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Modelling Financial Instability: A Survey of the Literature

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Alexandra Lai

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Alexandra Lai

Monetary and Financial Analysis Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
laia@bankofcanada.ca

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Abstract

The magnitude and frequency of recent financial crises underscore the importance of understanding financial instability for the purpose of crisis prevention and crisis management. This paper brings together and adds structure to the theoretical literature on financial instability and the implications they carry for policy-makers. In addition to clarifying the theoretical underpinnings for studying financial crises, it points to several directions for future theoretical research necessary to fill the gaps of our understanding of financial instability.

JEL classification: G20, G21, G28
Bank classification: Financial institutions; Financial markets; Financial services

Résumé

L’ampleur et la fréquence des crises financières observées récemment font ressortir l’importance d’une bonne compréhension des causes de l’instabilité financière, dans l’optique de la prévention et de la gestion des crises. L’auteure passe en revue et synthétise les travaux théoriques consacrés à l’instabilité financière et examine leurs implications pour la conduite des politiques publiques. Elle clarifie les fondements théoriques de l’étude des crises et suggère diverses pistes de recherche fondamentale susceptibles de mener à une meilleure compréhension de l’instabilité financière.

Classification JEL : G20, G21, G28
Classification de la Banque : Institutions financières; Marchés financiers; Services financiers

1. Introduction

Recent crises in Latin America and East Asia have revived interest in models of financial instability. The magnitude and frequency of crises over the last few decades have underscored the importance of crisis prevention and crisis management. Understanding what underlies financial instability and what happens during a crisis (positive analysis) can lead to better policies towards preventing and resolving crises (normative analysis). This paper seeks to contribute to the understanding of the causes of financial instability by reviewing the approaches that have been taken in modelling instability in domestic financial systems.

Financial stability is defined as the ability of a financial system to resist a crisis for a given shock to the system. It is a continuous measure over system characteristics for a given shock. This implies that the scale along which stability is measured is not fixed but varies with the shock under consideration. A financial crisis is the occurrence of a systemic event in the financial system, which is defined as "an event that will trigger a loss in economic value or confidence in a substantial portion of the financial system that is serious enough to . . . have significant adverse effects on the real economy" (G-10 Working Party on Financial Consolidation 2001, 126). Hence, financial crises are manifestations of financial-system instability that impose significant costs on the real economy. Systemic risk is the probability of a crisis occurring.

The scope of this paper is limited to domestic financial crises or the domestic aspects of global crises. Therefore, it does not discuss models of currency crises.[1] Although sharp asset price declines are often associated with financial crises, this paper does not examine the causes of asset market crises (defined as large declines in asset prices), because it views such asset price declines as a trigger, albeit an important one, for financial crises, rather than as an underlying cause of financial instability. Asset market crashes constitute a crisis only insofar as they set off a banking crisis or the financial accelerator. Models of financial crises based on moral hazard created by an ill-designed financial safety net (usually meant to deal with the inherent vulnerabilities of the financial system) are also excluded from this survey. However, policy solutions to reduce the likelihood of financial crises and to mitigate the cost of crises when they occur must also take into account the possible perverse incentives for inappropriate and excessive risk-taking that a poorly designed safety net might encourage. Understanding how government guarantees and the behaviour of regulators can create moral hazard problems in the financial system is thus an important part of learning how to deal with financial crises. However, this survey focuses only on models of the *inherent* instability of financial systems.

Although financial crises are complex phenomena, it is possible to break a crisis down into its two components: initiation and propagation. A financial crisis can be initiated by the failure of one or several banks. The failure can result from a run on banks and imply a failure of markets for

[1] There are various surveys of the literature on international financial crises, or currency crises. One such survey is a *Bank of Canada Review* article by Osakwe and Schembri (1998).

liquidity, to which banks turn to meet their short-term liquidity needs. By themselves, however, bank failures do not necessarily mean that a financial crisis is underway. In an uncertain world, firms and banks are subject to failure even when the economy is functioning smoothly, and failure need not imply a deviation from social optimality. It is the other component of a crisis, propagation, that distinguishes individual bank failures from a financial crisis. Propagation takes place through contagion, or a spreading of failures from one financial institution to another (or one part of the financial system to another), and through the financial accelerator, which amplifies (real and financial) shocks and provides a channel for financial events to affect the real economy. Propagation can lead to a collapse of the financial system and result in significant real costs for the economy.

A financial crisis can be initiated by a run on a bank as a result of coordination failure among the bank's depositors. Banks are characterized by balance sheets that exhibit "maturity mismatch," which means that banks' liabilities (predominantly composed of deposits) tend to be short-term, while their assets tend to be long-term and illiquid. A run on a bank occurs when the bank's demand for liquidity, owing to withdrawals by depositors, exceeds the short-term value of its assets. A group of models focuses on how runs on banks originate. These models identify coordination failure as the root of banks' vulnerability to runs. Section 3 reviews models of bank runs based on coordination failure. Coordination failure can cause one bank or an entire banking system to fail. However, in the absence of linkages between banks in the form of information spillovers or credit exposures, whether a run occurs at a bank depends only on the decisions of that bank's depositors. It is only by coincidence that runs are experienced by several banks. Thus, these models are theories of crisis initiation.

When a bank's need for short-term liquidity exceeds its reserve of liquid assets, it faces a potential liquidity crisis. The bank can acquire liquidity by liquidating some of its long-term assets (usually at a loss), drawing on its deposits at other banks, or borrowing from other banks with excess liquidity. Hence, a necessary part of crisis initiation is that individual banks' liquidity needs are not met by markets for liquidity. The second group of models surveyed in this paper focuses on markets for liquidity and investigates the circumstances under which such markets are inefficient. If markets for liquidity are efficient, a solvent bank should never be illiquid, since it will be able to sell its long-term assets or borrow against its long-term assets to tide over its liquidity problems. Banks with liquidity needs in excess of their liquid assets turn to markets for liquidity, and banks with excess liquidity have an incentive to lend to illiquid banks. Markets for liquidity, however, can be inefficient because of market power or information asymmetries. In that case, liquidity problems at healthy banks can turn into solvency problems when the banks are forced to sell their long-term assets below their fair value, or when they are unable to borrow enough funds on the interbank lending market. Section 4 reviews the literature on the market provision of liquidity. In addition to an initiating factor for individual bank failures, inefficiencies in markets for liquidity can aid the spread of failures and are also part of crisis propagation.

The propagation aspect of financial crises implies that there is a spillover dimension to financial crisis. Liquidity or solvency problems faced by one or a subset of banks can spread contagiously to other banks. The third group of models are theories of bank contagion. They examine the channels through which financial distress can spread from bank to bank. The two main channels examined are information spillovers and credit exposures. Information spillovers can arise when bank fundamentals are correlated and problems at one bank are taken as signals about the viability of other banks. Credit exposures among banks arise from risk-sharing contracts, such as interbank deposits, and from banks' participation in netting payment systems. Section 5 reviews theories of bank contagion.

By definition, financial crises are financial events that have significant adverse effects on the real economy. Models of the financial accelerator focus on translating financial events into real effects for the economy. This class of theories demonstrates the ability of the financial sector to amplify shocks to an economy via a mechanism called the financial accelerator. These models are reviewed in section 6.

Section 7 concludes.

2. Stylized Facts about Financial Crises

Financial crises are complex phenomena that exhibit many characteristics, some of which are described below.

Financial crises involve substantial real costs in economic output.

> Crises lead to misallocation and underutilization of resources, resulting in losses of real output. To provide a rough estimate of the costs of crises, studies typically compare GDP growth after a crisis to trend GDP growth. The cost in lost output is estimated by adding up the differences between trend growth and actual growth in the years following the crisis until the period in which annual output growth returned to trend. For the period 1980-95 (a period which excludes the Asian crisis), an International Monetary Fund study (IMF 1998) of 53 industrial and developing countries identified 158 currency crises and 54 banking crises. The study estimated that the cumulative output loss associated with the 158 currency crises was an average of 4.3 per cent of trend GDP. Banking crises were more costly: cumulative output loss from the 54 banking crises averaged 11.6 per cent. When banking and currency crises occurred within a year of each other (such phenomena have recently been termed "twin crises" in the literature), the losses were substantially larger, amounting to 14.4 per cent, on average. Output losses were, on average, greater in emerging than in industrial economies.

Financial crises are episodic, or transitory.

> Financial crises, even for the countries that incur them most frequently, are transitory in duration and effect. For the sample of crises identified in an IMF (1998) study, recovery from

currency crises took, on average, about 1.5 years, banking crises about 3 years, and twin crises slightly more than 3 years.

The onset of a crisis is difficult to predict.

There is no strict correspondence between the preconditions for and the occurrence of a financial crisis. Certain features in an economy may be associated with higher risk (for example, a high ratio of short-term debt to short-term assets and short term to total foreign debt), but they do not necessarily imply a crisis. The five countries that experienced currency crises during the Asian crisis had rapid growth in bank credit and money supply relative to their GDP, and high levels of outstanding bank credit and money supply, but the three economies in the region with the highest ratios of short-term to total external debt in mid-1997 were Singapore, Taiwan, and Hong Kong, which were the countries in the region that were least affected by the Asian crisis. Furthermore, there is evidence that the East Asian crisis was not anticipated by world markets (Marshall 1998).

Crises are often preceded by a period of credit expansion.

Kaminsky and Reinhart's (1999) study of 26 banking and 76 currency crises in 20 countries for the period 1970 to mid-1990 concluded that a common precursor to a crisis was an above-normal rate of growth in money and credit.

Crises involve liquidity shortages.

In banking markets, a liquidity crunch can result from the liability side of banks' portfolios owing to runs on deposits, usually by wholesale depositors, or from the asset side owing to declines in banks' cash-asset ratios. A decrease in banks' loans-asset ratios also implies a credit crunch. Sharp interest rate increases on deposits and loans indicate that the decline in bank lending is a supply-side phenomena.

Banking crises were generally accompanied by declines in bank deposits and bank lending, and increases in the interest rates on loans and deposits (Gupta 1996). However, from a sample of 32 banking crises over the period 1970-95, bank runs occurring without currency runs did not result in a significant change in the total deposit-to-GDP ratio. Therefore, there were runs on individual banks but not on the banking system as a whole. A banking crisis that was accompanied by a run on currency, however, saw significant decreases in the deposits-to-GDP ratio (Dermirghuc-Kunt, Detragiache, and Gupta 2000).

There is asset price instability.

Stock and real estate market collapses typically accompany or precede banking crises. This was true of Japan in 1990, Scandinavia (Norway, Finland, and Sweden) in the 1980s, Mexico in 1994, and East Asia in 1997. According to Kaminsky and Reinhart (1999), who studied a range of crises in 20 countries, a typical crisis was preceded by an average rise in the price of stocks of about 40 per cent per year above that occurring in normal times. The prices of real estate and other assets also increased significantly. At some point, the bubble burst and the stock and real estate markets collapsed (not necessarily simultaneously). In many cases, banking and/or currency crises followed. Although it is usual for both stock and real estate markets to collapse, there is no evidence that the collapse of both types of markets is necessary for a financial crisis to ensue.

There is contagion within and across markets.

Contagion within banking markets is a common feature of financial crises. In the Swedish (1990) and Norwegian (1985) banking crises, the problems first emerged in finance companies and then spread to banks, owing to the banks' involvement in the finance companies (Drees and Pazarbasioglu 1998). In Argentina (1995), depositor runs started at wholesale banks and spread to retail banks. Contagion in the banking sector was evident in Paraguay (1995) and Venezuela (1994) as well (Garcia-Herrero 1997).

There is a loss of confidence by investors.

A loss of confidence manifests itself as a flight to quality (currency, domestic or foreign). Evidence of a loss of investor confidence can be seen in the dramatic reversal of capital flows associated with recent financial crises. For example, between 1996 and 1997, the capital inflow to the five Asian crisis economies went from \$93 billion to $-$\$12.1 billion. This reversal represented 11 per cent of the combined GDP of those five countries.

3. Coordination Failure

This group of models focuses on how disruptions to the financial system can originate as a consequence of the financial system's structure. This disruption occurs when a run on the banking system is initiated by depositors. Diamond and Dybvig (1983), henceforth referred to as DD in this paper, demonstrate that the characteristics of demand deposit contracts, combined with the maturity mismatch (in which a bank's potential repayment obligations exceed the value of its liquid assets) in banks' portfolios, create payoff externalities that are at the heart of the banking system's fragility. An important question arises as to why contracts between banks and savers take the form of demand deposit contracts. An explanation of why the banking sector is vulnerable to runs must clarify why demand deposit contracts are used.

DD motivate deposit contracts as a decentralized way of implementing first-best risk-sharing among agents in an economy. Banks thus provide insurance to consumers against liquidity shocks by offering consumers demand deposit contracts. Jacklin (1987) shows that, under the assumptions of the DD model, banks can also implement first-best risk-sharing by issuing equity instead of demand deposits, and thus avoid runs. However, under more general specifications of preferences than that used in DD, there are conditions under which first-best risk-sharing can be implemented through deposit contracts but not equity contracts. Hence, Jacklin (1987) demonstrates that demand deposits that cannot be traded provide greater risk-sharing than do equity shares that are freely traded. Other motivations for deposit contracts focus on their disciplining role, which enhances the banks' ability to perform their roles as intermediaries.[2]

Models of bank runs can be classified as random crises models where financial crises arise purely as a result of coordination failure unrelated to fundamentals, and fundamentals-based crises models, in which financial crises are triggered by weak fundamentals. The crucial ingredients in these models are payoff externalities among depositors, so that the payoff to any individual depends on the actions of other depositors. Fundamentals-based instability requires, in addition to payoff externalities, some sort of information spillovers resulting from (noisy) interim private information in the face of uncertainty about asset returns.

3.1 Multiplicity of equilibria

In a typical model of bank runs, banks exist to insure private agents against uncertain liquidity requirements. Liquidity preference is ex ante stochastic and, when realized, is private information. This information asymmetry leads to the failure of markets to provide insurance against liquidity risk. Banks that offer deposit contracts arise as a response to the missing market for risk-sharing.

The basic model is provided by DD. There are three dates in the model: dates 0 (planning period), 1 (interim period), and 2 (final period). Ex ante identical agents have uncertain liquidity needs at the planning stage when investments are made. Agents can invest in a liquid storage technology or in a productive but illiquid investment project that yields higher returns. After choosing their portfolio, agents discover at date 1 whether they are impatient and have to consume immediately, or patient and can wait until the next period to consume. In an autarkic equilibrium, agents invest a portion of their endowment in the productive asset initially, but after the realization of the preference shock, impatient investors liquidate their investment at a loss, while patient investors wait for the project to reach full term. Patient consumers are thus able to consume more than impatient consumers. At the planning stage, each agent would prefer a consumption plan that trades some date 2 consumption for date 1 consumption. That is, agents would like to insure themselves against the bad luck of being an impatient consumer.

A bank, by offering demand deposit contracts, can support optimal risk-sharing. However, since deposit contracts promise payment on demand while funds are invested in long-term assets, there is a maturity mismatch in the bank's portfolio. If more depositors than expected withdraw in the short

[2] See, for example, Calomiris and Kahn (1991), Qi (1998), and Diamond and Rajan (2000).

term, the bank does not have sufficient short-term assets to pay off all withdrawing depositors, and must liquidate its long-term assets at a loss. The liquidation of long-term assets reduces the amount available to depositors who withdraw later, raising the incentives to withdraw early. Therein lies the payoff externality. In other words, the deposit contract leads to strategic complementarity in the actions of patient depositors, where the return to a depositor's action increases with the number of other depositors undertaking the same action. The Nash game between patient depositors, who decide whether to withdraw at date 1 or date 2, has multiple equilibria: a "good" one where optimal risk-sharing is achieved, and a "bad" one that entails a run on the bank. Banking instability is captured by the existence of the "bad" equilibrium, in which a run on banks destroys risk-sharing and interrupts production.

Bank runs are rational but based on self-fulfilling expectations. Although depositors are collectively better off if they all do not run on the bank, individual depositors are better off running, given their expectations. This implies that depositors who try to leave a failing bank last are hurt the most, creating an incentive for depositors to leave early. The same can be said for lenders who invest in other countries when payoff externalities exist. This means that crises can happen quickly and dramatically as everyone rushes for the exit.

To formalize the above argument, consider the following characterization of the model. There is a continuum, of measure 1, of (ex ante identical) individuals, each endowed with one unit of the consumption good at date 0 and nothing in the following periods. At date 1, individuals learn whether they are patient or impatient. Impatient consumers have preferences described by $u(c_1)$, while patient consumers have preferences described by $u(c_2)$, where c_1 is consumption at date 1 and c_2 is consumption at date 2. The fraction of impatient consumers in the population is given by t, which we will assume for the time being to be known at date 0. The utility function $u(c)$ is assumed to exhibit relative risk-aversion greater than one.

Productive technology exhibits illiquidity in the sense that investment is unproductive in the short run but productive in the long run. For each unit of good invested, the productive technology yields R (greater than 1) units after two periods and r (which is less than or equal to 1) units after one period.[3] The technology described ensures that individuals will invest some portion (all if $r = 1$) of their endowments in the productive technology in autarky and liquidate their investment if they turn out to be impatient. Using subscripts to denote the period during which consumption occurs and superscripts to denote an autarkic equilibrium, autarky involves the consumption plan $c_1^a = 1, c_2^a = R$. The first-best (full-information) allocation, however, is (c_1^*, c_2^*) such that $u'(c_1^*) = Ru'(c_2^*)$ and $tc_1^* + \frac{1-t}{R}c_2^* = 1$. A relative risk-aversion greater than one and $R > 1$ implies that $1 < c_1^* < c_2^* < R$.

In a decentralized solution, a bank can achieve first-best risk-sharing by offering agents demand deposit contracts such that depositors can obtain c_1^* by withdrawing at date 1 or an equal share of

[3] DD assume that $r = 1$, but, in papers that are to be discussed, some authors assume that $r < 1$, with no substantial change in the results. Letting $r < 1$ allows the possibility of runs even when preferences are such that relative risk-aversion is less than 1.

the bank's date 2 profits at date 2. When all patient depositors withdraw at date 2, each obtains c_2^*. This is more than they can obtain by withdrawing early. Hence, incentive compatibility is satisfied and patient depositors will prefer to withdraw at date 2 rather than at date 1. However, such an equilibrium is predicated on a patient depositor who chooses to wait, believing that all other patient depositors are behaving in the same way. Suppose that this is not true and a patient depositor expects z other patient depositors to withdraw at date 1; then, assuming that the bank remains solvent, waiting until date 2 to withdraw yields a payoff $\frac{1-(t+z)c_1^*}{1-t-z}R$. This payoff is decreasing in z, indicating strategic complementarity. There is a value, $\bar{z} < 1-t$, such that the incentive compatibility constraint of patient depositors is violated whenever $z > \bar{z}$, and all patient depositors will withdraw at date 1. Any z that lies strictly between 0 and $1-t$ cannot be a Nash equilibrium. For $z \in (0, \overline{z}]$, patient depositors are better off waiting till the next period to withdraw and hence none will withdraw in the interim period. This equilibrium corresponds with $z = 0$ and is the one that implements first-best allocation. For $z \in (\overline{z}, 1-t)$, patient depositors are better off withdrawing immediately; hence, all of them will choose to withdraw and an equilibrium is obtained when all patient depositors withdraw immediately ($z = 1-t$). This is thus another Nash equilibrium, where a run on the bank occurs at date 1. In this equilibrium, all patient depositors choose to withdraw early.

Because of the sequential service constraint, the bank will pay out c_1^* to all depositors who withdraw early as long as it remains solvent.[4] However, since $c_1^1 * > 1$, not all depositors can be paid if all depositors withdraw at date 1. Hence, when a run on the bank occurs, the bank becomes insolvent and fails. The bank run equilibrium is the result of a coordination failure, since depositors would have been better off if no run had occurred; they would have avoided the bank-run equilibrium if they had been able to coordinate their actions.

3.2 Expectations formation and equilibrium selection

The following models impose more structure to endogenize the formation of expectations and equilibrium selection in coordination failure models of bank runs. These models address the criticism of multiple equilibria models regarding the unexplained formation of expectations that lead to one or another equilibrium. Morris and Shin (1998, 2000), Goldstein and Pauzner (2000), and Chari and Jagannathan (1988) introduce small amounts of uncertainty into a DD framework to coordinate actions. Morris and Shin (1998, 2000) and Goldstein and Pauzner (2000) introduce uncertainty about asset payoffs and noisy interim information. Interim information that is imperfectly correlated with fundamentals serves as a coordination device that leads to the selection of either the "good" equilibrium or the "bad" equilibrium. Chari and Jagannathan (1988) introduce information spillovers. A portion of depositors are informed and will withdraw upon observing poor fundamentals. Uninformed depositors try to infer asset return by the number of withdrawals observed. They face a

[4] The sequential service constraint specifies that a bank has to pay out sequentially, in full, to depositors in line to withdraw as long as the bank has the funds to do so.

signal extraction problem because aggregate liquidity risk causes the signal to be noisy. In these models, the unique equilibrium includes a panic bank run with positive probability. Although runs on banks can still be panics (based on self-fulfilling expectations) that are not necessarily justified by economic fundamentals, the occurrence of panics is correlated with economic fundamentals. The poorer the economic fundamentals, the more likely the runs.

3.2.1 Removing common knowledge

Morris and Shin (2000) argue that the indeterminacy in multiple equilibria models is a consequence of two simplifying modelling assumptions: (i) economic fundamentals are common knowledge, and hence (ii) agents are certain about other agents' behaviour in equilibrium. Taking the deposit contract as given, Morris and Shin (2000) demonstrate that allowing agents to have a small amount of idiosyncratic uncertainty about economic fundamentals pinpoints a unique equilibrium where bank runs occur with positive probability. In particular, bank runs are more likely the weaker the economic fundamentals. Hence, it is possible for shifts in beliefs to be correlated with shifts in fundamentals. Goldstein and Pauzner (2000) go further to consider that the deposit contract that allows runs (one where potential short-term obligations exceed the value of bank assets in the short term) may no longer be optimal with the introduction of noise. They examine the optimal deposit contract when bank runs can occur in equilibrium, and characterize the conditions under which the optimal deposit contract allows bank runs.

Consider the following description by Goldstein and Pauzner (2000) to see how noise can eliminate indeterminacy. The economy is a modified DD economy with stochastic returns to the long-term asset. The return to the risky, long-term asset is $R(\theta)$. R is increasing in θ, which represents the state of the economy, a random variable distributed on the interval $[0, 1]$ and realized at date 1. Assume that $R(\theta) > 1$ for all θ. In addition, the risky asset can be liquidated at date 1 to yield one unit for each unit of investment liquidated. This ensures that the risky technology dominates the storage technology, as in the DD economy. Since $E_\theta[R(\theta)] > 1$, all the endowment is initially invested in the risky asset and an amount equal to date 1 consumption is liquidated at date 1. The optimal allocation, (c_1^*, c_2^*), involves date 1 consumption that is greater than one and that can be implemented by banks offering demand deposit contracts ($r_1 = c_1^*,\ r_2 = c_2^*$) when no bank runs occur.

Suppose that each agent receives a perfect signal, $x = \theta$ at date 1. For a given deposit contract, (r_1, r_2), satisfying $1 < r_1 \leq \frac{1}{t}$ (which is the condition necessary for bank runs to occur), the following partitioning of fundamentals can be defined. There exists a value of θ, denoted by $\underline{\theta}$, such that the incentive compatibility constraint of patient depositors is violated even if no patient depositor withdraws early.[5] Clearly, if the signal received is less than $\underline{\theta}$, each patient depositor will choose to withdraw. Goldstein and Pauzner assume that the interval $[0, \underline{\theta}]$ is non-empty and call

[5] That is, $R(\underline{\theta})(1 - tr_1)/(1 - t) = r_1$. The left-hand side of the expression is the return to date 2 withdrawal, conditional on all patient depositors waiting until date 2 to withdraw.

this the "lower dominance region." As well, they assume that there exists a value of θ, denoted by $\bar{\theta}$, such that no patient depositor will withdraw early if the realization of θ is not smaller than $\bar{\theta}$. They assume that the interval $[\bar{\theta}, 1]$ is non-empty and call it the "upper dominance region." Hence, for fundamentals that fall in the lower or upper dominance region, the actions of patient depositors are uniquely determined. For realizations of θ in the intermediate region, $[\underline{\theta}, \bar{\theta}]$, however, a coordination problem exists and there are two possible Nash equilibria: a no-run and a bank-run equilibria.

Suppose that each agent i receives a private and noisy signal, $x_i = \theta + \epsilon_i$, at date 1, where ϵ_i are small error terms that are independently and uniformly distributed over the interval $[-\epsilon, \epsilon]$. The signal does two things: (i) it provides information about the true state of the economy, and (ii) it provides information about other agents' signals, which allows an agent to make inferences about those other agents' actions. That is, on observing a high signal, an agent knows it is likely that other agents have received a high signal as well, since signals are clustered around the true state of the world.

For θ in the intermediate region, the noisy signal now serves to coordinate patient depositors' actions. For any $r_1 \geq 1$, there is a unique threshold signal, $\theta^*(r_1)$, such that each patient depositor who receives a signal above $\theta^*(r_1)$ will not run on the bank, while each agent who receives a signal below $\theta^*(r_1)$ will run on the bank. A unique trigger-strategy equilibrium to the game results where, given that $r_1 > 1$, there is a positive probability of bank runs. For a realization of fundamentals, θ, that is greater than $\theta^*(r_1) + \epsilon$, there is no possibility of a bank run, and for θ less than $\theta^*(r_1) - \epsilon$, there is a total bank run with probability one. For realizations in the range $(\theta^*(r_1) - \epsilon, \theta^*(r_1) + \epsilon)$, partial runs on the bank occur and the extent of the run is higher the poorer the fundamentals. Although the realization of θ uniquely determines whether patient agents will run on the bank, and the extent of the run, most bank run episodes (that occur in the intermediate region) are still driven by self-fulfilling expectations. That is, running on the bank is rational only if one expects others to do so. Hence, noisy signals about fundamentals serve as a coordination device for the expectations of patient depositors, but they do not eliminate coordination failure.

3.2.2 Herding

In Chari and Jagannathan (1988), some agents receive information on the payoffs to the risky long-term asset, while the uninformed agents coordinate on the number of early withdrawals observed. This is a model of information spillovers that, together with payoff externalities, can lead to a panic bank run. As in DD, depositors receive preference shocks and impatient depositors withdraw early. The proportion of impatient depositors, however, is uncertain and hence there is aggregate liquidity risk in the economy.

Banks offer deposit contracts that promise depositors, who deposit 1 unit of endowment at date 0, a return 1 at date 1 or an equal share of bank profits at date 2. Each impatient depositor withdraws at date 1. Patient depositors have the option of withdrawing some or all of their deposits at date 1. Suppose that a patient depositor leaves the amount $k \in [0, 1]$ in the bank (withdraw $1-k$); this amount, k, is reinvested and yields $\tilde{R}k$. $\tilde{R}$ is a random variable, which takes on a high value, $H > 1$, with probability p, and 0 with probability $1-p$. There is an externality in consumption so that the amount available for consumption at date 1 depends on the aggregate level of consumption desired at that date, or,

$$c_1 = \begin{cases} 1-k & \text{if } K \leq \overline{K} \\ (1-a)(1-k) & \text{if } K > \overline{K}, \end{cases}$$

where K is aggregate reinvestment at date 1.

As in DD, consumers do not know whether they are patient or impatient until date 1. However, a random fraction, $\tilde{t}$, are impatient. At date 1, the realization of $\tilde{t}$ can take on one of three values: $t \in \{0, t_1, t_2\}$, with probabilities r_0, r_1, and r_2, respectively. In addition, a random fraction, $\tilde{\alpha}$, of patient depositors receive perfect information about prospective date 2 returns. $\tilde{\alpha}$ is realized at date 1 and can take on one of two values, $\alpha \in \{0, \overline{\alpha}\}$, with probability $1-q$ and q. These informed depositors decide how much to leave in the bank based on their information, $k^I(R)$. They will withdraw completely upon observing poor fundamentals. That is, $k^I(0) = 0$. Uninformed depositors observe the aggregate reinvestment level and recognize that the aggregate level of date 1 investment contains information about the informed depositors' signal. They attempt to extract that information, and so condition their withdrawals on aggregate investment, $k(K)$. Chari and Jagannathan restrict parameters to ensure that uninformed individuals have a non-trivial signal-extraction problem. Thus, when uninformed depositors observe a low level of aggregate investment, they cannot tell whether it is because the proportion of impatient depositors was high, $t = t_2$, or whether informed depositors had received bad news, $R = 0$. Aggregate investment at date 1 is given by

$$K = \alpha(1-t)k^I(R) + (1-\alpha)(1-t)k(K).$$

Obviously, we can interpret the situation as one where uninformed individuals observe the lineup at the bank but are unable to tell whether depositors in the lineup are impatient depositors or informed depositors who have received bad news.

Chari and Jagannathan show that there are conditions, determined by model parameters and the characteristics of the deposit contract offered by banks, under which a panic equilibrium exists where all depositors withdraw ($K = 0$) upon observing a high level of withdrawals even if no informed agents have received bad news about asset returns. Hence, bank runs can occur not only when fundamentals are poor, but also when liquidity needs are high.

Chari and Jagannathan provide an example of a herding model applied to bank runs. Herding models are based on the assumption that agents observe private but noisy signals and take their actions based on those private signals and publicly observable actions of agents that preceded them.

In a typical model, agents have to make similar decisions in sequence.[6] Agents face a discrete action space in which the number of actions they can take is limited. Information is private and imperfect, but actions can be publicly observed, leading to "social learning," in which agents who have not taken action try to infer other agents' information from their actions. Herding almost always results, with agents eventually disregarding their private information and relying only on public information. Furthermore, it is possible that agents "herd" on a wrong choice. An information cascade occurs when no new information is revealed by the actions of agents. In many herding models, the information structure is such that an information cascade occurs when agents herd. One group of models features discrete signals that lead to robust cascades; that is, once a cascade occurs with agents herding on a particular action, that cascade persists. Continuity of signals can lead to fragility of cascades: a contrary action or small amounts of new information can reverse an existing cascade. These models demonstrate that herding behaviour can be rational. Moreover, the equilibrium action obtained is highly sensitive to the sequence of signals received, resulting in idiosyncratic behaviour, in the sense that random events determine the type of behaviour on which individuals herd.

3.3 Bank fragility as a commitment device

Diamond and Rajan (2000, 2001a) develop a theory of banking based on non-commitment and liquidity creation that provides a useful role for the coordination failure that arises from deposit contracts. Their papers suggest that while deposit contracts can cause problems for the banking system in some states of the world, they exist to overcome another problem, that of limited commitment. An asset is said to be *illiquid* when the holder of that asset is unable to issue claims on the asset to its full value. That is, it is impossible to pledge the full value of the asset to lenders. In Diamond and Rajan's framework, assets are illiquid because of limited commitment in the presence of specific skills that cannot be packaged with the asset. Consider a world where a number of entrepreneurs each have a project in need of funding. Individual entrepreneurs have specific abilities vis-a-vis their projects, so that the cash flows each can generate exceed what anyone else can generate from it. Entrepreneur cannot commit their human capital to their projects, except on a spot basis. A lender can extract future repayment only by threatening to take away the project and selling it to the next-best user. But because the entrepreneurs can threaten to withhold their human capital in the future, the lender can extract only a fraction of the cash flows generated by each project. Thus, projects are illiquid in the sense that they cannot be financed to the full extent of the cash flows they generate.

An investor who lends at the onset of the project learns about the project and how best to redeploy the project's assets, effectively becoming a "relationship lender." Suppose that only the relationship lender knows the next-best use of the project's assets; the relationship lender has

[6] Although most models feature exogenous timing of actions, Chamley and Gale (1994) and Chari and Kehoe (1998) show that herding is robust to the endogenous timing of actions.

specific skills to lend to the entrepreneur. However, the relationship lender may not be able to raise much money against the asset (the loan) held, since that lender is unable to commit to repaying to outside lenders the full amount that can be extracted from the entrepreneur. Thus, the loan is also an illiquid asset. Diamond and Rajan (2000) show that the relationship lender can use a commitment device to commit to repayment up to the full value of the loan. An example of this device is a bank that funds itself with demandable deposits subject to a sequential service constraint. The relationship lender, now a bank, effectively commits to using its specific collection skills on the depositors' behalf, since any attempt to renegotiate deposit repayments will cause a run. The sequential service constraint creates a collective-action problem among depositors: rather than make concessions (which may be in their collective interest), individual depositors find it rational to run immediately to recover full repayment of their deposit. In this way, the bank can commit to pass on the full proceeds of investment to depositors, essentially creating liquidity. The bank's ability to carry out its function of liquidity creation is therefore inseparable from its potential fragility. In a world with no uncertainty, a bank maximizes the amount of credit it can offer to entrepreneurs by financing with only demand deposits.

Diamond and Rajan (2001a) present the cost of financing with demand deposits by considering a world of uncertainty. Without uncertainty, the possibility of runs exerts market discipline on the bank, but runs are never observed in equilibrium.[7] With uncertainty in project returns that is observable but not verifiable, however, a capital structure composed solely (or mainly) of demand deposits is vulnerable to runs when realized project cash flows are too low. The banker has to trade off liquidity creation against the cost of bank runs. It may be optimal for the bank to partially finance itself with a softer claim that can be renegotiated in the future. This claim is "capital." Capital holders are not subject to a collective-action problem and thus cannot commit to not renegotiate. This allows the bank to capture some rents in the future, reducing its ability to raise funds (create liquidity) in the present. The optimal bank structure is obtained by trading off the costs against the benefits of capital. This model explains why bank capital is costly in terms of reducing the bank's ability to create liquidity and enhance the flow of credit.

Diamond and Rajan (2001b) return to a certain world in which competition among banks is introduced with (identical) banks facing a capital requirement, k (either exogenously imposed or endogenously determined as a result of unmodelled uncertainty). The economy has three dates (0, 1, and 2) and there is a large number of entrepreneurs, each with a project that requires an investment of one unit of consumption good at date 0. Projects can either be early (with probability α) or late, producing C at date 1 or 2, respectively. All uncertainty about projects is resolved at date 1. Prior to paying off, projects can be restructured to yield c_1 at date 1 and c_2 at date 2 with certainty, or they can be disrupted, with assets being redeployed to their next-best use to yield γC at date 1 for an early project or date 2 for a late project. It is assumed that $c_1 + c_2 < 1 < \gamma C < C$. Financiers coming in later get nothing from restructuring or disrupting the project. With capital

[7] There are no payoff externalities among depositors as in DD, and hence no equilibrium with a bank run.

requirement, k, a bank can pledge to outsiders only a fraction, $\frac{1}{1+k}$, of the total value of the bank (which means that the bank extracts a rent equal to $\frac{k}{1+k}$ of the total value). There are a large number of investors at date 0, each endowed with less than one unit of consumption good at date 1. Date 0 investors value date 1 consumption only. In addition, total endowment at date 0 is less than the total number of projects, so the economy is short of investment capital at date 0. Fresh investors are born at date 1, however, so there is no capital shortage at that date.

Owing to the capital shortage at date 0, the amount of funds each bank can raise at date 0 is normalized without loss of generality to be 1, and banks extract all the rent from entrepreneurs that can be pledged, contracting with entrepreneurs for a repayment, $P_1 = \gamma C$, at date 1. Assuming that banks are able to diversify, each bank has a fraction, α, of bank loans that turns out to be early projects. Hence, at date 1, a fraction, α, of bank loans are paid off and a fraction, $1 - \alpha$, of loans are in default and have to be renegotiated. A late project can either be restructured and sold for $c_1 + c_2$ at date 1, or continued by rescheduling payment to the next date to yield γC at date 2. The banker is able to extract rent of the amount $\frac{k}{1+k}\gamma C$ from continued projects and hence would prefer to reschedule debt payment. However, when $\frac{\gamma C}{1+k} < c_1+c_2 < \gamma C$, there is a conflict of interest between the banker and the bank's investors. Investors prefer that late projects be restructured. Hence, the banker chooses the minimum fraction, μ, of late projects to be restructured subject to the requirement of paying off investors at date 1. The optimal fraction of projects to be restructured is a function of the capital requirement: $\mu(k)$. In particular, it is decreasing in k. At the same time, the amount that a bank can pledge to outsiders is $\frac{(1-\mu(k))(1-\alpha)\gamma C}{1+k}$ at date 1 and $\frac{V(\mu(k))}{1+k}$ at date 0, where $V(\mu) = \alpha\gamma C + (1-\alpha)\mu(c_1 + c_2) + (1-\alpha)(1-\mu)\frac{\gamma C}{1+k}$. Both the amounts the bank can pledge to outsiders at date 0 and date 1 are decreasing in the capital requirement, k. Hence, although bank capital acts as a buffer against adverse shocks, it is costly in the sense that it limits the amount of external funds the bank can raise at dates 0 and 1.

Diamond and Rajan consider the consequences of an unexpected adverse shock to the timing of project cash flows. Suppose that α falls to α^L at the end of date 0 and before date 1. While this does not change the present value of projects, the maturity of projects has lengthened. This could be the result of a *temporary* economic downturn or terms-of-trade shock. This adverse shock increases the number of late projects that have to be restructured at date 1, and if α^L is low enough it will precipitate a bank run upon the realization of the shock. In this event, *all* projects, including early projects, are restructured, leading to a net loss of value to the economy.

3.4 Discussion and policy implications: coordination failure

Theories of bank runs resulting from coordination failure describe the effects of a loss of confidence by investors resulting from a shift in expectations. Banks that are solvent in the long run can be pushed into failure when too many consumers withdraw their deposits in the short run, as excess withdrawals, or runs, create liquidity problems in the banking sector. In the DD model, these shifts in expectations are unexplainable and the factors causing the shifts have been labeled sunspots. Other theories try to explicitly model the changes in expectations and they point to changes in information as the trigger for the shift in expectations that may lead to bank runs. These are partial equilibrium models that abstract from the real part of the economy by modelling these as exogenous projects, or loans, that banks undertake on behalf of depositors. Bank contracts are restricted to demand deposit contracts. However, demand deposit contracts are not necessarily the only contracts that can implement the optimal risk-sharing desired by consumers. Given that demand deposit contracts involve the potential cost of bank runs, they may not be the optimal contracts, either. With the exception of Diamond and Rajan (2000, 2001a, and 2001b), this literature has not explicitly provided a rationale for the use of demand deposit contracts, but it notes that those contracts are observed in reality and are optimal in the context of other models.

Financial crises are the result of a coordination failure in which a Pareto-inferior equilibrium is chosen. Central authorities should intervene if they can eliminate the coordination failure when private arrangements cannot. For example, deposit insurance can help to coordinate patient consumers' actions to obtain the good equilibrium where only impatient consumers withdraw early. Allowing banks to suspend convertibility of deposits (to cash) when a threshold level of early withdrawals is reached can also eliminate the coordination failure. Suppose that the bank suspends convertibility when a level, t, of early withdrawals is reached. This ensures that there is always an amount, $(1 - tc_1^*)R$, of resources to be shared among depositors who withdraw in the next period. Under a suspension, a patient depositor can always obtain more by waiting (and getting at least c_2^*) than by withdrawing early. Hence, the incentive of patient consumers to withdraw early is removed and coordination failure is eliminated. A deposit insurance scheme achieves the same thing by ensuring that the patient depositor will always receive c_2^* by withdrawing in period 2. A suspension of convertibility or a deposit insurance scheme ensures that the first-best allocation is always obtained but is never exercised in equilibrium, and is therefore costless, when there is no aggregate uncertainty.

DD consider the case of aggregate uncertainty in the fraction of the population that is impatient. That is, the fraction of impatient consumers, t, is stochastic at date 0 and realized only at date 1. In that case, demand deposit contracts cannot achieve (full information) optimal risk-sharing, because optimal risk-sharing in this economy involves consumption levels that are contingent on the realization of t, but deposit contracts and investment decisions are taken prior to the realization of t and hence cannot be made contingent on t. Even a bank contract with suspension of convertibility will not be able to achieve optimal risk-sharing, although suspension will generally improve on uninsured contracts by preventing runs. However, demand deposit contracts with government deposit insurance financed by an "optimal tax" can implement first-best risk-sharing. The deposit insurance has to be financed by a tax on all wealth held at date 1, which depends on the number of withdrawals during that period. First, by ensuring that date 2 withdrawals always dominate date 1 withdrawals for patient consumers, the insurance scheme eliminates runs. Second, by conditioning the amount of tax collected on the number of withdrawals (which is equal to the realization of t, since no runs occur), after-tax payoffs can be made contingent on the realization of t. Thus, by choosing the correct level of taxes, optimal risk-sharing can be achieved. In summary, the possibility of coordination failure by itself does not justify government intervention, since private arrangements (such as bank contracts with suspension) can eliminate the coordination failure. This is not the case when there is aggregate uncertainty in the economy. Although suspensions can improve welfare, they cannot achieve first-best in a world with aggregate uncertainty. On the other hand, government deposit insurance financed by an appropriately designed tax scheme can.

By extending the basic DD model to a small open economy with foreign capital inflow, Chang and Velasco (1999a, b) show that short-term foreign debt without automatic rollover can create an additional source of coordination failure, one among foreign lenders. It does not mean that capital inflow per se is bad for the economy. Capital inflow augments an economy's resources and allows the economy to achieve higher levels of welfare, but its short-term nature can be harmful when foreign lenders cannot coordinate on the Pareto-superior equilibrium. Eliminating coordination failure among domestic depositors still leaves the possibility of a coordination failure among foreign lenders. The open-economy equivalent to a suspension of convertibility by the bank is a standstill. Models of international liquidity crises resulting from coordination failures justify standstills as a means of eliminating coordination failure among foreign lenders. As with the closed-economy case, standstills can be costly when there is aggregate uncertainty.

Greater transparency of information is an important part of efforts to improve financial structure. Equilibrium selection models, such as those provided by Morris and Shin (2000), and Goldstein and Pauzner (2000), provide a framework for discussing changes in the structure of information. Information plays a subtle role in these models. The replacement of common knowledge with noisy observable signals creates an apparent coordination among depositors that leads to a unique equilibrium. The information structure can be changed in two distinct ways. The first involves the removal of asymmetric information to restore common knowledge. This brings us back to the world of DD where coordination failures and financial crises can arise for a larger range of fundamentals. The second aspect of improving information transparency involves increasing the precision of private information but not eliminating noise completely. This decreases the range of fundamentals for which self-fulfilling runs can occur.

Taxing early withdrawals (or levying an exit tax in an open economy subject to self-fulfilling runs by foreign investors) is another way to reduce the likelihood of self-fulfilling runs. An early-withdrawal penalty effectively reduces the payoff to early withdrawal relative to waiting. This measure is costly because it penalizes consumers who need to consume early and it restricts the ability of the bank to offer optimal risk-sharing deposit contracts.

The self-fulfilling nature of runs implies that they are sometimes not justified by economic fundamentals. This creates a role for a lender of last resort to bail out illiquid banks. Intervention can always improve welfare if authorities have better information about bank fundamentals. But when authorities are no better than the public at distinguishing a fundamentally sound bank facing liquidity problems from one that is unsound, lender-of-last-resort activities can be justified only if the expected benefit of preventing the failure of sound but illiquid banks outweighs the expected cost of bailing out unsound and illiquid banks.

Diamond and Rajan (2000, 2001a, 2001b) provide a useful role for the coordination failure characteristic of bank deposit contracts. In this framework, eliminating coordination failure has a cost in terms of inhibiting the ability of banks to raise financing in the first place. Banks choose an optimal financing structure that entails some fragility to create liquidity and enhance the flow of credit in the economy. Under certainty, this fragility does not result in financial crises, since runs never happen. But things can unravel in the face of a bad shock as the fragility of the banking system leads to a financial crisis. One can categorize policy responses in terms of ex ante and ex post measures. Ex ante stabilization measures, such as higher capital requirements, deposit insurance, and bank contracts with suspension of convertibility, remove the commitment value of deposits and limit the ability of the bank to raise funds in the first place. Hence, these measures prevent crises by preventing banking itself! From this viewpoint, it is not necessarily welfare-improving to avoid crises altogether. It may be preferable to allow crises to happen and manage them to minimize their costs. This is in direct contrast to the previously described models of coordination failure. In those models, coordination failure is an undesirable by-product of demand deposit contracts and authorities can always improve social welfare by removing the possibility of coordination failure.

There is no shortage of potential investors at date 1 and hence no aggregate shortage of liquidity in this model. The bank cannot raise enough to pay off existing deposits, since it cannot commit to give outside investors sufficient future returns. Hence, unsubsidized lending to the bank will not prevent a crisis. To prevent runs, banks must be provided with subsidized loans after a shock. Subsidized recapitalization and ex post suspension of convertibility have the same effect as a subsidized loan. These measures differ only in terms of which group in the economy bears the cost. With subsidized loans and recapitalization, taxpayers bear the cost of the subsidy, while with an ex post suspension, existing depositors are the source of the subsidy. The model also shows that only banks with relationship loans should be considered for a bailout. Furthermore, in a dynamic framework, these bailouts are costly, in that they remove the commitment value of deposits and limit the financing that banks can raise in the future. Ultimately, the justification for an ex post bailout, whoever pays for it, must be that the short-run benefit to the economy exceeds the long-run loss of commitment value.

4. Inefficient Liquidity Provision

Banks in need of short-term liquidity can liquidate their long-term assets or borrow from other banks with excess liquidity. If markets for liquidity are efficient, then a solvent bank that faces short-term liquidity problems will be able to obtain liquidity to tide over its problems. However, markets for liquidity may be inefficient, owing to market power or informational asymmetries. This section reviews models in which liquidity provision by asset markets and the interbank market are explicitly modelled.

In the models of bank fragility previously discussed, the deposit contract that implements optimal risk-sharing has the unfortunate consequence of exposing banks to destabilizing runs. Banks are exposed to this risk because they have to operate with a balance sheet in which the liquidation value of their assets is less than the potential value of their liabilities, to provide liquidity services. Most of these models assume an exogenous cost to liquidating the long-term asset holdings of banks. This cost is specified by a technology for liquidating the long-term asset. After the planning stage, bank liquidity is determined solely by whether a bank run occurs.[8] Critics point out that it is relevant to consider other sources of liquidity available to a bank that experiences a run. Alternatives to disrupting the long-term project and selling off the assets for some predetermined "scrap" value are markets in which banks can issue claims on their long-term assets, or interbank markets that allow banks to borrow from each other ex post or hold prior claims on each other that can be drawn on when liquidity is required.

Introducing market sources of liquidity endogenizes the cost of liquidity for banks that need it. A relevant question is whether markets provide enough liquidity. The answer has important implications for the lender-of-last-resort function of central banks. If the markets are efficient at channelling liquidity from those banks with excess liquidity to those in need of it, a fundamentally sound bank that faces short-term liquidity problems (for example, excessive withdrawals) will be able to obtain funds to tide over its liquidity problems. However, if markets for liquidity are inefficient, even sound banks can see a liquidity problem turn into a solvency problem. There may be a need for open-market operations in the face of aggregate liquidity problems, but emergency liquidity assistance targeted at individual banks is justified only if markets are believed to be inefficient at distributing liquidity in the banking system.

4.1 Endogenous asset values

The papers discussed in this section address the criticism that many models of bank runs based on the DD framework take the liquidation cost of long-term assets to be exogenous. Donaldson (1992) develops a model where a bank that requires cash beyond its holdings of liquid reserves can issue securities, or claims, on its illiquid assets. Agents that provide liquidity by holding large reserves of illiquid assets are called reserve agents. The prices of securities issued by banks are determined by the competition among reserve agents. When the demand for liquidity is low or if no reserve agent has market power, securities trade at a "fair" price that is determined by its fundamentals. However, if the demand for liquidity is high or the *distribution* of cash among reserve agents is such that some agents possess market power, securities trade at an average price below that of their fair

[8] Liquidity here pertains to the ability of financial institutions to meet their short-term need for cash.

value.

In this economy, banks invest all of their deposits in illiquid assets that yield a bank-specific return, R_j, for bank j. Suppose that bank j has deposits of dollar amount α_j and promises a return on deposits, R^D (common across banks). The dollar amount of securities that bank j can issue is $\alpha_j R_j$. Let δ be the average price of a bank security of face value of one dollar. When the market for bank securities is competitive, δ is equal to one. However, the market power of each reserve agent, i, is determined by (i) the total need for cash by banks, (ii) the level of liquid reserves held by agent i, C_i, and (iii) the upper bound on the rate of exchange between securities and cash determined by foreign lenders' (exogenous) reservation price.

Consider a technology shock to some banks that causes their rate of return on illiquid assets to fall below the rate of return promised to depositors. That is, some banks become fundamentally insolvent, $R_j < R^D$ for some j. Depositors will start a run on those banks because of the sequential service constraint on deposit contracts. The banks will issue securities to meet their cash needs. This can lead to a high enough demand for liquidity that the captive power of reserve agents increases and the average price (δ) of securities falls. This makes liquidity more costly for all banks. If the average security price falls enough that some banks that are fundamentally solvent ($R_s > R^D$) become "liquidation insolvent" ($\delta R_s < R^D$), those banks will be run on as well. Hence, contagion can arise.

In this model, the amount of liquidity in the market is exogenous but it can be costly precisely when the need for it is high. The model shows how a productivity shock that causes a few banks to become insolvent can make liquidity so costly that it creates liquidity problems even for solvent banks.

Allen and Gale (1998), in addition to endogenizing the value of banks' illiquid assets, endogenize the amount of liquidity available in markets for bank assets. They show that such an asset market inevitably underprovides liquidity, because it is costly to hold liquid reserves. In their paper, they consider the view that bank runs are necessary to achieve optimal risk-sharing. In their model, bank runs are not undesirable in that they support optimal risk-sharing in an economy where the return to the long-term asset is stochastic and the realization of the technology shock becomes public information only in the interim period after investment has been made. Their model is similar to the DD economy, except for the following differences. As with DD, there is a storage technology, but the illiquid technology yields a stochastic return, $R \geq 0$, at date 2. In addition, the long-term asset cannot be liquidated. This assumption of complete illiquidity of the long-term asset rules out self-fulfilling bank runs; that is, runs based on coordination failure. The uncertainty about R is resolved at date 1 and everyone observes a perfect signal about project returns.

First-best risk-sharing results in a consumption plan such that consumption levels in *both* periods are contingent on the realization of R. In particular, $c_1^* = \min\{L + RK, \frac{L}{t}\}$ and $c_2^* = \max\{L+RK, \frac{RK}{1-t}\}$, where the optimal portfolio (L, K), with L denoting liquid asset holdings and K investment in the risky illiquid asset, is determined by resource constraints, $tc_1^*+(1-t)c_2^* = L+RK$

and $L+K=1$. When the return to the illiquid asset is low, $R \leq \frac{(1-t)L}{tK}$, date 1 and date 2 consumption are equal, while for high returns, date 2 consumption is greater than date 1 consumption.

Consider the implementation of the optimal allocation by banks. Allen and Gale (1998) drop the sequential service constraint and assume that banks can write deposit contracts contingent on the number of withdrawals in each period. Hence, the deposit contract promises to pay $\bar{c}$ at date 1 if there are not more than t withdrawals, and $\frac{L}{n}$ where n is the number of date 1 withdrawals if $n > t$. Depositors who withdraw at date 2 get an equal share of bank profits. In equilibrium, n is such that patient depositors are indifferent between withdrawing early and waiting. Setting $\bar{c} = \frac{L}{t}$ implements the optimal allocation. Runs occur (when $n > t$) if and only if $R < \frac{(1-t)L}{tK}$. In this event, $n-t$ patient depositors withdraw early, while $1-n$ of them wait until date 2 to withdraw. The indifference condition, $\frac{L}{n} = \frac{RK}{1-n}$, determines the equilibrium number of date 1 withdrawals, n, and the extent of the run. It also implies that each depositor obtains a payoff, $L + RK$, which is simply the first-best payoff in the state of the world where asset returns are low.

In this model, runs are optimal and occur with positive probability. They are necessary to implement the optimal allocation, and they achieve it by making consumption in period 1 contingent on R. This "equilibrating" role of bank runs is possible only because of the complete illiquidity of the long-term asset, which implies that there will always be something left for patient depositors who withdraw at date 2. Early withdrawal by other patient depositors thus positively affects the payoff to date 2 withdrawal and lowers the return to date 1 withdrawal. In this model, depositors' actions are no longer strategic complements.

Allen and Gale (1998) show that relaxing the assumption of complete illiquidity of the long-term asset by introducing a market for the long-term asset holdings of the bank destroys the equilibrating mechanism of bank runs. The introduction of an asset market leads to a total run when runs do occur, because the terms of a standard deposit contract require the bank to pay all depositors withdrawing at date 1 the promised amount of $\bar{c}$ as long as it is able to do so. The bank has to liquidate all its assets at date 1 if it cannot pay $\bar{c}$ to every depositor who demands it. When the return to the illiquid asset is low enough, there is a total bank run, as any patient depositor who waits until date 2 gets nothing. At this point, all depositors withdraw at date 1 and receive an equal share of the bank's total liquidation value, $L + P(R)K$, where $P(R)$ is the price at which the risky asset trades at date 1. If the price at which the asset trades is equal to its long-run value, $P(R) = R$, in the event of a bank run, the first-best allocation is obtained. However, Allen and Gale show that the price obtained by the bank for its illiquid asset holdings in the event of a bank run is necessarily lower than its "fair" (long-run) value; that is, $P(R) < R$.

The price, $P(R)$, is endogenously determined. To determine this price, investors with liquid assets must be introduced to the asset market. Allen and Gale (1998) assume that there are two types of participants in the asset market: banks and a large number of (identical) risk-neutral wealthy speculators. Banks hold portfolios (L, K) of the safe asset (cash) and risky asset to maximize depositors' date-0 expected utility. Speculators hold portfolios (L_s, K_s) to maximize expected date 2 wealth subject to wealth constraints: $L_s + K_s \leq W_s$. If bank runs occur with positive probability, then speculators will hold a positive amount of the liquid asset, $L_s > 0$. Assuming that W_s is large enough, speculators hold positive amounts of both liquid and illiquid assets in equilibrium. A necessary and sufficient no-arbitrage condition for speculators to hold both assets is

$$E\left[\max\left\{1, \frac{R}{P(R)}\right\}\right] = E[R].$$

There are two values of asset return, R^* and R^0, such that the following is true. If $R \geq R^*$, there is no run and the illiquid asset trades at its "fair" value, $P(R) = R$. If $R \leq R^*$, there is a run and the bank sells all of its risky asset holdings, K. The price of the risky asset is determined by both the returns to the asset and the amount of liquidity in the market. That is, the price of the risky asset is given by $P(R) = \min\{R, L_s/K\}$. At some levels of R, the price of the risky asset may be constrained by the cash holdings of speculators, L_s. Let $R^0 = \frac{L_s}{K}$. Then, for $R \leq R^0$, the market is liquid enough to pay the "fair" value of the risky asset, but for $R > R^0$ the market is liquidity-constrained and the sale of the bank's portfolio of risky asset will drive down asset prices. Thus, speculators get a windfall gain, while depositors incur a windfall loss. Suppose that $R^0 < R^*$. Then,

$$\begin{aligned} P(R) &= R \quad \text{if } R \leq R^0 \text{ and } R \geq R^* \\ &= \tfrac{L_s}{K} \quad \text{if } R^0 \leq R \leq R^*. \end{aligned}$$

Since $P(R) \leq R$ for all R, L_s must satisfy $E[R/P(R)] = E[R]$. The market underprovides liquidity for intermediate realizations of R exactly when the banks need it: in the event of a bank run.

The market thus underprovides liquidity (where liquidity is measured by how easily investors can realize the long-term value of their investment). Ironically, by improving the liquidity of the bank's holdings of the long-term asset (although underproviding it), the asset market destroys the equilibrating mechanism of bank runs and first-best risk-sharing among depositors. In addition, it creates a redistribution from depositors to speculators in the asset market, since speculators benefit from purchasing the long-term asset at a price below its long-run value.

Allen and Gale (2000b) note that the market's provision of liquidity is inadequate because investors require an incentive for providing liquidity, since the return on holding the liquid asset is lower than the return on holding the illiquid asset. Investors obtain this incentive in the form of a capital gain if they can buy the illiquid asset cheaply enough in the interim period. Thus, the market will be willing to provide liquidity to distressed banks only if the terms are sufficiently profitable, which means that the asset has to be sold at a level below its fair value.

4.2 Interbank markets for liquidity

The papers discussed in this section consider the banking sector to consist of multiple, heterogeneous banks. In this context, banks that experience liquidity problems can turn to other banks for liquidity. This is in contrast to the papers discussed earlier, which modelled economies with a single bank (or, equivalently, identical banks). A run on a bank is thus a run on the banking system and it is associated with system-wide illiquidity. In a multibank economy, a role arises for the interbank market as a provider of liquidity. If there is no aggregate uncertainty and each bank's investment in liquid assets is publicly observable, then banks can fully insure themselves against liquidity risk by lending to each other. The following models focus on the possibility of a market failure in the interbank market that can turn liquidity problems faced by banks into solvency problems. In addition, interbank markets may provide the channel through which liquidity or solvency problems at one bank (or a small group of banks) can spread contagiously to other banks, leading to system-wide problems. Contagion in the banking sector is discussed in the next section.

Bhattacharya and Gale (1987) show that, with information asymmetry, interbank markets can lead to an underprovision of liquidity because of free-rider problems. They develop a model of interbank lending based on the DD framework in which there is no aggregate risk. The authors assume away self-fufilling bank runs, but allow banks to face idiosyncratic withdrawal risks because they are not sufficiently diversified across depositors. These assumptions motivate the existence of an interbank market, where banks that face heavy withdrawals can borrow from those that do not. This reduces the amount of (costly) liquid reserves that each bank needs to hold. However, there is asymmetric information in that banks privately observe the realization of their liquidity needs and their investment decision is private information. This informational asymmetry implies that banks will free-ride on each other for liquidity and underinvest in liquid assets, because the return on interbank loans is lower than the return from long-term investment. Since all banks hold too few liquid assets, aggregate liquidity in the system is low relative to the first-best (full-information) equilibrium.[9]

There is a continuum of measure one of banks. The (ex ante) representative bank is identical to the DD bank which faces liquidity shocks at date 1 from depositors withdrawing early. Unlike DD banks, however, the banks here face idiosyncratic liquidity shocks. The proportion of depositors who are impatient consumers (and hence need to withdraw early) can be t_1 or t_2 with probabilities p_1 and $p_2 = 1 - p_1$, respectively. In addition, $0 < t_1 < t_2 < 0$ and $p_1 t_1 + p_2 t_2 = t$, a constant. There is, thus, no aggregate uncertainty in the economy. This motivates risk-sharing among banks, which involve the liquid banks (those with a low liquidity shock, t_1) lending to the illiquid banks (those with a high liquidity shock, t_2) in an interbank market after the realization of the liquidity shock at date 1. Banks with sufficient reserves to meet their liquidity shocks are described as liquid; otherwise, they are illiquid. The first-best solution solves the problem

$$\begin{aligned} \max_{c_1, c_2} \quad & tu(c_1) + (1-t)u(c_2) \\ \text{s.t.} \quad & tc_1 = L \;\; \text{and} \;\; (1-t)c_2 = (1-L)R, \end{aligned}$$

and yields exactly the same consumption allocation as DD, (c_1^*, c_2^*) where $u'(c_1^*) = Ru'(c_2^*)$ and

[9] Although the underinvestment in liquid assets does not lead to bank failures, since there is no aggregate uncertainty, it is inefficient in that the consumption plans that bank contracts support are suboptimal.

$tc_1^* + \frac{1-t}{R}c_2^* = 1$. The first-best level of investment in the liquid asset is $L^* = tc_1^*$.

However, with asymmetric information, one can achieve only the second-best interbank contract by solving an incentive-constrained social planner's problem:

$$\begin{aligned} \max_{c_{1i},c_{2i}} \quad & \sum_{i=1,2} p_i[t_i u(c_{1i}) + (1-t_i)u(c_{2i})] \\ \text{s.t} \quad & p_1 t_1 c_{11} + p_2 t_2 c_{12} = L \\ & p_1(1-t_1)c_{21} + p_2(1-t_{22})c_{22} = (1-L)R. \end{aligned}$$

The maximization is also subject to the patient depositors' incentive-compatibility constraints, $c_{1i} \leq c_{2i}$, and the banks' incentive-compatibility constraints for revealing their types.

One can state the banks' incentive-compatibility constraints more clearly by reframing the problem in terms of the banks' investment in liquid assets, L, and the interbank contract (B, D), where B is the amount borrowed by illiquid banks (lent by liquid banks) in the interbank market at date 1, and D is the gross borrowing (lending) rate in the interbank market. This implies that DB is the amount repaid at date 2. That is, $B = t_2c_{12} - L$ and $DB = (1-L)R - (1-t_2)c_{22}$. The authors assume that $p_1 = p_2$ and restate deposit contracts as $c_{1i} = \frac{(-1)^i B + L}{t_i}$ and $c_{2i} = \frac{(-1)^{i+1}DB + (1-L)R}{1-t_i}$. There are two ways in which a bank can deviate: at date 0 by investing an amount $l \neq L$, and at date 1 by reporting a type $s(i) \neq i$. Then, the social planner's problem can be written as

$$\begin{aligned} V^* = \quad & \max_{B,D,L} \sum_{i=1,2} t_i u\left[\frac{(-1)^i B + L}{t_i}\right] + (1-t_i)u\left[\frac{(-1)^{i+1}DB + (1-L)R}{1-t_i}\right] \\ \text{s.t.} \quad & V^* \geq \sum_{i=1,2} \left\{ t_i u\left[\frac{(-1)^{s(i)} B + l}{t_i}\right] + (1-t_i)u\left[\frac{(-1)^{s(i)+1}DB + (1-l)R}{1-t_i}\right]\right\}, \end{aligned}$$

for any $(s(i), l)$. Solving this, the authors show that, in equilibrium, banks underinvest in the liquid asset relative to the first-best optimum, so that $L < L^*$.

Bhattacharya and Fulghieri (1994) obtain different results when, instead of assuming stochastic withdrawals, they assume that banks face uncertainty in the timing of short-term asset payoffs. While the long-term asset yields R units with certainty after two periods, the short-term asset yields one unit at date 1 (with probability p) or one unit at date 2 (with probability $1-p$). That is, with probability $1-p$, the short-term asset does not pay off at date 1 and the bank faces a liquidity shortage, which it meets by borrowing on the interbank market. The (incentive-constrained) second-best equilibrium in this model has the return on interbank lending being strictly higher than the return on the long-term asset. That is, holding liquid reserves is costly, but being a liquid bank in the interbank market is profitable. Hence, in the second-best equilibrium, banks may under- or overinvest in the liquid asset.

The main difference between the two models is in the amount of liquid reserves at banks after the liquidity shock is realized at date 1. In Bhattacharya and Gale (1987), both types of banks have the same amount of liquid reserves, but they differ in their need for cash to meet early withdrawals.

Either type of bank can misrepresent itself in the interbank market. The authors show that when the interbank rate is lower than the rate of return on the illiquid asset, the optimal deviation for both types of banks is to borrow on the interbank market, whereas the opposite is true when the interbank rate is higher. Under the model parameters, the interbank rate is lower than the return on the illiquid asset in equilibrium. Thus, it is necessary to induce the bank with excess liquidity to represent itself truthfully and lend on the interbank market. This is done by lowering the amount it is required to lend on the interbank market. Hence, investment in the liquid asset and the size of loans in the interbank market are lower relative to first-best. In Bhattacharya and Fulghieri (1994), a bank that discovers its short-term investment does not pay off until date 2 (an illiquid bank) is unable to misrepresent itself as a liquid bank by lending on the interbank market. Hence, one needs only to ensure that a liquid bank, whose short-term investments pay off on time, has no incentive to deviate. This can be achieved by increasing the interbank rate relative to the return to illiquid investment. Hence, the investment in the short-term asset, as well as the size of loans on the interbank market, may be higher or lower relative to first-best.

Alger (1999) assumes that the level of liquid reserves of banks is observable, but introduces credit risks into the interbank market. Two ex ante identical banks make their portfolio decisions at date 0 and face a liquidity shock at date 1. The proportion of early withdrawals is random (it can be high or low), but negatively correlated across the two banks. Hence, there is no aggregate uncertainty about early withdrawals. In addition, banks face a technology shock: the illiquid asset pays off R with probability $1 - p$, and 0 with probability p at date 2. Illiquid asset returns are correlated across banks. This technology shock is realized at date 1 but it is private information until the final period. At date 0, the planning period, banks choose the amount of investment in liquid and illiquid assets. Investing in liquid assets is costly because the expected return from long-term investment is strictly positive. Banks hold liquid assets to meet their liquidity needs associated with date 1 withdrawals. They can also turn to the interbank market to meet their liquidity needs. Independent of the realization of the liquidity shock, banks can be solvent or insolvent. A bank's solvency is private information. Interbank lending is thus subject to credit risk.

Alger (1999) examines interbank risk-sharing when banks have the first-best level of liquid reserves (that is, banks choose investment in liquid assets equal to the average liquidity needed in the interim period to meet withdrawal shocks). Following the realization of liquidity and solvency shocks, there is an illiquid bank and a liquid bank. If a liquid bank is insolvent, it will always lend to the illiquid bank in a "gamble for resurrection." However, a liquid and solvent bank may not lend if credit risk, or the probability that it will not be repaid (when the other bank turns out to be insolvent), is high enough, leading to a collapse of the interbank market. Thus, the interbank market can fail to supply liquidity if credit risks are too high. In addition, Alger points out that the amount of credit risk in the economy may be related to the state of the business cycle. Specifically, credit risks, and hence the likelihood of an interbank market collapse, increase with a downturn. The amount of credit risk in the economy is an important determinant of the equilibrium that prevails, and hence the biggest drawback to Alger's paper is that credit risks are exogenous.

4.3 Discussion and policy implications: inefficient liquidity provision

Theories that focus on the inefficient provision of liquidity by markets reinforce the idea that otherwise-solvent banks can fail as a result of liquidity problems. Hence, the cause of crises is banking sector insolvency arising from widespread liquidity problems. Asset price declines can also result from the fire-sale of assets by banks desperate for liquidity. These partial equilibrium models focus on the interbank market for liquidity and abstract from the factors that trigger runs by assuming exogenous liquidity shocks to banks in the form of excessive withdrawals. They demonstrate that these markets can be inefficient when there are market imperfections and this inefficiency may prevent a solvent but illiquid bank from obtaining the necessary liquidity to avoid insolvency. The types of interbank contracts that exist in each model are predetermined. For example, in Bhattacharya and Gale (1987), banks write contracts with each other prior to liquidity shocks that obligate a liquid bank to lend (at a pre-specified interest rate) when an illiquid bank approaches it. In the models of Alger (1999), Allen and Gale (1998), and Donaldson (1992), banks do not write contracts beforehand and turn to lending markets only after liquidity shocks are realized.

Asset markets can fail to provide banks with liquidity when the value at which the asset trades, when bank runs occur, is lower than the asset's fundamental value, as demonstrated by Allen and Gale (1998). Intervention by the central bank, however, can achieve first-best in this world. The central bank, by injecting liquidity into the economy, supports the long-term asset's price. This can be done by a repurchase agreement, whereby the bank sells its long-term assets to the central bank for cash at date 1 when a run occurs and buys them back for the same price at date 2. By providing liquidity in this way, the central bank ensures that the bank does not suffer a loss by liquidating its holdings of risky asset prematurely.

In the interbank lending markets with no credit risks, the main implication for intervention is whether the first-best level of liquid balances, $L = L^*$, can be enforced. If an ex ante reserve requirement of L^* can be enforced, ex post trading across the banks in the interbank market will implement the first-best solution. The non-observability of the investment decisions of banks makes perfect enforcement unrealistic. However, even noisy monitoring of banks may increase welfare relative to the second-best. When there is credit risk in the interbank lending market, enforcing the first-best level of liquid reserves no longer ensures efficiency, as trade can fail to take place when credit risks are too high. One policy implication is to install mechanisms that ensure trade in the interbank market, or to have an open credit line from the central bank. This argument, however, is based on the absence of moral hazard in the model and the assumption that there is no cost to forbearance (allowing an insolvent bank to continue operating).

5. Contagion in Banking Markets

Financial crises typically involve contagion in banking and other financial markets. This section examines the literature on (domestic) bank contagion.[10] An important policy question to be examined in the context of contagion is whether insolvent financial institutions, and not just illiquid ones, should be bailed out.

Contagious bank failures can result from information externalities or explicit credit linkages between banks. Credit linkages between banks can arise from interbank risk-sharing or from banks' participation in payment and settlement systems, and they cause banks' performances to be correlated even when "fundamentals" are independent across banks. Information contagion occurs when depositors perceive the performance (fundamentals) of banks to be correlated. Liquidity problems at one bank may also be transmitted to other banks through the market for bank assets. When a run occurs on a bank, the bank generally must sell its assets quickly, possibly at fire-sale prices, and/or borrow funds, possibly at higher interest rates. This can turn a liquidity problem into a solvency problem. The reduction in bank asset prices can adversely affect the value of other banks' assets to an extent that it creates liquidity problems for them. When banks hold claims on other banks, a run on one bank is likely to affect other banks directly as the affected bank withdraws its interbank funding.

5.1 Information contagion

In this category of models, there are no credit linkages among banks. Payoffs are correlated across banks so that what happens at one bank is seen as providing information about the payoffs to deposits at other banks. Hence, the failure of a bank, or a subset of banks, can cause depositors at other banks to revise downwards their expectations of their banks' viability, to the extent that they will initiate a run on those banks. Hence, the arrival of new information regarding problems at other banks can trigger a crisis in which problems spread beyond the banks that are fundamentally unsound.

Chen (1999) examines a model where payoff externalities owing to demand deposit contracts and information spillovers create the conditions for contagious bank runs even if Pareto-dominated equilibria, or self-fulfilling bank runs based on coordination failure, are ruled out. The economy modelled consists of multiple banks that invest in risky long-term projects. The returns to the banks' risky investments are positively correlated across banks. At each bank, a proportion of patient depositors gets a perfect signal about the outcome of their bank's risky project. The signal is observed first by the depositors of a subset of the banks and can result in the failure of some banks. The depositors at other banks may respond to the noisy signal provided by the number of bank failures and run on their banks even before they receive information about the outcome of their

[10] See Sbracia and Zaghini (2000) for a review that focuses on the specific role of banks in the international transmission of crises.

own bank's projects. This occurs because uninformed depositors will respond to the information provided by the failure of other banks. Informed depositors, aware that uninformed depositors may initiate a run, also withdraw early, before they receive information about their banks' asset returns. Hence, runs at individual banks can be contagious and provoke a banking panic on the rest of the banks.

There are N banks in the economy, each with a measure one of depositors who deposit one dollar at their banks. Each bank's risky long-term project yields $R > 1$ with probability $1 - a$ and $r < 1$ with probability a at date 1. Project returns are correlated across banks because they depend on the state of the economy. If the state of the economy is good, $a = a_g$, and if the economy is bad, $a = a_b$, where $a_g < a_b$. At date 0, the prior probability of the state of the economy being bad is η_0. Hence, the expected probability of getting a bad project is $a_0 = \eta_0 a_b + (1 - \eta_0)a_g$ at each bank. At date 1, a fraction, β, of the patient depositors at each bank learn whether the outcome of their bank's risky project is good or bad. It is assumed that the preference shocks and information are revealed at N_1 banks first during the interim period and then at the other $N - N_1$ banks later during the same period.

At date 1, preference shocks and information are revealed at N_1 banks. A bank fails if its informed depositors withdraw early, precipitating a run on the bank by the uninformed depositors. Chen assumes that depositors pick the Pareto-dominant equilibrium where multiple equilibria exist to focus on contagion owing to information spillovers. Thus, only the banks with bad projects fail and the number of bank failures among the first group of banks, K_1, is observed by the depositors at the other $N - N_1$ banks before preference shocks and information are revealed at those banks. Upon observing K_1, depositors at the $N - N_1$ banks update their beliefs about the state of the economy. The posterior probability of the state of the economy being bad is thus a function of K_1, $\eta_1(K_1)$, and the posterior probability of a bad project at each of the other $N - N_1$ banks is $a_1(K_1) = \eta_1(K_1)a_b + [1 - \eta_0(K_1)]a_g$.

Given banks' deposit contracts (r_1, r_2) where $r_1 > 1$, there is a critical value, K_1^*, such that the depositors at the remaining $N - N_1$ banks will all run on their banks if the number of failures among the first N_1 banks exceeds that critical value. Furthermore, K_1^* is weakly decreasing in the a priori probability of low investment returns at banks, η_0, and the promised payoff to early withdrawals, r_1. It is weakly increasing in the promised payoff to late withdrawals, r_2. Thus a banking panic is more likely the higher the prior belief that the state of the economy is bad and the higher the date 1 deposit payment. Clearly, the possibility of a banking panic influences the optimal deposit contract offered by banks. Chen (1999) provides numerical examples to demonstrate that there exist parameter values for which the optimal deposit contract involves a positive probability of bank runs.

5.2 Contagion via credit linkages

While interbank connections can help prevent the failure of individual banks by redistributing liquidity in the banking system, it may come at the cost of contagion risk. The network of liabilities across the banking system may transmit illiquidity problems, even failures, within the system through the unwinding of positions of failed banks. The following papers focus on the direct capital linkages (or credit exposures) that arise from interbank relationships as a contagion mechanism.

Freixas, Parigi, and Rochet (2000) modify the DD economy to allow for heterogeneous banks that are spatially separated, each with a continuum, of measure 1, of depositors. Each bank, i, has a long-term project that yields a deterministic payoff, R_i, at the final date. This long-term asset can be liquidated for $\alpha < 1$ at an earlier date. The uncertainty in this model arises not from uncertainty in the timing of consumption but in the location of consumption. Agents deposit their money at the bank of their original location (their home bank) at date 0 and consume at the final date, date 2. However, depositors are hit by a location shock at the interim date, date 1. Thus, for each bank, a portion, t, of their depositors have to travel and will need to consume at their new location. These travelling depositors can do one of two things: (i) withdraw their funds from their home bank and travel with their funds, or (ii) transfer their deposits to the bank in their new location, in which case their consumption is determined by their share of the new bank's assets. The second option is available to depositors only if banks extend credit lines to each other. Early withdrawal requires banks to either hold liquid assets or liquidate part of their long-term investment, both of which are costly. Hence, banks are motivated to extend credit lines to each other to economize on their liquid asset holdings and avoid liquidation of their long-term investments.

The structure of interbank connections depends on the pattern of travel. Assume that banks and consumers are symmetrically located around a circle, with each location (and bank) indexed by the integer $i = 1, 2, ..., N$, which increases as we move in a clockwise direction. Freixas, Parigi, and Rochet (2000) examine two types of travelling patterns (and hence interbank credit flows): (i) "credit chain lending," in which depositors travel from location i to location $i + 1$, and (ii) "diversified lending," in which a portion of travelling depositors from each location travel to all other locations. That is, each bank swaps an equal number of depositors with all other banks. With "credit chain lending," each bank, j, extends a credit line to its neighbour bank, $j - 1$, only. With "diversified lending," each bank extends credit lines uniformly to all other $N - 1$ banks. The sharing rule in the event of a bank failure is important in determining equilibrium actions. The authors assume that the following sharing rules apply in the case of a bank closure: (i) all the liabilities of a bank have the same priority at date 2, and (ii) if a bank is closed at date 1, its assets are shared between its own depositors only. Hence, all of its depositors (and no one else) get an equal share of its assets at date 1 if a bank fails at that date.

Suppose that each bank at date 0 offers a deposit contract that promises D_0 at date 1 as long as the bank has not failed, and an equal share in its assets at date 2. Travelling depositors at each location play a coordination game at date 1 that determines the value of their date 2 consumption. At date 1, depositors travelling from location i to location j (where they consume) choose the fraction, x_{ij}, of their deposit to maintain in the bank. What is not withdrawn at date 1 is transferred to the bank at the depositors' new location. Let each unit of deposit at bank j be worth D_j at date 2. Then, travelling depositors from location i consuming in location j will either withdraw all their deposits at date 1 ($x_{ij} = 0$ if $D_j < D_0$), or transfer all their deposits to bank j ($x_{ij} = 1$ if $D_j \geq D_0$). Clearly, D_j depends on the actions of depositors at that location, which are, in turn, influenced by their expectations of the actions of depositors at the locations they will travel to. There are multiple equilibria to the coordination game. In one equilibrium, all depositors transfer their deposits to their new location and no long-term assets are liquidated. In the other equilibrium (the "gridlock equilibrium"), all depositors run on their home banks at date 1, because they expect to be denied consumption at their new location owing to a run on the bank at that location. Such expectations are self-fulfilling. Thus this type of banking system is vulnerable to coordination failures, like the bank in the DD economy.

Freixas, Parigi, and Rochet (2000) next abstract from coordination problems among depositors, so that a bank fails only if it does not have the resources to meet its obligations towards its depositors, and they assume an exogenous failure of one bank to examine the possibility of contagion. Suppose that bank k is closed at date 1. This has two consequences for the banking system. First, there is an unwinding of the positions of bank k, since $\pi_{ik}D_k$ assets and $\pi_{ki}D_i$ liabilities disappear from the balance sheet of bank k, where $\pi_{ik},\ i \neq k$ is the fraction of depositors at location i who travel to location k. Second, a proportion, π_{ik}, of depositors from each location i travelling to location k will be forced to withdraw at date 1, and this forces bank i to liquidate some of its assets to meet the early withdrawals. If this amount is sufficiently large for some bank i, that bank will be forced into failure at date 1. The failure of another bank i as a consequence of the closure of bank k is contagion. The authors show that the contagion risk of the banking system is lower under a "diversified lending" structure than it is under a "credit chain lending" structure, where credit risk is more concentrated for each bank. Moreover, the system with a "diversified lending" structure becomes more stable as the number of banks, and locations, increases, and becomes completely stable, so that no contagion can occur when this number is large enough. On the other hand, the number of banks has no effect on the stability of a system with a "credit chain lending" structure.

Allen and Gale (2000a) construct a model of contagion based on a modified DD economy with spatially separated banks, where regional liquidity shocks (the number of impatient consumers in each location) are idiosyncratic but the aggregate demand for liquidity is fixed. Thus, banks have an incentive to hold interregional claims on each other to insure themselves against regional liquidity shocks. An interbank market in which banks hold deposits at other banks is one way to implement risk-sharing among banks. As in Allen and Gale (1998), Pareto-dominated equilibria are ruled out, thus eliminating self-fulfilling runs on banks.

There are three dates, $t = 0, 1, 2$, in the economy with banks located in four ex ante identical regions, A, B, C, and D. Banks can invest in two types of assets: a short or liquid asset that yields 1 per unit invested after one period, and a long or illiquid asset that yields $R > 1$ per unit invested after two periods. The long asset can be liquidated before maturity for a value $r < 1$.

Each region has a continuum of mass 1 of consumers who deposit their endowment of one unit in the region's bank. Consumers are ex ante identical but learn (privately) of their type at date 1. In each region, a proportion, w, of consumers are impatient; w varies across regions and can take on one of two values, $w \in \{w_H, w_L\}$, where $0 < w_L < w_H < 1$. There are two states of the world, S_1 and S_2, each occurring with probability 0.5, which affect the realization of each region's liquidity shock, w:

	A	B	C	D
S_1	w_H	w_L	w_H	w_L
S_2	w_L	w_H	w_L	w_H.

Note that the realizations of w at adjacent regions are perfectly negatively correlated. In aggregate, the proportion of impatient consumers is $\gamma = 0.5(w_H + w_L)$ and there is no aggregate uncertainty.

Optimal risk-sharing in a decentralized economy, where consumers deposit in banks and banks invest in short (liquid) and long (illiquid) assets to deliver levels of consumption promised by bank deposit contracts, entails deposit contracts that promise first-best consumption levels (c_1, c_2) to impatient consumers (who withdraw early) and patient consumers (who withdraw late), respectively, where $u'(c_1) = Ru'(c_2)$ and $(1 - \gamma)c_2 = (1 - \gamma c_1)R$. Banks invest the amount $y = \gamma c_1$ in the short asset and $x = 1 - \gamma C_1$ in the long asset. This means that in either state of the world, the banks in two regions will find their liquid assets short of the value of their date 1 withdrawals by consumers, and the banks in the other two regions will find themselves with excess liquidity after meeting consumers' withdrawal demands. Hence, banks hold deposit contracts in each other to insure against a high-liquidity shock, $w = w_H$. Those banks experiencing a high level of consumer withdrawals can then draw on their deposits at date 1 cash-rich banks to meet their withdrawals. The amount of deposits banks hold depends on the structure of the interbank market, which is exogenously determined in this model.

The interbank market is complete when banks in a region, i, have claims on banks in all other regions, $j \neq i$. In a "complete" interbank market, banks in region i hold deposits of $z = \frac{W_H - \gamma}{2}$ at banks in regions $j \neq i$, where $i, j \in \{A, B, C, D\}$. In an "incomplete" interbank market, banks hold deposits at banks in one adjacent region only. For example, banks in region A hold deposits of $z = w_H - \gamma$ at banks in region B, banks in region B hold deposits of the same amount, z, at banks in region C, banks in region C hold deposits of z at banks in region D, and banks in region D hold deposits at banks in region A. In another possible market structure, called "disconnected," banks in regions A and B hold deposits of $z = w_H - \gamma$ in each other and banks in regions C and D hold deposits of z in each other. All of these market structures can implement the first-best allocation (c_1, c_2) under the assumptions of the model.

An “incomplete” structure of claims where banks hold deposits only at banks in an adjacent region can implement optimal risk-sharing. The model examines contagion in the context of this market structure. A problem arises if there is an *unanticipated* aggregate liquidity shock that has the potential to force the banks in region A into bankruptcy at date 1. That is, the realization of w in a zero-probability state, $\overline{S}$, is

	A	B	C	D
$\overline{S}$	$\gamma - \epsilon$	γ	γ	γ.

Note that in state $\overline{S}$ there is an aggregate liquidity shortage at date 1, since aggregate liquidity is $4\gamma c_1$ while aggregate demand for liquidity is $(4\gamma + \epsilon)c_1$.

Even after drawing on their deposits at the banks in region B, the banks in region A are forced to liquidate some of their long-term assets to meet the excess demand for liquidity. If the excess demand for liquidity, ϵc_1, is so large that banks in region A cannot meet it by liquidating their long assets while maintaining incentive compatibility (such that the return from withdrawing at date 2 exceeds the return from withdrawing at date 1), these banks will face a run by depositors and are forced into bankruptcy.[11] When a bank fails at date 1, the date 1 value of a unit of deposits at the failed bank is worth less than the contractual amount specified, c_1. Denote the value of a unit of deposit at bank i as q_i. The value of a unit of deposit on a bank in region A is worth $q^A = c_1$ when the bank is not bankrupt. However, when the bank is bankrupt, the value of its deposits is

$$q^A = \frac{y + rx + zq^B}{1+z} < c_1.$$

In bankruptcy, the value of assets of region A's banks is the sum of y, the amount of the short asset, rx, the amount obtained from liquidating the long asset, and zq^B, the value of deposits on region B banks while the value of liabilities is $(1+z)q^A$. $1+z$ is the number of claimants on bank A's assets. This assumes that all depositors are treated equally in the event of bankruptcy. The equilibrium value of q^A must equate the value of assets and liabilities. If region B's banks are not bankrupt, $q^B = c_1$. This provides the upper bound for q^A under bankruptcy,

$$\overline{q}^A = \frac{y + rx + zc_1}{1+z}.$$

Thus, the failure of region A's banks results in a decline in the value of the claims on the banks in region A. The banks in the adjacent region D (which hold deposits on the failed banks in region A) see a fall in the value of their assets. If this fall in value is large enough, banks in the adjacent

[11] Define a buffer $b(w)$ as the maximum amount that can be obtained by liquidating long assets without violating the depositors' incentive-compatibility constraint. Then,

$$b(w) = r\left[x - \frac{(1-w)c_1}{R}\right].$$

Therefore, if $\epsilon c_1 > b(\gamma + \epsilon)$, the banks in region A will be run on and forced into bankruptcy.

region can be forced into bankruptcy as well.[12] This, in turn, decreases the value of the assets of the banks in the next region, which can then be pushed into failure. A run in one region can, therefore, spread to other regions contagiously via the financial linkages created by interbank deposits. Moreover, Allen and Gale (2000a) demonstrate that if region D's banks go bankrupt in response to the bankruptcy of region A's banks, the spillover effect on region C's banks is larger than the initial spillover effect on region D. Thus, in the "incomplete" interbank market structure, when two regions' banks are forced into bankruptcy by an excessive liquidity shock in one of the regions, that failure will spread contagiously to the banks in all other regions.

The ability of a run to spread from one region to another depends crucially on the pattern of interconnectedness among banks and the fact that financial linkages take the form of pre-existing claims on other banks, as in Freixas, Parigi, and Rochet (2000). The "incomplete" interbank market is more fragile, or more vulnerable to contagion, than a "complete" interbank market. A "complete" interbank market ensures that the spillover effects of bank failures in one region on the asset values of other banks are spread over a large number of regions. Thus, for a shock of the same size, ϵ, contagion need not occur in this market structure. As well, as the number of regions increase, a "complete" interbank market becomes more stable as the spillover effects are spread over a larger number of regions. The same is not true for the "incomplete" interbank market structure, since spillover effects become larger as failure spreads from one region to another. Hence, increasing the number of regions simply increases the effect of the initial shock. In a "disconnected" market structure, the banks in region B are more vulnerable than under the "incomplete" market structure, but contagion is contained to regions A and B only. Finally, if liquidity in the interbank market were provided ex post, as in Bhattacharya and Gale (1987) and Alger (1999), there would be no possibility of contagion.

Dasgupta (2000) presents a two-bank version of Goldstein and Pauzner (2000), in which banks hold deposits on each other. Each bank's risky-asset returns depend on some underlying "fundamental"; that is, bank i's risky asset will pay off $R(\theta_i)$ at date 2, where θ_i is uniformly distributed on some finite interval and independently distributed across banks. In addition, banks face regional liquidity (withdrawal) shocks at date 1 that are negatively correlated. The two banks share liquidity risk by holding interbank deposits on each other. Then, at date 1, after the realization of liquidity shocks, the bank in the high-withdrawal region (the debtor bank) gets a payment, x, from the bank in the low-withdrawal region (the creditor bank) and owes the creditor bank an amount, $xR(\theta_d)$, at date 2, where the subscript d on θ denotes the debtor bank. This means that the payoff to date 2 withdrawals at the creditor bank is a function of the debtor bank's performance, precisely because the value of the creditor bank's deposits on the debtor bank depends on whether the debtor bank is bankrupt or not. This spillover is the channel through which contagion can occur, as in Allen and Gale (2000a).

[12] The spillover effect (or, the decline in the value of deposits held on region A's banks) on banks in region D if the banks in region A go bankrupt is $z(c_1 - q^A)$. If $z(c_1 - q^A) > b(\gamma)$, region D's banks will be run on and forced into bankruptcy also.

As in the Goldstein and Pauzner (2000) model, depositors observe noisy signals at date 1 about their bank's fundamentals. Dasgupta (2000) considers a case where the depositors at one bank observe their signals first and make their withdrawal decision before the depositors at the other bank observe their signals. Each bank's patient depositors then play a game in which the unique (trigger-strategy) equilibrium specifies a cut-off value, θ_i^*, for each bank, i, in which patient depositors at bank i withdraw at date 2 if they observe signals greater than (or equal to) θ_i^*, and at date 1 otherwise. It may be the case that the bank at which signals are observed last has equilibrium cut-off values that depend on the failure or success of the other bank. There are two possible states at date 1: (i) depositors at the debtor bank (the bank with the high liquidity shock) observe their signals and make their withdrawal decisions first, and (ii) depositors at the creditor bank (the bank with the low liquidity shock) observe their signals and make their withdrawal decisions first. Each of these cases yields a different game.

The game in which the creditor bank's depositors observe signals first yields the values $(\theta_c^*,\ \theta_{dF}^*,\ \theta_{dS}^*)$, where θ_{dF}^* is the cut-off value at the debtor bank conditional on the creditor bank's failure and θ_{dS}^* is the cut-off value conditional on the creditor bank's success. Similarly, the game in which the debtor bank's depositors observe signals first yields the values $(\theta_d^*,\ \theta_{cF}^*,\ \theta_{cS}^*)$, where θ_{cF}^* is the cut-off value at the creditor bank conditional on the debtor bank's failure and θ_{cS}^* is the cut-off value conditional on the debtor bank's success. Contagion is then defined as a situation where a bank's likelihood of failure is higher if the other bank has failed than if the other bank has not failed: $\theta_{iF}^* > \theta_{iS}^*$. Dasgupta (2000) shows that when interim information is first received at the creditor bank, no contagion exists: $\theta_{dF}^* = \theta_{dS}^*$. The failure of the creditor bank does not affect the debtor bank's chances of success. However, the reverse is not true. The failure of the debtor bank adversely affects the creditor bank's chances of success: $\theta_{cF}^* > \theta_{cS}^*$. That is, contagion flows in one direction, from the debtor bank to the creditor bank. Furthermore, the author demonstrates that the intensity of contagion $(\theta_{cF} - \theta_{cS})$ increases with the size of the capital links, x, across the banks.

Although this paper does not survey the literature on payment systems, the participation of banks in payment and settlement systems also creates credit exposures among banks that give rise to the possibility of contagion. In netting systems, intraday credit exposures can become large and contagion can occur if collateral requirements are insufficient, because participants who had been net creditors of the failed institution may have sent payments to other institutions in the expectation of funds that are no longer forthcoming.

5.3 Discussion and policy implications: contagion

The literature on bank contagion demonstrates that contagion can arise among banks with and without credit exposures to each other. Contagion can lead to widespread liquidity problems in the banking system and can cause otherwise solvent banks to fail. The onset of a crisis is often unpredictable, but the spread of liquidity problems from the originally troubled banks to other banks may be predictable. Contagion tends to occur among banks that are similar to each other (so that their performances are perceived to be correlated) or among banks with large credit exposures to each other. The risk of contagion in these models, however, is sensitive to the type of linkages, the pattern of linkages, and the intensity of the exposures. These factors are taken as given in these models. For example, in the models of Allen and Gale (2000a) and Dasgupta (2000), banks share risk by holding interbank deposits rather than by engaging in ex post interbank lending. More work needs to be done to rationalize these features before we have a consistent theory of contagion.

Contagion risk can be eliminated or minimized by bailout guarantees, lender-of-last-resort operations, or collateral requirements and net exposure caps in payment and settlement systems. As with bank runs arising from coordination failure, contagion risk is often modelled in this literature as an undesirable by-product of optimizing actions that banks take (for example, risk-sharing among banks). In this case, eliminating contagion risk will improve social welfare if doing so is not too costly. In contrast, Rochet and Tirole (1996) point out that contagion risk is not necessarily bad when it promotes market discipline. The risk of contagion owing to interbank credit exposures may induce peer monitoring, which can reduce the insolvency risk of banks in the first place by reducing the scope for private, profitable bank mismanagement.

Rochet and Tirole (1996) argue that insulating banks from each other's liquidity shocks and eliminating contagion risks completely removes the incentives for banks to monitor each other. They focus on the question of how an optimal system of interbank lending and peer monitoring can minimize risks ex post while preserving ex ante incentives for costly monitoring. They examine these issues in a model where investment by banks is subject to moral hazard because bank debt holders and bank managers cannot contract on the amount of effort supplied by managers. The moral hazard limits the amount of cash a bank is able to raise to fund its investment activities. After investment is undertaken at date 0, banks are subject to liquidity shocks at date 1 that determine the size of the cash infusions required to keep their projects going. Banks have to raise additional funds from outsiders if the liquidity shock is in excess of their liquid reserves, and banks that are unable to raise sufficient funds have to liquidate their project and thus fail.

In autarky (no interbank trade), some banks are forced to liquidate projects with positive net present value (and thus fail) owing to their inability to raise sufficient cash from outsiders when they are hit with large liquidity shocks. It is assumed that date 1 peer monitoring among banks reduces the private benefits of shirking by bank managers and eliminates the moral hazard. In the presence of an interbank loans market, banks that face smaller shocks and have surplus liquidity might lend to banks with a shortage of liquidity if they are able to monitor the borrowing bank at a cost that is not too large. Rochet and Tirole show that under incentive-constrained optimal interbank lending, the outcome of a borrowing bank is independent of the liquidity shock to the lending bank. However, to provide incentives for monitoring, the lending bank's survival should be tied to the borrowing banks' performance. Hence, the optimal mechanism sometimes requires that a solvent bank with exposure to illiquid banks be closed. That is, it may be necessary to allow contagious failure of banks to motivate optimal monitoring. Hence, the optimal public policy trades off the cost of contagion against the benefits of market discipline induced by contagion risk or the cost of reducing contagion risk.

6. Financial Accelerator

The definition of a financial crisis given earlier in this paper makes it clear that an event is considered a crisis only if it has adverse consequences for the real economy. We thus need models that explain how financial events (or more precisely, disruptions) can impinge on the real economy and thus on welfare. Financial accelerator models directly address the notion of a link between the financial system and the real economy.

The financial system is viewed by this class of models as an important source and driver of real business cycle fluctuations. The idea that there is a link between financial structure and real output is not new. The collapse of the financial system along with real output during the Great Depression led Fisher (1933) to theorize that high debt levels in the wake of the prosperity preceding 1929 made the economy vulnerable to adverse economic shocks. Although the direct effect of a business downturn was to precipitate bankruptcies, which in turn fed the downturn, the more important effect was an indirect propagation mechanism. The deflation accompanying the economic slowdown redistributed wealth from debtors to creditors. This decline in net worth induced borrowers to cut back on current expenditures and future commitments, sending the economy further down. This is Fisher's debt-deflation theory of the Great Depression. Interest in the linkages between financial structure and the real economy was revived by empirical work (in particular, by Bernanke 1983) that lent credence to the view that financial factors were important in explaining the severity of the Great Depression.

The literature that followed developed the theoretical framework in which the state of borrowers' balance sheets was a source of real output fluctuations. At the heart of these models are information asymmetries or limited commitment (the inability of agents to precommit to a specific course of action) that restrict the fraction of returns from investment that can be pledged to outsiders. Borrowers then need sufficient inside capital (personal wealth, project cash flows, physical assets) to attract and retain finance for investment projects. If the value of inside capital falls, because of lower profits or a revaluation of assets, lenders will liquidate positive net present value projects when the returns to lenders, net of the fraction that must go to borrowers, are negative. This is ex post efficient from the lenders' viewpoint, but socially inefficient. This process can set off a "financial accelerator" effect that amplifies and propagates shocks through time, resulting in excess volatility relative to a standard real business cycle model without market frictions.

Bernanke and Gertler (1989, 1990) show that the optimal financial contract in the presence of information asymmetries involves an agency cost arising from the need to monitor or audit the borrower, both of which are costly actions to the lender.[13] This monitoring or auditing cost is passed on to the borrower, in that the lender demands a bigger share of the returns from successful projects relative to the perfect information case. Thus, the agency cost associated with borrowing results in a higher cost of external funds relative to internal funds (that is, an external funds premium). Borrowers can reduce the agency cost of debt by investing their own wealth, as inside capital helps to align the interests of borrowers and lenders. Hence, there is a negative relationship between borrower net worth (inside capital) and agency costs. A borrower with higher net worth is not only less dependent on external financing, but faces a smaller premium on external funds. Hence, there is an inverse relationship between borrowers' wealth and their costs of investment. Bernanke and Gertler (1989) show that, in a dynamic model of investment, this feedback between agency costs of investment and borrower net worth creates a mechanism whereby shocks to the economy are amplified and propagated through their effects on the borrowers' cash flows. For example, consider an adverse productivity shock that lowers current cash flow. This induces a greater need for external financing while raising a firm's external funds premium and, consequently, the cost of new investments. Declines in investment lower economic activity and cash flows in subsequent periods, amplifying and propagating through time the effects of the initial shock.

The net worth of borrowers is also affected by changes in the value of real and financial assets, creating an asset-price channel. In another variant of financial accelerator models (Kiyotaki and Moore 1997), the inability of lenders to prevent borrowers from defaulting strategically leads them to require that borrowers post collateral. The value of assets pledged as collateral reduces incentives for strategic default by borrowers and hence increases the amount of borrowed funds available to them. Hence, borrower net worth, measured in terms of the value of a firm's pledgeable assets, is important for determining the firm's debt capacity, or credit limit. In this model, durable assets serve both as a factor of production and collateral for loans. The pledging of assets used as inputs to production creates a link between the firm's debt capacity and the value of those assets, since debt capacity determines the level of investment that a cash-constrained firm may undertake and thereby influences the firm's demand for inputs and hence the price of those assets used as input to production. This feedback between asset price and credit limits creates a financial accelerator effect that can amplify small shocks and propagate them through time. Consider an adverse asset price movement that reduces firms' collateral value and their ability to borrow. This causes firms to cut back on investment or liquidate existing investments. The accompanying reduced demand for assets further exacerbates the decline in asset prices.

The effect of the financial accelerator on the real economy is twofold. First, since borrower net worth is likely to be procyclical, an additional source of fluctuation and persistence is introduced into a standard real business cycle. Second, exogenous shocks to borrower net worth can initiate real macroeconomic fluctuations. The financial accelerator tends to be asymmetric in its effects on the

[13] The result of asymmetric information is moral hazard, a situation in which the payoff to lenders from a project depends on the actions undertaken by borrowers after the project has been initiated and where a conflict of interest exists between lenders and borrowers.

business cycle. That is, the impact of the financial accelerator is likely to be more pronounced in an economic downturn than in an upturn. A necessary condition for the financial accelerator to exist is borrowing by firms. In a downturn, an increasing number of firms become cash-constrained, making the effects of the financial accelerator more potent. During an economic upturn, the external funds premium falls and debt capacity increases as firms' balance sheet positions improve. Although firms may continue to seek debt financing even when internal funds are sufficient to cover investment needs (because corporate governance considerations also determine the capital structure of firms), it is likely that firms will turn increasingly to internal funds to finance their investments as their balance sheet positions improve. Firms that are not cash constrained have investment plans that do not depend on their debt capacity and depend only weakly on the external funds premium. The financial accelerator is less important the weaker the link between the external funds premium and investment.

6.1 Discussion and policy implications: financial accelerator

In financial accelerator theories, financial crises are represented by a deepening of an economic downturn or an end to an economic upturn, which implies that a crisis episode can be preceded by a buildup in credit and is short-lived. Insofar as the triggers (shocks to productivity or to financial variables) are unanticipated, these theories imply that financial crises tend to be unpredictable. As well, a financial crisis can be precipitated by, and exacerbate, asset price instability. The importance of this group of models is that they formalize the idea that financial crises can amount to substantial costs in terms of real output. Finally, in the models described, any shock can set off the financial accelerator and potentially lead to an economic downturn. It would be more satisfactory to have models that feature threshold effects, so that shocks have to be above a critical size to set off the financial accelerator and precipitate a financial crisis.

Since financial accelerator theories do not deal with the causes of crises but the channels through which financial crises can affect the macro economy, they do not offer policy advice for crisis prevention, but they do offer advice for limiting the costs of crises. The main policy implication is that countercyclical measures have to be more aggressive than in the absence of the financial accelerator. In particular, these theories give a role to monetary policy in resolving financial crises. Monetary policy can offset the effects or even reverse the direction of the financial accelerator. Since the effects of the financial accelerator are likely to be asymmetric and more pronounced in an economic downturn, fiscal and monetary easing should be more aggressive during an economic downturn that involves financial accelerator effects than tightening should be during an upturn.

7. Conclusion

The economic literature on financial crises identifies: (i) the sources of financial instability, (ii) the triggers of financial crises, and (iii) the extent to which better design of financial system infrastructure can mitigate crises by (a) eliminating the sources of fragility, (b) reducing the occurrence of triggers, and (c) reducing the cost of crises when they occur. Point (iii) deals with policy implications for crisis prevention (parts a and b) and crisis resolution (part c). Tables 1 to 3 provide a summary of the answers to the questions posed.

Table 1: Sources of Instability

Crisis initiation	Coordination failure among depositors.
	Inefficiencies in markets for liquidity owing to asymmetric information or market power.
Crisis propagation	Information spillovers.
	Credit exposures.
	Debt financing in asymmetric information and limited commitment environments.

Table 2: Triggers of Crises

Sunspots	Arbitrary shifts in expectations can trigger bank runs (Diamond and Dybvig 1983).
New information	Triggers shifts in expectations, which can lead to bank runs (Morris and Shin 1998, 2000; Goldstein and Pauzner 2000; Chari and Jagannathan 1988).
	In multibank context, can lead to contagion with (Chen 1999) and without (Dasgupta 2000) credit exposures.
Productivity shocks	Lead to runs owing to coordination failure in full information environment (Diamond and Rajan 2001a, 2001b).
	In multi-bank models with credit exposure, can lead to contagion (Allen and Gale 2000a; Freixas, Parigi, and Rochet 2000).
	Trigger financial accelerator (Bernanke and Gertler 1989, 1990; Kiyotaki and Moore 1997).
Financial shocks	Asset price declines can turn bank liquidity problems into solvency problems (Allen and Gale 1998) and lead to contagion (Donaldson 1992).
	Trigger financial accelerator (Bernanke and Gertler 1989, 1990; Kiyotaki and Moore 1997).

Table 3: Policy Implications

Eliminating/reducing coordination failure	Deposit insurance, suspension of convertibility, transparency (removal of information asymmetry), taxing early withdrawals, capital requirements, subsidized lending to, and recapitalization of, banks.
Ensuring efficiency of markets for liquidity	Injection of liquidity through repurchase agreements, enforcing first-best investment in liquidity through monitoring, capital requirements.
Reducing contagion risk	Bailout guarantees, lender-of-last-resort operations, collateral requirements for payment systems participation, restricting credit exposures.
Reducing impact of the financial accelerator	Countercyclical monetary and fiscal policies.

We might assess each theory (or group of models) according to how well they explain crisis initiation and propagation, and how well they fit the stylized facts. It is clear, however, that each of the groups of theories typically focus on either the initiation or propagation aspect of financial crises and explain only a subset of the stylized facts. Indeed, they were each developed to explain different aspects of financial crises. For example, financial accelerator models seek to model the connection between financial events and the real economy, whereas the other theories examine financial events more closely and leave out the real economy. Contagion theories abstract from initiating factors of crises and investigate only the propagating factors, while coordination failure models focus on the initiating factors. Furthermore, except for financial accelerator theories, the models are all partial equilibrium in nature and leave aspects of economic behaviour exogenous and incomplete. In particular, they neglect the existence of markets for financial assets. We need to look at the literature as a whole to gain some understanding of financial instability and crises. Looking at only isolated parts will give an unsatisfactory picture of financial crises.

Although the theoretical literature on financial crises sheds much light on the origins of financial instability and crises, it does not yet provide us with a complete understanding of financial crises. In particular, not enough work has been done to advance our understanding of financial systems as consisting of both financial markets and institutions, since most theories of financial markets ignore institutions while theories of banking ignore asset markets.[14] Therefore, we do not have a good theory about how households choose the channels through which they invest their wealth (whether through banks that act as intermediaries or more directly through financial markets), and the factors that determine the relative amounts of wealth invested through those channels. To better understand the origins of financial instability, we require theories that can investigate the interactions between financial markets and intermediaries, and their implications for financial stability.

[14]This point was made by Gale in a presentation at a London School of Economics conference (October 2000).

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