which each lender has a list of telephone numbers that includes the numbers of potential borrowers, and each borrower has a similar list that includes the numbers of potential lenders. If borrowers and lenders choose numbers at random, the probability of a match displays increasing returns. Kultti (1998) describes a somewhat more elaborate model.[1] In his approach, lenders are posted at fixed locations, and borrowers randomly choose a location. If there is a lender at the location and there are no other borrowers, a match is made with certainty. If there is a lender and more than one borrower at the location, a borrower is chosen at random to match with the lender. Finally, if there is no lender at the location, no match is made. One can think of these locations as bank branches, where some branches have exhausted their loan capacity. Kultti (1998) shows that if the number of locations does not change as the number of borrowers and lenders increases, the matching probabilities display increasing returns.[2]

Now, I consider in greater detail a micro model of matching, similar to Kultti's (1998), that implies increasing returns. Suppose there are M locations. To successfully match, a lender and a borrower must go to the same location. They cannot communicate before traveling to a location, so the event of a lender and a borrower being in the same location is purely random. Ex ante, all locations look the same to both lenders and borrowers. I assume that lenders and borrowers make their location decision at random, independently of the other lenders and borrowers. Therefore, the probability that a given borrower or a given lender arrives at any particular location is $1/M$.[3]

An interpretation of this set-up is that the "locations" are banks or other intermediaries. Lenders are agents with excess liquidity. To match with borrowers, the lenders must go through an intermediary. Lenders choose the intermediary at random. Similarly, borrowers visit intermediaries at random to apply for a loan. The loan application process is sufficiently time-intensive that a borrower can only apply at one intermediary.

Suppose there are l lenders and b borrowers at a given location. If $l = 0$ or $b = 0$, no matches take place at that location. If $l = b$, all the lenders and borrowers at that location match with probability one. If $l > b$, the b borrowers are allocated randomly among the lenders, so the probability of a given lender obtaining a match is b/l, and all borrowers obtain a match with probability one. Similarly if $b > l$, the probability of a given borrower obtaining a match is l/b, and all lenders obtain a match with probability one. To summarize,

$$Prob\{lender\ matching \mid b,l\} \min\left(\frac{b}{l},1\right);$$

$$Prob\{borrower\ matching \mid b,l\}\ min\left(\frac{l}{b},1\right).$$

I now compute the unconditional probability that a lender will match. Let B denote the number of borrowers seeking loans, and let L denote the number of lenders seeking to match with borrowers. The probability that a given lender will be at a particular location is $1/M$. For $n = 0, 1, ..., L$, the probability that n lenders will arrive at a particular location is denoted by $p_l(n|L)$, as follows:

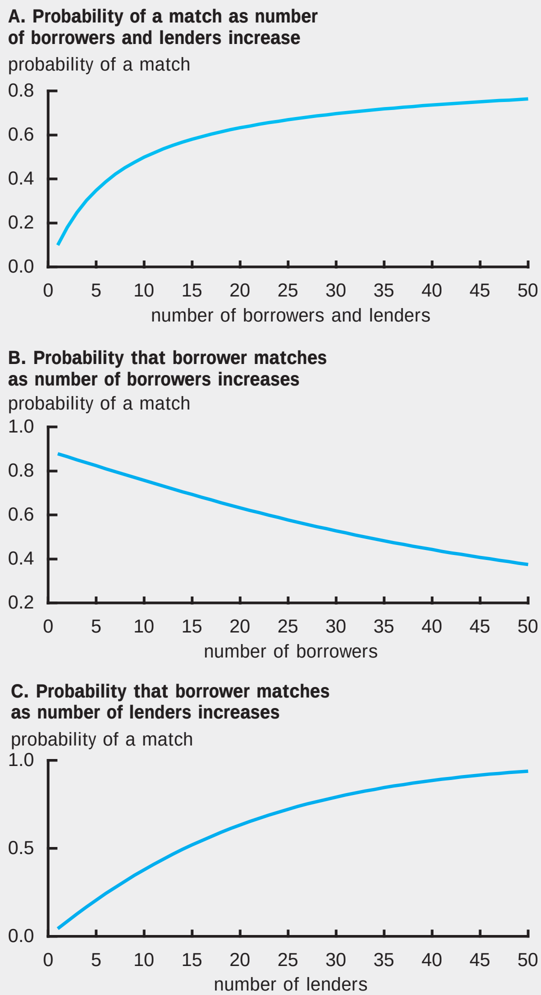
$$p_l(n|L) = \frac{L!}{n!(L-n)!}\left(\frac{1}{M}\right)^n\left(1-\frac{1}{M}\right)^{L-n}.$$

Similarly, for $n = 0, 1, ..., B$, the probability that n borrowers will arrive at a particular location is denoted by $p_b(n|B)$, as follows:

$$p_b(n|B) = \frac{B!}{n!(B-n)!}\left(\frac{1}{M}\right)^n\left(1-\frac{1}{M}\right)^{B-n}.$$

FIGURE A1

Effect of matching probabilities of increase in numbers of borrowers or lenders



Notes: The top panel gives the probability that a lender or borrower matches as both the number of lenders and the number of borrowers increase at the same rate. The middle panel gives the probability that a borrower matches as the number of borrowers increases (holding lenders fixed). The bottom panel gives the probability that a borrower matches as the number of lenders increases (holding borrowers fixed).

To determine $prob_{borr}(B,L)$, the probability that a given borrower matches, one must sum overall possible values of l and b:

$$\text{A1)}\quad prob_{borr}(B,L)= \sum_{l=0}^{L}\sum_{b=0}^{B-1}\min\left(\frac{l}{b+1},1\right)p_b(b|B-1)\,p_l(l|L).$$

In the second summation, I sum only to B–1 because we are concerned with the number of *other* borrowers that show up at the same location as the given borrower. There are only B–1 other borrowers. The expression for $prob_{lend}(B, L)$, the probability that a given lender matches with a borrower, is analogous:

$$\text{A2)}\quad prob_{lend}(B,L)= \sum_{b=0}^{B}\sum_{l=0}^{L-1}\min\left(\frac{b}{l+1},1\right)p_b(b|B)\,p_l(L-1).$$

The increasing returns property is illustrated in the first panel of figure A1. As both L and B rise, the probability of a match (given by equation 19 or 20) increases. As illustrated in the last two panels of figure A1, equation A1 implies that the probability of a given borrower matching is increasing in the number of lenders, L, (holding B constant) and decreasing in the number of borrowers B (holding L constant). Similarly, the probability of a given lender matching is increasing in B and decreasing in L.

[1]See also Hall (1999).

[2]More generally, this result holds if the number of locations increases at a slower rate than the number of borrowers and lenders.

[3]This explicitly rules out equilibria of the form, "All borrowers and all lenders choose to go to the *k*th location with probability one."

APPENDIX B

Proofs of propositions

Proposition 1

Let functions V_{borr} and V_{lend} be defined as in equations B1 and B2 of box 1. $Prob_{borr}(B, L)$ is increasing in L and decreasing in B. Therefore, the condition

$$Q_{N_{lend}} \geq N^*$$

and equation 7 imply that $V_{borr}(B_{good}, Q_{N_{lend}}) \geq R^{autarky}$ for all $B_{good} \leq N_{borr} - N_{bad}$. This implies that all good borrowers enter the match. However, if all good borrowers enter the match, then equations 4 and 8 imply that the value of entering the match to a lender exceeds R^f, regardless of the decisions of the other lenders.[1] Therefore, all lenders enter the match. This ends the proof.

Proposition 2

If $R^f = R^{low}$, equations 9 and 10 together imply that if $Q_{i-1} < N^*$, it is optimal for the ith lender to enter the match, *even if no good borrowers enter the match*. This follows because equation 9 ensures that, for arbitrary $\tilde{N}$,

$$prob_{lend}(N_{bad}, \tilde{N})(\theta R_{lend} + (1-\theta) R^{salvage}) + (1 - prob_{lend}(N_{bad}, \tilde{N}))$$

is decreasing in $\tilde{N}$. (Recall that $prob_{lend}(N_{bad}, \tilde{N})$ is decreasing in $\tilde{N}$: As more lenders compete with a given lender, the probability that a lender matches goes down.) This in turn means that at least N^* lenders will enter the match, regardless of what any of the other lenders or good borrowers do, so $Q_{N_{lend}} \geq N^*$. According to proposition 1, this is sufficient for the high coordination equilibrium to prevail. This completes the proof.

Proposition 3

To prove proposition 3, note that the monetary policy rule ensures that there will always be at least N^* lenders committing to enter the match. By proposition 1, this is sufficient to ensure that the high-coordination equilibrium prevails. This completes the proof.

[1]This assertion uses the fact that assumption 8 implies that $V_{lend}(B,L)$ is decreasing in L. Therefore, if $V_{lend}(N_{borr} - N_{bad}, N_{lend}) \geq R^f$, then $V_{lend}(N_{borr} - N_{bad}, L) \geq R^f, \forall L \leq N_{lend}$.

NOTES

[1]An account of the events surrounding the Russian default can be found in Perotti (2000).

[2]Immediately following the announcement of the rate cut, the Dow Jones Industrial Average dropped. Press reports indicate that many investors expected a bigger rate cut. The U.S. Chamber of Commerce described the move as “underwhelming in its modesty” (Schlesinger and Wessel, 1998b), and investors in bond futures “were treating a half-point cut by year’s end as a certainty, and a half-point cut tomorrow as a reasonable possibility” (Schlesinger, 1998). The federal funds futures market supports this assertion. From September 25 through 28, the price of the October federal funds futures contract implied an expected fed funds rate of around 5.16 percent for the month of October (down from 5.5 percent before September 29). This implies that investors put substantial probability on a cut of 50 basis points or more at the September FOMC meeting.

[3]“[M]arkets had been rife with rumors about the possibility of an intermeeting move for the past week or so. …” in Greenlaw (1999).

[4]The fed funds futures market gives a forecast of the 30-day average federal funds rate over the month of October. The funds rate was already at 5.25 percent. A rate cut in mid-October to 5.00 percent would move the 30-day *average* of October rates to 5.125 percent. If investors only assigned a 50 percent probability to such a rate cut, the expected average rate would be approximately 5.18 percent.

[5]The magnitudes of the declines were as follows: UK, 23 percent; Germany, 19 percent; Japan, 18 percent; Canada, 28 percent; Italy, 32 percent; and France, 29 percent.

[6]I would like to thank Eileen Smith of the Chicago Board Options Exchange for providing me with these data.

[7]The actual peak in the volatility index came on October 8, 1998, the date of the trough in the S&P 500 index.

[8]The behavior of default spreads for other G-7 countries gives a less clear picture of the start and end of the crisis. For Canada, France, Italy, and the UK, these spreads move roughly in line with the U.S. data (although the interbank spread for France is so volatile that it is difficult to identify peaks and troughs with any degree of certainty). The German interbank spread peaks in November 1998, several weeks after the peak in U.S. data. Finally, the behavior of default spreads in Japanese data is rather different from the other G-7 countries. In particular, the Japanese interbank spread shows little evidence of a liquidity crisis until a pronounced spike in mid-November 1998, well after the crisis abated in the U.S.

[9]The Board of Governors’ Senior Loan Officers Survey can be found on the Internet at www.federalreserve.gov/boarddocs/SnLoanSurvey/. The surveys in August and November 1998 followed the Board’s usual procedure of asking respondents about credit conditions over the preceding three months. Therefore, the November survey reflected most of the crisis period. In contrast, the September 1998 survey was a special survey that only asked about credit conditions over the previous month.

[10]This characterization of markets during the crisis is confirmed by other sources. For example, Morgan Stanley Dean Witter reported a sharply reduced volume of activity across the corporate borrowing spectrum. (Roach, 1998.) Similarly, a strategist at Merrill Lynch asserted that “there were literally occasions when you could not get a bid of any kind for debt that was a reasonable risk” (The Economist Newspaper Limited, 1998, p. 75).

[11]See Schlesinger and Wessel (1998a).

[12]BIS (1999, p. 42).

[13]The role of the Federal Reserve Bank of New York in the recapitalization of LTCM was limited to providing meeting facilities for the involved parties. The Federal Reserve provided no funds in the LTCM workout.

[14]According to the U.S. Department of Commerce, Bureau of the Census (1998), the U.S. exports of goods and services to Argentina, Mexico, and Brazil in 1997 exceeded $93 billion (13.5 percent of total U.S. exports), while U.S. imports from these countries totaled almost $98 billion (11.2 percent of U.S. total). In contrast, U.S. exports to Russia totaled $3.4 billion (0.49 percent of the U.S. total) with imports from Russia totaling $4.3 billion (0.50 percent of the U.S. total).

[15]Brady bonds are U.S. dollar-denominated obligations of various developing countries, mainly in Latin America.

[16]For Indonesia and Malaysia, swap yields for maturities up to two years and forward exchange rates for up to one year closely track the spot exchange rates for these currencies. That is, these forward-looking markets did not anticipate the currency devaluations. Data on these particular markets are not available for Korea and the Philippines, but yields on government bonds (five-year maturity for Korea, one-year maturity for the Philippines) display the same patterns as the Indonesian and Malaysian swap yields: they did not budge until these countries devalued their currency. The only country where interest rates (as measured by swap yields) and forward exchange rates moved before the devaluation was Thailand. For that country, both rates started to increase six weeks before the devaluation of the baht. However, this coincided with the initial speculative attacks on the baht and the Thai government's initial attempts to defend its currency peg. See Halcomb and Marshall (2001).

[17]See Burnside, Eichenbaum, and Rebelo (1998).

[18]In developing this model, I benefited from extensive discussions with François Velde.

[19]These second and third characteristics were also associated with the Asian crisis of 1997. The reduction in liquidity provision took the form of a reversal of short-term capital flows from western countries. Needless to say, stock markets fell precipitously in all five Asian crisis countries.

[20]In this example, which is discussed in Cooper and John (1988), there can be more than two equilibria.

[21]The classic demonstration of how a search model can give rise to a thick markets externality is Diamond (1982).

[22]I'd like to thank Eric French for suggesting this interpretation.

[23]It would be preferable to have the contract emerge as the equilibrium outcome of a bargaining game. This approach is not straightforward to implement. The Nash (1953) axiomatic approach to solving the two-person bargaining problem does not generalize to a game with asymmetric information. An alternative would be to specify a noncooperative bargaining game. For example, one could assume that either the borrower or lender is randomly given the right to make a single take-it-or-leave-it offer. (Mortensen and Pissarides, 1998, note that this game under full information implies the same solution as a particular version of the Nash bargaining problem.) It is beyond the scope of this article to explore the range of noncooperative game theoretic approaches to this problem. As a result, I adopt the simple expedient of an exogenous contract.

[24]My assumption that a lender who fails to match gets a zero net return captures the idea that there is some opportunity cost to committing to provide loans, rather than investing exclusively in the risk-free investment. However, the analysis would not be changed substantially if a lender who fails to match received a small positive return.

[25]Lagos (2000) develops a model of passenger–cab matching that implies constant returns to scale. The difference between this model and the model I develop in appendix A is that Lagos (2000) assumes a continuum of passengers and cabs, whereas my model assumes that both passengers and cabs are discrete and finite in number.

[26]More recently, DenHaan, Ramey, and Watson (1999) and Burdette, Imai, and Wright (2000) propose search models that give rise to nontrivial multiple equilibria even with constant returns to scale.

[27]The baseline parameters used in figure 4 are: $N_{lend} = 20$; $N_{borr} = 30$; $R = 2$; $R_{lend} = 1.2$ (so $R_{borr} = 0.8$); $R^{salvage} = 0.5$; $p^b = 0.2$; $\theta = 0.75$. Parameter N_{bad} is set equal to its expected value of 6. I use the model of $prob_{lend}$ and $prob_{borr}$ described in appendix A, equations A2 and A1, with parameter $M = 10$.

[28]Of course, this static model cannot address the question of why existing assets decline in value. If existing productive assets utilize a continued flow of credit to maintain high profitability, a reluctance of lenders to provide credit would presumably reduce asset values. However, it would require a dynamic extension of this model to analyze this effect formally.

[29]In the literature on financial fragility, this is typically done by assuming an exogenous "sunspot process," whose realization determines the state of optimism in the economy. (See, for example, Chang and Velasco 1998, Christiano and Harrison 1996, and Burnside, Eichenbaum, and Rebelo 2000.) I do not explicitly implement this approach for rendering the model dynamic, but to do so would be straightforward.

[30]While figure 5, panel B displays the real overnight interest rate, the relevant rate for bank incentives is the expected rate of return from holding longer-term fixed income securities. Forecasting expected real holding period returns is a process fraught with difficulty, and I do not attempt to do so here. However, simple term structure models (such as the expectations hypothesis) imply that expected real holding period returns move with short-term real interest rates. Figure 5, panel B suggests that the expected returns relevant to bank decisions fell substantially as a result of the Federal Reserve's expansionary policy from 1991 to 1993.

[31]Quoted in Murray (1987).

[32]For an account of these events, see the Securities Exchange Commission report excerpted in Kamphuis et al. (1989).

[33]For example, the Morgan Stanley Dean Witter *Global Economic Forum* of September 25, 1998, noted that a large rate cut at the FOMC meeting four days later "… may reflect a potentially profound transformation in the Fed's basic philosophy." The forum argued "… that the biggest risk of all is that the world's policymakers may not be up to the task at hand." Similarly, Jacob Schlesinger wrote in the *Wall Street Journal* of September 28, 1998, that "an easing of monetary policy would mark a swift and amazing turnaround in the central bank's fundamental economic outlook. For well over a year, the Fed's greatest concern has been inflation, not recession."

[34]Schlesinger and Wessel (1998a), p. A3.

[35]Morgan Stanley Dean Witter (1999).

[36]Minutes of the FOMC can be obtained from the Federal Reserve website at www.federalreserve.gov/fomc/minutes/.

[37]Schlesinger and Ip (1998).

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