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Financial Institutions, Financial Contagion, and Financial Crises

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Financial Institutions, Financial Contagion, and Financial Crises

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Abstract

Financial crises are endogenized through corporate and interbank market institutions. Single-bank financing leads to a pooling equilibrium in the interbank market. With private information about one's own solvency, the best illiquid banks will not borrow but rather will liquidate some premature assets. The withdrawals of the best banks from the interbank market may lead more solvent but illiquid banks to withdraw from the market, until the interbank market collapses. However, multi-bank financing leads to a separating equilibrium in the interbank market. Thus, bank runs are limited to illiquid and insolvent banks, and idiosyncratic shocks never trigger a contagious bank run.

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I. Introduction

It has been documented that financial crises often accompany problems in financial institutions, probably at some specific stages of development. The recent financial crises in Japan and Korea, and the major financial crises in Europe and America in the late 1920s and in earlier times, are some examples. This paper develops a theory which endogenizes financial crises through institutions related to the corporate sector and the interbank market. The basic idea is that different ways of financing corporate investment projects may affect the nature of bankruptcy in failing projects. This in turn affects information in the interbank market. For financial institutions unable to commit to liquidate bad projects, there will be informational problems between entrepreneurs and banks, which will cause informational problems among banks in the interbank market. Severe information problems in the interbank market can lead to a market failure, which creates conditions for a financial crisis.

In our model, an economy has many banks which receive deposits (*à la* Diamond and Dybvig, 1983) and invest in long-term projects with stochastic returns. A technological shock can affect a project's returns and thus cause a bank to become insolvent. A liquidity shock can make a bank illiquid. If in the interbank market lenders are able to distinguish solvent and insolvent banks, i.e., there is a separating equilibrium, when a solvent bank faces an excess of early withdrawals, it should be able to borrow. However, banks which are both illiquid and insolvent will not be able to borrow. Therefore, bank runs are limited to illiquid and insolvent banks, and idiosyncratic shocks will never lead to a contagious bank run in such an economy.

If lenders in the interbank market are unable to distinguish solvent and insolvent banks, i.e., there is a pooling equilibrium, then all illiquid banks will be treated in the same manner. That is, all banks with a positive value of realized assets will be asked to repay the same amount, which implies that the solvent banks will have to subsidize the borrowing of the insolvent banks. With private information about one's own solvency, a better bank will face a higher cost of borrowing due to this implicit subsidy. When the expected costs of borrowing for illiquid banks with the best portfolios are higher than the costs of liquidating their premature assets, the banks will choose not to borrow but rather to liquidate some of their premature assets. The withdrawals of the best illiquid banks from the interbank market will generate negative externalities: the average quality of borrowers in the interbank market will be depressed. This may make the costs of borrowing for the remaining solvent banks also higher than the costs of liquidating some of their premature assets. Thus, more banks will withdraw from the market, and the quality of the interbank market will deteriorate further. With a repetition of this process, we show that idiosyncratic shocks can trigger a collapse of the interbank market.

However, a pooling equilibrium in the interbank market does not always lead to a financial crisis even when there are idiosyncratic shocks. This is because the expected

borrowing cost for the best banks monotonically decreases with the homogeneity of the projects' quality, as measured by uncertainty. If the projects are very homogeneous in quality, the interbank market will always work well and there will be no financial crisis. But when the projects are heterogeneous, a pooling equilibrium in the interbank market becomes an incubator for financial crises.

This result has implications for the timing of a financial crisis in a pooling equilibrium economy. The economy should have no trouble when most of its sectors are similar, e.g., most projects are at similar imitation stages; but the situation will change when the projects are more heterogeneous, such as when the imitation stage of the economy has ended.

One of our major contributions to the literature is to model the function and failure of the interbank market with the presence of both liquidity and technological shocks and imperfect information. We introduce an interbank market with multi-banks, liquidity trading, and market imperfections into the Diamond-Dybvig model (1983).[1] We show that a certain type of financial institution makes information in the market symmetric; in that case the likelihood of a bank run can be greatly reduced (although not eliminated completely). A contagious bank run in our model is a result of an interbank market failure, which is caused by another type of financial institution which generates an informational problem in the market. We extend the Akerlof's (1970) lemon problem from real markets to the liquidity market with informational asymmetry between lenders and borrowers in the interbank market. Moreover, in our model the informational problem in the market is endogenized.

Hayek (1945) outlined a principle according to which it is the market, rather than the government, that provides the right information for the economy to operate efficiently. However, what this means in the context of a financial crisis is unclear. One of our major contributions is to provide a model to illustrate that a commitment mechanism to liquidate bad projects can make solvency information available to the market on a timely basis.

With respect to the recent literature on banking, our work is complementary to that of Diamond and Rajan (1999). Their focus is the incentive problem when there is a limited commitment while the informational problem is assumed away. In contrast, our focus is a contagious bank run when there is an interbank market failure.

With respect to the recent literature on financial crisis, Aghion, Bolton, and Dewatripont (1999) and Allen and Gale (2000) are closely related to our work in that they also model financial contagion in a multi-bank model. But their emphases are very different from ours. Aghion, Bolton, and Dewatripont (1999) focus on systematic shocks to the entire banking system. In comparison, we focus on financial crisis caused by idiosyncratic shocks.

[1] See Bhattacharya and Gale (1987) and Rochet and Tirole (1996) for recent contributions on modeling the interbank market with liquidity trading.

We study a mechanism of negative externalities in the interbank market that transforms idiosyncratic shocks into bank failure contagion.

Allen and Gale (2000) derive financial contagion from the incompleteness of the structure of interregional claims. Similarly, we also derive financial crisis from the shortcomings of banking institutions. If we reinterpret our interbank market as a form of interconnectedness among all the banks in their model, then what we show is that even with a complete structure of interregional claims, informational problems in the market can still lead to financial contagion.

In our model, the pooling and separating equilibria in the interbank market are endogenized through two types of financial institutions. A financial system where key decisions on project refinancing are made by 'multi-agents' is more likely to liquidate bad projects ex-post. The reason is that the costs of renegotiation are higher when there are 'multi-agent decisions'; hence liquidations are more likely to occur; that is, multi-bank financing can be used as a commitment device to create a separating equilibrium. In contrast, financial systems where key decisions are made by single agents do not face such high renegotiation costs and thus are more likely to restructure rather than to liquidate; that is, the system is not able to commit to stopping bad projects, thus good and bad projects are pooled together. Examples of such 'single-financier' systems include the main-bank system in Japan and the principal-transaction-bank system in Korea.

To focus on our major points, we analyze two types of a "pure" economy: 1) an economy where every project is financed by one bank only – a pure pooling equilibrium economy; and 2) an economy where every project is co-financed by two banks – a pure separating equilibrium economy. We also suppose that the choice of the financial system in an economy depends on some exogenous reasons that make multi-financier financing too costly, such as high costs to enforce contracts.

The idea about using multi-financiers as a commitment device is related to Dewatripont and Maskin (1995), Hart and Moore (1995), and Bolton and Scharfstein (1996). To focus on problems in the interbank market, in this paper we treat this part as a reduced form with some explanations. This reduced form can be derived from one of those contractual foundations, or from some other foundations, such as Huang and Xu (1999).

The remainder of the paper is organized as follows. Section 2 establishes the basic structure of the model and analyzes the relationship between financial institutions and the two types of equilibria. Section 3 investigates how a contagious bank run is created under a pooling equilibrium and when it may lead to a financial crisis; and it explores what will happen under a separating equilibrium. Section 4 examines government policy, in particular the central bank's lender-of-last-resort policy. Section 5 discusses other policy implications,

including discussions on the Asian "miracle" vs. the Asian financial crisis, the transparency of financial institutions and liberalization of the financial sector, and corruption and financial crisis. The final section presents our conclusions. The appendix contains the proofs of the lemmas.

II. The Model

In our three-period model, an economy has M banks, $N \times M$ depositors, and many entrepreneurs. Each entrepreneur has an idea about a new investment project with a stochastic outcome, but has no capital to finance it. Banks are risk-neutral profit maximizers that choose to invest liquidity in projects initiated by entrepreneurs.

All the M banks in the economy are ex-ante identical, and each N depositor deposits \$1 in a bank. Thus, each bank's asset is $\$N$. The M banks form an interbank market to trade liquidity. We assume that the liquidation of a bad project is observable by all the banks.

There are two types of depositors – as in Diamond and Dybvig (1983): early and late risk-averse consumers, with early consumers only consuming at $t = 1$, and late consumers only consuming at $t = 3$. Ex ante, all depositors are identical and not aware of their types until $t = 1$. They make their investment decisions on their endowment of \$1 based on an ex-ante belief about the riskiness of the banking system and about the market equilibrium return on deposits.

In this economy, among all the projects proposed by the entrepreneurs, λ percentage of the projects are of a good type, and the rest are of a bad type. Ex ante, neither the entrepreneurs nor the banks know which projects are good and which projects are bad, although they both are aware of the distribution. By working on a project an entrepreneur will learn its type earlier than the bank(s). The way that a project is financed determines the time that the entrepreneur's private information is revealed to the bank(s).

We suppose that a project takes three periods to finish, requires a total investment of $I_1 + I_2 + I_3$, where I_τ is the required investment in period τ, and $I_\tau \gg 1$. The technology of the project has a constant return to scale. A good project generates an ex-ante profitable return, $Y > I_1 + I_2 + I_3$, while a bad project generates no return as it stands. A bad project, however, can be reorganized at date 2; the best return a reorganized bad project can generate is X, and $I_3 < X < I_2 + I_3$, that is, it is ex-ante unprofitable but can be ex-post profitable. The expected return from a project in the pool is positive, that is, $(1-\lambda)X + \lambda Y - I_1 - I_2 - I_3 > 0$.

Moreover, we assume that if a project is financed, at date 1 an entrepreneur will learn its type, but the bank(s) still will not know it. At date 2, the bank(s) will know the type of the project, and if it is a bad one, a decision will be made either to liquidate or to reorganize.

We analyze two types of economies, each of which has a distinct financial institution: 1) an economy where every project is financed by one bank only; and 2) an economy where every project is co-financed by two banks. We refer to the former as a case of single-bank financing, and to the latter as a case of multi-bank co-financing. Here, single-bank financing reflects real cases where financing decisions are made by a single agent, such as the case of government-coordinated financing where the government makes the financing decisions, or the case of the principal-bank system where the principal bank makes the financing decisions (e.g., in South Korea) and, of course, also true single-bank financing or internal financing. Multi-bank co-financing reflects cases where there are diversified and decentralized financial institutions and a large number of agents are involved in investment decisions. We do not endogenize the choice of a financial system in an economy. One of the plausible reasons for the choice of a financial system is exogenous costs, such as contract enforcement costs which may discourage multi-financing. When the costs are high, a single-financier system will be chosen.

A. Financial Institutions and Informational Problems

In this subsection we explain how financial institutions can cause informational problems in an interbank market.[2] We assume that an entrepreneur always prefers to have his project completed regardless of its type; but when completion is not possible, he prefers to quit the project as soon as possible. To express this assumption in a formal way, we assume that an entrepreneur gets a private benefit b_t from working on a project, where t denotes the date when the project is either completed or terminated at $t = 1, 2, 3$. Specifically, if an entrepreneur quits the project at date 1, he gets a low private benefit, $b_1 > 0$. If a bad project is liquidated at date 2, an entrepreneur gets an even lower private benefit b_{2b}, where $0 \leq b_{2b} < b_1$. At date 3, if a bad project is reorganized and completed, it will generate a private benefit $b_{3b} > b_1$ to an entrepreneur; in the case of a good project, it will generate a private benefit, $b_{3g} > b_{3b}$, to an entrepreneur. To summarize, we have $b_{3g} > b_{3b} > b_1 > b_{2b} \geq 0$.

With respect to financing, a project can be financed by one bank alone, or can be co-financed by two (or more banks) jointly.

The timing of the game related to project financing is as follows:

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[2] Those who are not particularly interested in the endogenization of informational problems, but are keen to know how informational problems in the interbank market lead to financial crisis, can omit most of this subsection and start from Lemma 1.

- Date 0: All parties know the distribution of the projects and the depositors, but no one knows the type of each project and the type of each depositor. The bank(s) offer a take-it-or-leave-it contract to an entrepreneur. If the contract is signed, the bank(s) will invest I_1 units of money into the project during period 1.
- Date 1: The entrepreneur learns the type of the project. If the entrepreneur stops the project (liquidation), he gets a private benefit $b_1 > 0$ and all the banks observe the liquidation of the project. However, unless a project is stopped by the entrepreneur the bank(s) still does (do) not know the type of the project and further I_2 units of money are invested. Moreover, the bank(s) will know the distribution of their own project better than before as its private information, i.e., λ_m, is more accurate than the prior λ.
- Date 2: The type of a project becomes public knowledge:
  - If a project is of a good type, a further I_3 will be invested.
  - If a project is of a bad type, a decision whether to liquidate or to reorganize has to be made.
    - If a project is liquidated the bank(s) get(s) zero and the entrepreneur gets b_{2b}; otherwise,
    - if a project is reorganized, I_3 will be invested.
- Date 3: All projects are completed,
  - for a good project, return Y goes to the bank(s), the entrepreneur gets b_{3g};
  - for a bad project, return X goes to the bank(s), the entrepreneur gets b_{3b}.

If a project is a good one, it generates a high return Y no matter how it is financed. For a bad project, we suppose that there are several strategies to reorganize it during the third period, but only one of these strategies can generate X, which is ex post profitable. However this strategy can only be selected and implemented when all the involved bank(s) is (are) in agreement.

Under single-bank financing, given that the earlier investments are sunk, the bank will choose an ex-post efficient strategy to reorganize the project such that the payoff is greater than the ex-post cost of refinancing, I_3. As a result, the bank is unable to commit to terminating a bad project ex post.

Moreover, the fact that the bank is not able to commit to terminating a bad project affects the entrepreneur's ex-ante incentives to reveal information. When the entrepreneur at date 1 discovers that his project is a bad one, he anticipates that the project will still be continued and refinanced by the bank at date 2 as long as it lasts until then. Consequently, if he decides to quit the project, he gets private benefit b_1; if he decides to continue the project,

the bad project will always be refinanced by the bank and will generate a private benefit $b_{3b} > b_1$ to the entrepreneur. Therefore, the entrepreneur will always choose to continue a bad project after he privately discovers its type. This implies that in an economy where every project is financed by one bank, the information to separate the good projects from the bad ones is available neither to the financier nor to the interbank market at date 1.

However, in the case of multi-bank financing, the asymmetric information and conflicts of interest among the co-financiers related to reorganizing the project incur a cost, F for ex-post negotiations. When this cost, F, is high, the gain from reorganization is less than the total costs, i.e., $X < I_3 + F$. Therefore reorganization is not worthwhile and liquidation will follow.[3]

The commitment to liquidate a bad project at date 2 has a deterrent effect on entrepreneurs who have bad projects. Fearing further losses of his private benefit later, an entrepreneur will choose to quit a bad project as soon as he discovers it is bad. Assuming the observability of liquidation, this result implies that if all projects in an economy are financed by two banks, at date 1 information is available in the interbank market to separate the good projects from the bad projects.

The following lemma summarizes the above results.

Lemma 1 *At date 1, single-bank financing leads to a pooling equilibrium in the interbank market such that good projects cannot be distinguished from bad projects; multi-bank financing leads to a separating equilibrium in the interbank market such that good projects can be distinguished from bad projects.*

To simplify our language in the above lemma, in the reminder of the paper we call an economy under multi-bank financing an economy with hard-budget constraints (HBC); and an economy under single-bank financing an economy with soft-budget constraints (SBC), a term coined by Kornai (1980).

B. Deposit Contracts

We consider a one-good economy. Each depositor's $1 endowment can be stored from one period to the next, without any cost, or it can be invested in a bank which then invests in a project with stochastic technology, yielding a positive expected return in the future as described in the above section.[4]

[3] This is a reduced form of Huang and Xu (1999). It can also be derived from a variation of some other models, such as Dewatripont and Maskin (1995), Hart and Moore (1995), and Bolton and Scharfstein (1996).

[4] To highlight our points, we temporarily abstract government away from the model. The role of government will be incorporated into the model in a later section.

Each depositor's preference is defined as

$$U = \pi_1 u(C_1) + \rho \pi_2 u(C_2),$$

where C_j is the consumption of type j depositor; $j = 1$ being early consumers who consume at $t = 1$ and $j = 2$ being late consumers who consume at $t = 3$; π_j is the probability that a depositor is a type 1 or a type 2 consumer, and $\pi_1 + \pi_2 = 1$; $\rho < 1$ is the discount factor and $\rho(R+1) > 1$, where R is the return from investment, which is to be determined in later sections; and $u' > 0$, $u'' < 0$, and $(Cu')' = u' + Cu'' < 0$.

At date 0, consumers make a deposit decision by solving[5]

$$\begin{aligned} \max_{C_1} U &= \pi_1 u(C_1) + \rho \pi_2 u(C_2) \\ \text{s.t. } 1 &= \pi_1 C_1 + \pi_2 C_2/(1+R) \end{aligned}$$

In general, the first order condition of this problem is $u'(C_1^*) = \rho(1+R)u'(C_2^*)$. Given that $u' + Cu'' < 0$, $\rho < 1$ and $\rho(1+R) > 1$, we have $u'(1) > \rho u'(1) > \rho(1+R)u'(R)$. Consequently, an ex-ante optimal market equilibrium can only be achieved by increasing C_1 and decreasing C_2, that is, $C_1^* > 1$ and $C_2^* < 1 + R$.

As in Diamond and Dybvig, a market equilibrium, in which a bank implements deposit contracts with consumers, can Pareto dominate autarchy; that is for \$1 deposit at $t = 0$, a depositor receives either C_1^* at $t = 1$, or C_2^* at the end of the exercise. The bank holds $\pi_1 C_1^*$ (as cash) at no extra cost, and invests the rest in an illiquid project which yields a higher return. At equilibrium, an early consumer always wants to consume at $t = 1$, but a late consumer has no incentive to withdraw early. This is because when $\rho(1+R) > 1$, the first order condition $u'(C_1^*) = \rho(1+R)u'(C_2^*)$ implies $C_1^* < C_2^*$. Thus for a late consumer a deviation does not pay as long as other late consumers do not deviate.

However, as there is no perfect insurance against liquidity shocks, there may be a bank run equilibrium, that is, a simultaneous deviation of all late consumers. With the presence of an interbank market, the key for the existence of a bank run equilibrium is the possibility that the banks cannot solve their liquidity shortage problems by borrowing from the market. Conditional on this, all late consumers will withdraw at $t = 1$. This paper will focus on a mechanism whereby idiosyncratic shocks can trigger a bank run.

In our multi-bank economy there are N depositors in each bank and the realized numbers of type 1 and type 2 depositors in each bank are random draws from a binomial distribution of π_1 and $\pi_2 = 1 - \pi_1$ respectively.

[5] Here, $u(C_2)$ is the expected utility, because unlike in the Diamond and Dybvig model, in our model there is technological uncertainly.

C. Timing of the Model

Combining the outcome of the banks' investments in projects and the consumers' deposit decisions, the evolved timing of the game can be summarized as follows:

- Date 0: Depositors make a savings decision; the banks make an investment decision regarding how much and in which project to invest.
- Date 1: Early consumers withdraw their money from the banks; late consumers make decisions about whether to withdraw or to keep their deposits in the banks. A bank facing too many early withdrawals either has to borrow from other banks, liquidate premature assets, or face a bank run. All bad projects financed by multi-banks will be liquidated.
- Date 2: All single-bank financed bad projects will be reorganized by the banks.
- Date 3: All projects are completed; banks pay back the interbank loans if they borrowed at date 1; and late consumers collect their rewards.

III. Interbank Market Equilibria and Financial Crises

A. Pooling Equilibrium in the Interbank Market and Financial Crisis

In an economy with single bank financing at equilibrium all projects will last for three periods (an SBC economy), requiring a total investment of $(I_1 + I_2 + I_3)$, that is, at date 1 banks are not able to distinguish between good and bad projects. Moreover, each project's expected rate of return is $R^S(\lambda) = \frac{\lambda Y + (1-\lambda)X}{I_1+I_2+I_3} - 1 > 0$. Thus, with an endowment of N and anticipating the expected withdrawal at date 1, a bank's optimal investment decision is to hold $N\pi_1 C_1^*$ in cash and invest $N(1 - \pi_1 C_1^*)$ in a project at $t = 0$.[6]

We suppose that at date 1 banks in an SBC economy have better information than at date 0 because of their monitoring over one period of time, and this is their private information. This private information is difficult to convey since all banks have an incentive to falsely

[6] With an endowment of N and anticipating the expected withdrawal at date 1, a bank's optimal investment decision is to hold $N\pi_1 C_1^* + l^S$ in cash and invest $N(1 - \pi_1 C_1^*) - l^S$ in k^S projects at $t = 0$, where $l^S \geq 0$ is the amount of excess liquidity a bank puts aside ex ante, and

$$k^S = \frac{N(1 - \pi_1 C_1^*) - l^S}{I_1 + I_2 + I_3}.$$

Ex ante, each bank faces the same problem in planning its liquidity. The total supply of liquidity at date 1 in the economy, for any given l^S, is $M(N\pi_1 C_1^* + l^S)$. The total expected demand for liquidity in the economy is $MN\pi_1 C_1^*$. Thus, at equilibrium we must have $l^S = 0$; which makes the number of projects to be invested by each bank, k^S, being independent from liquidity management. Without a loss of generality, we assume $k^S = 1$.

report if there is a benefit of doing so. Moreover, we suppose that the only public information in the interbank market is the average quality of all the projects financed by all the banks in the market.

Formally, we suppose that at date 1 the manager of bank m $(m = 1, ..., M)$ learns privately that the probability of his project being good is λ_m. Moreover, the rank of the qualities of all the banks' projects is $\lambda_1 < \lambda_2 < \lambda_3 < ... < \lambda_M$, and the average quality is $\overline{\lambda} = \frac{1}{M}\sum_{m=1}^{M} \lambda_m$.

If the total number of early withdrawals at date 1 is smaller than the expected number $\pi_1 N$, a bank will have excess liquidity reserves to lend; if the total number of early withdrawals is more than $\pi_1 N$, however, the bank will face a liquidity shortage; we call this bank illiquid. An illiquid bank may solve its liquidity problem either by borrowing in the interbank market or by liquidating some of its investment prematurely.

In the case of borrowing, an illiquid bank issues a bond in the interbank market. With limited liability, a borrowing bank can only repay the bond if it has a good project. However, given that the market knows only $\overline{\lambda}$, all illiquid banks will be treated in the same way when they borrow. Therefore, all bonds issued by the banks have the same structure: contingent on the realization of the project at date 3, the bond pays,

$$\begin{cases} 1, & \text{if the project is good,} \\ 0, & \text{otherwise.} \end{cases}$$

To highlight our points, we assume that there is a Bertrand competition among lenders such that these banks break even in lending. Hence, given the lenders' belief that the probability that a bank will pay back 1 is $\bar{\lambda}$, the equilibrium bond price is $p^S = \bar{\lambda}$.

For an illiquid bank to raise \$1, it needs to issue $\frac{1}{p^S}$ shares of a bond in the interbank market. Thus, in order to deal with n excessive early withdrawal consumers for an amount of nC_1^*, a total of $\frac{nC_1^*}{p^S}$ shares of bonds should be issued. While the bond structure is the same for all illiquid banks, with the private information about the quality of each bank's project, the borrowing cost for each bank is different. For bank m, with a probability of being able to repay the bond as λ_m, the cost of raising nC_1^* dollars is $\frac{\lambda_m}{\bar{\lambda}}\frac{nC_1^*}{p^S}$, that is, the marginal borrowing cost is $C_B(\lambda_m) = \frac{\lambda_m}{\bar{\lambda} p^S} = \frac{\lambda_m}{\bar{\lambda}^2}$. Therefore, the higher the quality of a bank the higher the borrowing cost. Not surprisingly, $\bar{\lambda}$ has to be relatively high to λ_m to make the expected profit of bank m non negative.

Lemma 2 *An illiquid bank's expected profit will not be negative after borrowing if the average quality of the projects is high, i.e.,* $\bar{\lambda}^2 \geq \frac{\lambda_m(I_1+I_2-I_3)}{\lambda Y+(1-\lambda)X}$.

In addition to borrowing, an illiquid bank can also liquidate part of its assets prematurely to solve its liquidity problem. However, liquidating assets prematurely is costly.

We denote the exogenously given marginal cost of raising cash through liquidating premature assets as C_L.[7] Given the cost C_L, only the banks that have a non-negative net return after liquidating some of their assets, i.e.,

$E\left(\tilde{R}\right) = [(1-\lambda_m)X + \lambda_m Y - C_L n C_1^*] - I_1 - I_2 - I_3 - [(1-\pi_1)N - n]\, C_2^* \geq 0,$

view the option of liquidating some of their assets as desirable.

In general, at date 1 a solvent illiquid bank will compare C_B with C_L to decide how to raise cash. When $C_B \leq C_L$ then it will borrow; otherwise, it will liquidate some of the premature assets.

We suppose that there are $\bar{m}$ banks facing liquidity shocks. In order to highlight our points in a simple way, we assume that $\lambda_m = \lambda_{m-1} + \mu$ for all $m = 1, 2, ..., \bar{m}$; and that C_L is the same for every bank. Denoting $\bar{\lambda}_{\bar{m}} = (\sum_{i=1}^{\bar{m}} \lambda_i)/\bar{m}$, the following Lemma provides a condition for the proof of a contagious bank run.

Lemma 3 *With $\lambda_m = \lambda_{m-1} + \mu$, then $C_B(\lambda_{\bar{m}}) = \frac{\lambda_{\bar{m}}}{\bar{\lambda}^2_{\bar{m}}} \leq \frac{\lambda_{\bar{m}-1}}{\bar{\lambda}^2_{\bar{m}-1}} = C_B(\lambda_{\bar{m}-1})$, for $\bar{m} \geq 2$, and $\mu > 0$.*

Proposition 1 *If $C_B(\lambda_{\bar{m}}) = \frac{\lambda_{\bar{m}}}{\bar{\lambda}^2_{\bar{m}}} > C_L$, then there may be a contagious bank run equilibrium.*

Proof. Let us look at a situation where $\frac{\lambda_{\bar{m}}}{\bar{\lambda}^2_{\bar{m}}} > C_L > \frac{\lambda_{\bar{m}-1}}{\bar{\lambda}^2_{\bar{m}}} > \frac{\lambda_{\bar{m}-2}}{\bar{\lambda}^2_{\bar{m}}} ... > \frac{\lambda_1}{\bar{\lambda}^2_{\bar{m}}}$, that is, the cost for the best bank (with $\lambda_{\bar{m}}$) to issue bonds in the interbank market is higher than the liquidation cost; but the borrowing costs for all other banks are lower than the liquidation cost. Therefore, only the best illiquid bank will withdraw from the interbank market. But the withdrawal of the best bank from the market will lower the average quality of the borrowers in the interbank market such that $C_B(\lambda_{\bar{m}-1}) = \frac{\lambda_{\bar{m}-1}}{\widehat{\lambda}^2} > \frac{\lambda_{\bar{m}}}{\widehat{\lambda}^2} = C_B(\lambda_{\bar{m}})$, where $\widehat{\lambda} = \frac{1}{\bar{m}-1}\sum_{m=1}^{\bar{m}-1} \lambda_m$, according to the above Lemma. Thus, after the withdrawal of the best bank, the second best bank will face $C_B(\lambda_{\bar{m}-1}) > C_L$ and will withdraw from the interbank market. This will cause a further drop in the bond price. Repeating the process, the bond market price will decrease to a level whereby when the type-2 depositors observe this they will infer that all borrowing banks are insolvent. Thus there will be a run on the banks. This will lead to a contagious bank failure. ■

The ratio of $\frac{\lambda_{\bar{m}}}{\bar{\lambda}_{\bar{m}}}$ reflects how much a private evaluation of a project differs from a public evaluation, since $\lambda_{\bar{m}}$ is private information of bank $\bar{m}$ while $\bar{\lambda}_{\bar{m}}$ is public information. It is also a measurement of the heterogeneity of the projects' quality, that is, the more heterogeneous the projects' quality, the larger the difference can be between a private evaluation and a public evaluation. This proposition says that if projects financed by the banks in an SBC economy

[7] To keep the model simple, we treat the liquidiation cost as a reduced form. There is a large literature on the costly liquidation of premature assets to solve a financier's liquidity problem, e.g., see Shleifer and Vishny (1992) and Diamond and Rajan (1999).

have a high enough heterogeneity such that the borrowing cost for the best illiquid bank is higher than the liquidation cost, when there are many banks facing liquidity shocks, then a contagious bank run may be an equilibrium. A basic intuition to explain the result is that the market breaks down due to the asymmetric information generated by the SBCs. When the quality of a good bank is private information and the bank is treated as an average bank in the interbank market, it may find borrowing to be too costly and thus it will withdraw from the market. But this will generate externalities such that the average quality of the borrowers in the interbank market will decrease – which will induce more banks to withdraw from the market until there is a total collapse of the interbank market and a contagious bank run.

Proposition 2 *If* $\frac{\lambda_{\bar{m}}}{\bar{\lambda}^2_{\bar{m}}} \leq C_L$ *and* $\bar{\lambda}^2 \geq \frac{\lambda_m(I_1+I_2+I_3)}{\lambda Y+(1-\lambda)X}$, *then at equilibrium illiquid banks borrow in the interbank market and there is no contagious bank run in an SBC economy.*

Proof. When $\bar{\lambda}^2 \geq \frac{\lambda_m(I_1+I_2+I_3)}{\lambda Y+(1-\lambda)X}$ is satisfied, the banks borrowing in the interbank market will have a non-negative profit. Moreover, $\frac{\lambda_{\bar{m}}}{\bar{\lambda}^2_{\bar{m}}} \leq C_L$ implies that the borrowing cost for the best illiquid bank is below the liquidation cost. Thus, at equilibrium the bank's liquidity problem will be solved through borrowing. And all other illiquid banks will do the same. ■

A low ratio of $\frac{\lambda_{\bar{m}}}{\lambda_{\bar{m}}}$ implies a low heterogeneity of the projects' quality. The condition of $\bar{\lambda}^2 \geq \frac{\lambda_m(I_1+I_2+I_3)}{\lambda Y+(1-\lambda)X}$ means a high average quality of the projects. Specifically, it expresses that the average probability that the projects will be successful is high, and the expected return is high. This proposition says that if projects financed by the banks are more homogenous, such that the borrowing cost for the best illiquid bank (thus for all illiquid banks) is lower than the liquidation cost, and the average quality of the projects is high, then at equilibrium the problems of all illiquid banks can be solved in the interbank market in an SBC economy. Thus, idiosyncratic shocks do not cause a contagious bank run in an SBC economy. The intuition is that when projects are more homogeneous, the asymmetric informational problem is reduced (when projects are perfectly homogeneous, there will be no asymmetric informational problem), thus the best illiquid bank will not face too high of a borrowing cost; with high average quality projects, lenders can afford to lend at more favorable terms to all illiquid banks which reduces their borrowing costs.

These results have implications for the timing of a financial crisis in an SBC economy. When an economy is technically less developed such that most investment projects are characterized by imitations, the uncertainty of projects is low and the bank run contagion condition will not be satisfied. When an SBC economy is more developed such that a large proportion of investment projects consists of high-tech or R&D-intensive projects which are more uncertain, the bank run contagion condition is satisfied.

B. Separating Equilibrium in the Interbank Market and Bank Runs

In an economy with multi-bank financing (an HBC economy), at equilibrium all bad projects are stopped at date 1, and good projects will be completed.

To meet an expected number of early withdrawals a bank's optimal investment decision is to store cash in the amount of $N\pi_1 C_1^*$, and to invest all the rest — in the amount of $N(1-\pi_1 C_1^*)$ — into projects; each project is jointly invested with another bank, which will generate an HBC mechanism that liquidates bad projects at date 1.

Without a loss of generality, we suppose that each bank invests in k projects and invests $(I_1+l)/2$ in each project, where I_1 is a new project's initial investment; l is the liquidity stored for each project; and k and l are to be determined endogenously later. At $t=1$, a bank can sell its extra liquidity in the interbank market when uncertainties are realized; or a bank needs to borrow if it has more than expected good projects or it faces liquidity shocks. Thus, with an endowment of N, a bank can invest up to $N(1-\pi_1 C_1^*)$ in k real projects at $t=0$, where

$$k = \frac{2N(1-\pi_1 C_1^*)}{I_1+l}.$$

Each bank optimally chooses l to maximize its expected returns. That is,

$$\max_{l} \frac{2N(1-\pi_1 C_1^*)}{I_1+l}\left\{\lambda\left[Y - I_1 - l - \frac{(I_2+I_3-l)}{p}\right] + (1-\lambda)\left(\frac{l}{p} - I_1 - l\right)\right\}, \quad (1)$$

where, p is the price for liquidity. Banks trade liquidities in the interbank market at a price p for each share of bonds, where each share will be paid \$1 at date 3.

From the first order condition of the above program and the market clearing condition

$$\lambda(I_2+I_3-l) = (1-\lambda)l,$$

we have liquidity price,

$$p^* = \frac{I_1+\lambda(I_2+I_3)}{\lambda Y} \leq 1;$$

and liquidity reserves for each project,

$$l^* = \lambda(I_2+I_3).$$

At (l^*, p^*) the ex-ante (at date 0) expected rate of return of a project, R^H, is,

$$\begin{aligned} R^H &= \frac{1}{I_1+l^*}\left\{\lambda\left[Y - I_1 - l^* - \frac{(I_2+I_3-l^*)}{p}\right] + (1-\lambda)\left(\frac{l^*}{p} - I_1 - l^*\right)\right\} \\ &= \frac{\lambda Y}{I_1+\lambda(I_2+I_3)} - 1. \end{aligned}$$

In an efficient interbank market, where there is no extra cost of trading liquidity, R^H should be the same as the rate of return in trading liquidity at price p^*,

$$\frac{1}{p^*} - 1 = \frac{\lambda Y}{I_1+\lambda(I_2+I_3)} - 1.$$

Thus, no bank has an incentive to deviate from (l^*, p^*): ex ante holding more than l^* liquidity for a later selling (at $t=1$) in the interbank market will not generate a better expected return;

nor will holding less than l^* liquidity and investing more in projects generate a better return. The following Lemma records these results.

Lemma 4 *At equilibrium the liquidity price is* $p^* = \frac{I_1+\lambda(I_2+I_3)}{\lambda Y}$*; the amount of liquidity reserves for each project is* $l^* = \lambda(I_2 + I_3)$*; and the ex-ante expected rate of return for each project is* $R^H = \frac{\lambda Y}{I_1+\lambda(I_2+I_3)} - 1$.

In the event that a project is bad and aborted at date 1, liquidity $\frac{1}{2}l^*$ is saved, which the bank may sell in the interbank market to earn a higher return. If a project is good and to be continued at date 1, it will need $\frac{1}{2}(I_2 + I_3 - l^*)$ further liquidity to be completed. When a bank faces j good projects and $k - j$ bad projects, its balance of liquidity is,

$$\frac{1}{2}(k-j)l^* - \frac{1}{2}j(I_2 + I_3 - l^*) = \frac{1}{2}(k\lambda - j)(I_2 + I_3).$$

Obviously, without a liquidity shock a bank is a net liquidity provider to the interbank market if it has more bad projects, i.e. $k\lambda > j$, than the average in the banking system. Otherwise, it is a net liquidity borrower.

When there are excessive early withdrawals, i.e., the number of early withdrawals is greater than $N\pi_1 C_1^*$, given that the demand deposit contract requires that $C_1^* > 1$ and $C_2^* < 1 + R^H$, which implies that

$$\frac{C_2^*}{C_1^*} < 1 + R^H = \frac{1}{p^*},$$

it costs the bank

$$\frac{C_1^*}{p^*} - C_2^* = C_1^*\left(\frac{1}{p^*} - \frac{C_2^*}{C_1^*}\right),$$

at $t = 1$ to finance each excess early withdrawal. The expected return rate of a bank at date 1 when there are j good projects and n excess early withdrawals is

$$\begin{aligned} R_1^H &= \frac{1}{\frac{1}{2}k[I_1 + \lambda(I_2 + I_3)]}\left(\frac{1}{2}jY - \frac{(j-k\lambda)(I_2+I_3)}{2p^*} - nC_1^*\left(\frac{1}{p^*} - \frac{C_2^*}{C_1^*}\right)\right) - 1 \\ &= \frac{\frac{1}{p^*}\left(j\left(Yp^* - (I_2+I_3)\right) + k\lambda(I_2+I_3)\right) - 2nC_1^*\left(\frac{1}{p^*} - \frac{C_2^*}{C_1^*}\right)}{k[I_1 + \lambda(I_2+I_3)]} - 1. \end{aligned}$$

A negative excess early withdrawal number, i.e., $n < 0$, represents less than the expected early withdrawals, which implies an extra liquidity provision. It is intuitive and straightforward to see that R_1^H increases with the number of good projects, j, and decreases with the number of excess early withdrawals, n.

To highlight our points, we restrict our interests to cases where the total number of depositors in each bank, N, is large, the quality of projects, λ, is not too low, and the proportion of early type consumers, π_1, is not so large that $2\lambda^2 N(1 - \pi_1 C_1^*) \geq 1$; and $\pi_1 C_1^*$

is different enough from 1 such that $\frac{\lambda Y - I_1 - \lambda(I_2+I_3)}{\lambda Y C_1^* - C_2^*(I_1+\lambda(I_2+I_3))} \geq \frac{(1-\pi_1)}{(1-\pi_1 C_1^*)}$.[8] Then we have the following results.[9]

Lemma 5 *In an HBC economy,*

1. When the realized quality of a bank's projects is not worse than the average level (e.g., $j \geq k\lambda$), the bank is always solvent regardless of the presence of liquidity shocks.
2. When there are no excess early withdrawals (e.g., $n \leq 0$) a bank is always solvent regardless of the presence of technological shocks.

The first result says that when a bank's projects are not worse than average, the present value of the projects' returns will be enough to cover the cost of borrowing to deal with excessive early withdrawals even in a case where all depositors withdraw at date 1. Therefore, given symmetric information about the quality of a bank assets in the market, this bank will be able to borrow at the market rate to solve its liquidity problem. The second result says that when there are no excess early withdrawals, even in the worst case where a bank has no single realized good project, the return from selling liquidity at the market rate will keep the bank solvent.

The above results are based on the existence of an efficient interbank market which redistributes liquidities among banks according to the ex-post realized shocks. The efficiency of an interbank market is the result of an HBC mechanism in the banking sector that generates symmetric information among banks.

Lemma 6 *A bank becomes insolvent when it has no good projects and too many excess early withdrawals such that* $n \geq \frac{I\left(Y(I_2+I_3)-I^2\right)}{2\left(YC_1^*-C_2^*I\right)}$, *where* $I = I_1 + I_2 + I_3$.

Under a separating equilibrium solvency is public information in the interbank market; an insolvent bank will not be able to borrow in the market and thus faces a bank run. In general, given R_1^H decreases in n and increases in j, banks with a large enough n and small enough j will be unable to solve the liquidity shortage problem in the interbank market and thus will be subject to bank runs. However, due to the symmetric information in the interbank market, their bank runs do not have externalities, i.e. they will not affect the borrowing of the solvent banks in the market. Thus, bank runs are not avoidable but they are contained. The following proposition summarizes these results.

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[8] Given $p^* = \frac{I_1+\lambda(I_2+I_3)}{\lambda Y} < 1$ and $\frac{C_2^*}{C_1^*} < \frac{1}{p^*}$, $\lambda Y C_1^* - C_2^*\left(I_1 + \lambda\left(I_2 + I_3\right)\right) > 0$.

[9] The above restrictions are only for presentation purposes. Relaxing them will not alter the results qualitatively but make the presentation messier.

Proposition 3 *In an HBC economy a bank run occurs only in banks that face both severe technological shocks and liquidity shocks, but a contagious bank run in the banking system does not occur.*

An HBC mechanism generates symmetric information among banks. With the symmetric information the interbank market should be able to provide liquidity to all illiquid banks that are not hit too badly by technological shocks. As a result, although a bank run cannot be completely avoided, a contagious bank run does not occur in an HBC economy. In sharp contrast, in an SBC economy where information about the quality of bank investments is private to each bank alone, the interbank market is a lemon market. As a result, a bank run can be avoided completely when the projects are homogeneous; or there can be a contagious bank run equilibrium when the projects are heterogeneous and there are liquidity shocks.

IV. Lender of Last Resort and Bail-Out Trap

When there is an interbank market failure and costly early liquidation of premature assets, it may be desirable for the government to do something to stabilize the interbank market and to stop a contagious bank run. However, the problem in an SBC economy is that the government also faces an adverse selection problem.

In this section, we examine government policies from the perspective that these policies should minimize social welfare losses, defined as the sum of the costs of bank runs and policy implementation. We show that in an SBC economy, without reforming the financial institution, the best that the government can do is to rescue all the banks regardless of their quality, but this creates more commitment and moral hazard problems in the banking system.

In the economy, the government's role is to be the lender of the last resort (LOLR) by providing liquidity to illiquid banks.[10] The government, however, also faces an informational problem in that, like the interbank market, it only has imperfect information about the solvency of each bank and it is not able to distinguish good banks from bad banks, particularly during periods of crisis.[11] In reality, many central bankers indeed express their frustrations in trying to identify the solvency of illiquid banks. Unlike the interbank market, however, the government (or central bank) can deal with a market failure problem more effectively by providing a large amount of liquidity within a short time.

[10] Goodhart and Huang (1998) and Freixas (1999) model the LOLR. Allen and Gale (1998) analyze the LOLR in financial crises. These models do not deal with moral hazard problems as consequences of bailing out.

[11] We make this extreme assumption to highlight our points. Our model's qualitative results will still hold if we allow the government to have better, but not perfect, information than the market about the quality of the banks.

Focusing on the informational problem faced by the government and noting that the only asset an illiquid bank has is its investment in a risky project, we model LOLR loans as the government selling bonds to illiquid banks, with the banks' investments in the risky projects as (implicit) collateral. We suppose that the government's perception that the probability that an average illiquid bank will be able to repay is λ_G, the government will sell the bond at a price of p^G to the illiquid bank, and the bank repays the bond at date 3 contingent on the realization of the project,

$$\begin{cases} 1, & \text{if the project is good,} \\ 0, & \text{otherwise.} \end{cases}$$

Given the government's perception of the probability that an average bank can pay back is λ_G, bond price $p^S = \lambda_G$ may allow the government to break even.[12]

By setting bond price p^G the government can affect the operation of the interbank market. Moreover, by setting a higher price, i.e. $p^G > \lambda_G$, the government can provide subsidies (cheaper loans) to illiquid banks. However, as long as the government is not able to differentiate the quality of the illiquid banks, there will be only one bond price, p^G, for all illiquid banks. Thus, a better illiquid bank still faces a higher marginal cost of borrowing than an average bank. Specifically, the marginal cost of borrowing a government bail-out bond for a bank m with a quality of λ_m is

$$C_B = \frac{\lambda_m}{\lambda_G p^G}.$$

Obviously, C_B increases with the quality of the banks, i.e., with λ_m.

It is easy to see that for a given λ_G and C_L (marginal cost of liquidating premature assets), if p^G is not high enough there exists a $\lambda^* \equiv p^G C_L \lambda_G$, such that for $\lambda_m > \lambda^*$, $C_B > C_L$. That is, none of the banks with $\lambda_m > \lambda^*$ will accept the government bail-out bond (at price p^G) but will chose to liquidate their premature assets at a marginal cost C_L. However, unlike the case of no government intervention, the liquidation of premature assets by better banks will not lead to the collapse of the interbank market as long as the government has enough reserves to support the fixed bond price p^G.

We suppose that the government's objective is to select a bail-out strategy to halt bank runs with a minimum of social costs. Without knowing each bank's risk profile, the government should set p^G high enough to avoid social costs incurred by the liquidation of better assets by the better banks. However, this implies that all the illiquid banks will be bailed out. We call this a bail-out trap.

Proposition 4 *In an economy with single-bank financing, if a government has enough reserves but does not improve the banks' commitment capacities, the best the government can*

[12] The assumption that government is allowed to break even is a benchmark case. It is straightforward to change this into a case where the government has a fixed buget to bail out the banks.

do is to bail out all illiquid banks indiscriminately. This will prevent a bank run but will also produce a commitment problem in the economy.

A fundamental reason for such a bail-out trap is the commitment problem of banks in an economy which generates lemon problems in the banking system. The government's soft-budget policy will induce more moral hazard problems for bank managers. In the end, the economy becomes a victim of the government's LOLR policy which induces moral hazard problems and softens budget constraints in the banking sector.

A scheme which induces stronger banks to seek government assistance, while leaving weaker banks to deal with bank runs, requires the government to reverse its bond payment scheme such that a borrower in a deteriorating state should pay more than one in a good state. However, such a policy is not feasible as long as a failed bank has limited liability when it faces a run or goes bankrupt. Perhaps this is why in reality we never encounter such a government policy to deal with various banking crises, such as policies related to deposit insurance and the discount window.

The major obstacle which causes the failure of the interbank market and the malfunction of the LOLR policy is an informational problem. One may wonder whether the problem can be avoided if the government has a better-designed LOLR policy. Specifically, it may be interesting to examine whether the LOLR policy can be used as a screening device by the government in an SBC economy to sort out its informational problem so that solvent illiquid banks can solve their liquidity problems in the interbank market.

Intuitively, in this scheme, an LOLR policy is divided into two parts: providing liquidity and screening banks. Here, we focus on screening banks. Instead of targeting solvent banks, the central bank's LOLR package targets insolvent banks. The bail-out scheme is such that the central bank bond is distributed to any bank that asks for help. The bond is associated with a profit tax, in that all the profits of a solvent bank will be taken away, thus making such help not worthwhile for a solvent bank. However, without a profit, an insolvent bank does not expect to pay anything to get help from the central bank. Thus, all the insolvent illiquid banks will ask for help and all the illiquid banks left in the market will be solvent banks. Although the above scheme might be 'optimal' since only illiquid banks need to be bailed out by the government, this 'optimal' LOLR policy still leads to a bail-out trap.

In the above analysis the government has unlimited resources to bail out all the troubled banks, thus a bank run can still be averted. If the number of illiquid banks is large and the government has a binding budget constraint to deal with them, the government is not able to bail out all of them. Given the lemon problem in the banking system, the best the government can do is to bail out the banks randomly. In such a case, contagious risks cannot be eliminated. This is because without knowing the banks' quality and which bank will be

bailed out by the government, late consumers face the uncertainty of losing their deposits. In fact, a government refusal to lend may be interpreted by the market as a bad signal about the bank; this may explain what occurred to Finance One (a large financial institution) in Thailand. Finance One declared bankrupt in June 1997 after being denied help from the government, which in turn triggered a contagious bank run before the currency crisis (Corsetti, Pesenti, and Roubini, 1998).[13]

Thus, we have the following corollary:

Corollary 5 *In an SBC economy, if the government does not have enough capacity to bail out all the illiquid banks, the best the government can do is to bail out the banks randomly; as a result, there may be a contagious run on all those banks that do not receive government assistance.*

In contrast, in an HBC economy both the market and the government are aware of the quality of the illiquid banks. Thus, if there is a need for the government to intervene, for instance because of unexpected liquidity shocks, the government is able to bail out only the solvent illiquid banks. Therefore, in addition to the higher efficiency of the government rescue plan, there is less of a burden on the government's plan because insolvent banks can be identified and do not need to be bailed out.

Corollary 6 *In an HBC economy, if the interbank bond market cannot provide sufficient liquidity to illiquid banks, the government can always bail out only the solvent banks. Consequently, contagious risks are much smaller than in an SBC economy.*

Our theory also has strong policy implications for the central bank's LOLR policy and financial system reform. With respect to potential moral hazard problems related to the central bank's bail-out policy, it is argued that focusing on large banks, i.e., the too-big-to-fail (TBTF) doctrine of the LOLR (Goodhart and Huang, 1998) and a random LOLR policy (Freixas, 1999), may be preferable. Our theory implies that although a TBTF policy may be optimum when attention is restricted to a short run LOLR issue, it may not be a good policy for the long run. This is because a TBTF policy may distort the bank managers' incentives and thus trigger inefficient bank mergers. When all the banks are large, not only will the TBTF policy not work properly, but a random operation of the LOLR will not be feasible either, since each bank is too large to allow it to fail (what occurred in Japan and Korea may shed some light on this). Even worse, if the number of banks is small in an economy, it is more likely that an SBC problem will prevail. Then the SBC problem will cause a lemon problem in the interbank market, and this may lead to a bail-out trap for the economy. That is, the best that a rational government can do when banks are in trouble in an SBC economy is to bail out all of them

[13] We thank Charles Goodhart for his suggestions regarding this elaboration and for the example.

indiscriminately. Therefore, the optimal LOLR policy should not be isolated from financial institution reforms. In the long run, reforms related to hardening the budget constraints are key to preventing the central bank's LOLR policy from degenerating into an SBC engine.

V. Other Policy Implications

A. East Asian "Miracle" vs. East Asian Financial Crisis

Although our model is very stylized, it sheds some new light on our understanding of financial institutions and financial crises (e.g., phenomena documented by Kindleberger, 1996, and Delhasise, 1999), particularly the recent East Asian financial crisis.[14] The Korean, and Taiwan Province of China (POC), economies are good examples to illustrate that our theory, which links financial crises to financial institutions, is relevant.

Korea and Taiwan (POC) are at similar development stages, geographically close, and they also have similar technologies, labor inputs, and high savings (e.g., high shares of trade in GNP; recent transformations from a traditional economy to one that is oriented toward high-tech). However, while Korea was at the center of the East Asian crisis, Taiwan (POC) had been much less affected. Our explanation for this difference rests on the substantially different financial institutions in the two economies.

It is well documented that Korean development has been characterized by the establishment of large conglomerates (chaebols) through government-coordinated bank loans. In a typical case, financing decisions for projects in Korea are made by the government or by the principal bank among a group of investing banks.[15] Using the language of our model, this institution corresponds to the single-bank financing mode.

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[14] We are fully aware that the East Asian financial crisis involved many other issues, such as exchange rates and international investments, which our model does not discuss. However, we believe that the level of fragility of the financial institutions in those economies created conditions that determined whether moderate exogenous shocks could trigger a financial crisis. Some evidence shows that it was domestic bank runs in Korea that induced a drastic foreign capital outflow – the crisis phenomenon. If so, then our model may be used directly to explain the crisis. In any event, our model increases our understanding of the role of the interbank market in financial crisis.

[15] There is a large literature which documents how the Korean government makes major financing decisions across the economy. For example, in the 1970s the Korean government provided subsidized loans to promote investments in the heavy and chemical industries. In the 1980s, using similar financing approach, the government promoted specialization in the largest chaebols. Related to the government's involvement in financing decisions, after the mid-1970s the Korean government introduced a so-called "principal transaction" banking system. Under this system, the bank that was most involved financially with each chaebol was designated as the principal transaction bank to coordinate all lending activities. Other banks were supposed to follow the financing decisions of the principal bank.

It is also well documented that bankruptcies rarely occurred in Korea prior to the recent financial crisis (particularly in the chaebols); and information about investment quality was often unavailable.[16] Our theory says that single-bank financing leads to a pooling equilibrium in the interbank market, which can result in a financial crisis with moderate idiosyncratic shocks.

With respect to the cause of the financial crisis, it has been claimed by many economists, policy makers, and businessmen that the bankruptcy of several insolvent top chaebols in early 1997 triggered the crisis (e.g., Park, 1997). This observation is consistent with our prediction if the chaebols are viewed as banks and the investors (e.g., creditors) are viewed as depositors in our model. In fact, the chaebols are conglomerates with the functions of financial institutions.

In sharp contrast, Taiwan (POC) firms relied on diversified financial sources and there were frequent bankruptcies in the corporate sector. Inefficient firms were bankrupt, and information about investment quality was available.[17] Our theory predicts that in this economy the interbank market will function well and there should be no financial crisis when there are idiosyncratic shocks (regardless of the strength of the shocks).

Our theory also helps to reconcile the paradox between the East Asian "miracle" in the three decades prior to the mid-1990s and the East Asian "financial crisis" in 1997. In the period of early development, that is, during the catching-up period of the 1960s to the early 1990s, the projects were more homogeneous in terms of uncertainty due to the nature of technological imitation. In this case, our theory predicts that there are no project liquidations and no bank runs in an economy with a pooling equilibrium; that is, an SBC economy appears even to outperform an HBC economy and may attract a large number of investments. However, when an economy is on technological frontiers and attempts major innovations (e.g., South Korea since the early 1990s), the heterogeneity of the projects rises precipitously and the negative effects of an SBC economy are dominant, thus incubating trouble in the financial system.

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[16] From panel data of more than 40,000 Korean manufacturing plants for the 1983 - 93 period, Aw, Chung, and Roberts (1998) discover that the productivity of plants being closed down was about the same as that of those remained operating. This suggests that decisions involving the closure of plants were not related to efficiency considerations, i.e., such closures were not bankruptcies in a usual sense; thus, the observable plant closures did not give much information to investors.

[17] Using a large panel data set Aw et al. (1998) discover that the productivity of closed-down (disciplined) firms in Taiwan was 11.4 percent to 15.5 percent lower than that of other firms.

B. Transparency and Financial Liberalization

At a more general level, our results are closely related to another important policy issue: the transparency of the financial sector to the market and to the government. A widely held view emphasizes that policies can improve the transparency of financial institutions. However, the lessons of centralized economies and the long debate over the viability of centralized economies since the late 1930s (Lange vs. Hayek) both tell us that it is impossible to have transparency in all aspects of any economy. In light of such an impossibility, a key issue is which aspects are to be made transparent and how. Moreover, not only is it impossible to have transparency in all aspects of an economy, our theory suggests that targeting the wrong aspect of an economy to improve transparency can make things even worse.

Hayek (1945) outlined a principle according to which it is the market, not the government, that provides the right information for the economy to run efficiently. But what this means in the context of financial crisis is unclear. One of our major contributions is that we provide a model to illustrate that an HBC mechanism makes solvency information transparent to the market and to the government. Thus, it makes the financial market more stable and helps the government to intervene correctly when necessary.

Moreover, our theory implies that wrongly targeting transparency can result in disaster. This is because an HBC mechanism relies on the 'non-transparency' of the co-financiers' information regarding the reorganizing of a bad project. If this condition is changed but all other conditions remain the same due to a wrong policy, then the HBC mechanism is destroyed such that all the bad projects will be reorganized even when they are financed jointly.

To summarize, the essential message of our theory regarding this issue is that a key policy to improve transparency correctly and effectively may not be a policy which directly targets information, but a policy which hardens budget constraints or a policy which lowers the institutional costs of multi-financier financing.

Another important policy issue concerns the liberalization of financial institutions. To analyze this, we can change our model from an M-bank economy to a one-bank economy. According to our theory, a one-bank economy must be an SBC economy. Moreover, because all the deposits in the economy are pooled in one bank, there are no idiosyncratic liquidity shocks or technological shocks. Thus, although inefficient, this one-bank economy is almost immune from bank runs or financial crisis if there is no systemic shock.

Unlike the one-bank economy, an M-bank SBC economy is very sensitive to a contagious bank run due to the lemon problem in the interbank market. This comparison has important implications for policies/reforms of the banking system. The basic message is that the liberalization of financial institutions must be contingent on measures to harden budget

constraints. If liberalized banks are operating under an SBC, a liberalization policy alone may greatly destabilize the financial system! This simple analysis captures some characteristics of the reform/liberalization of banking systems. For instance, a major reform measure in the transition from a centralized economy to a market economy is to change the banking system from a one-bank system (at least conceptually one can regard all state banks as branches of one bank — the state bank) to a multi-bank system. Many of the banking system liberalization reforms in East Asia prior to 1997 were carried out in this spirit. According to our theory, a banking system reform designed to enhance competition as described above can induce huge contagious risks to the system if simultaneously the system is not designed to harden budget constraints.

C. Corruption and Financial Crisis

To highlight our points, in our basic model we assume that there is no corruption in the economy. All the problems are generated from corruption-free and 'pure' economic institutions. Now we relax this assumption to look at how corruption affects financial institutions and the likelihood of a financial crisis.

There are two aspects of corruption that can be introduced into our model to generate relevant results. The first aspect is that corruption itself can be a mechanism of an SBC (Shleifer and Vishny, 1993); that is, when it is discovered that a project is a bad one at date 2, in a corrupted economy firms and/or financial institutions have the option of bribing the government to bail out the project regardless of profitability (the option will be even stronger if bailing out a project is ex post profitable). Thus, with the presence of corruption there will be a more serious SBC syndrome. Moreover, with serious corruption it may be very difficult for a multi-financier institution, e.g., an equity market, to operate due to the lack of contract enforcement and the lack of transparency in the market. As a result, HBC mechanisms may be destroyed or HBC banks may be out-competed by corrupted banks.

If the impact of corruption is restricted to the above aspect, all of our theoretical results will be qualitatively unchanged. However, there is another aspect of corruption that can enter into our model; that is, corruption can affect the selection of projects. It turns out that with this aspect in our model the timing and likelihood of a financial crisis can be changed significantly.

To illustrate this, suppose that at date 0 there is asymmetric information such that entrepreneurs know the distribution of the projects better than the banks; moreover, some risky projects may be beneficial to some entrepreneurs. In a corrupted economy an entrepreneur may bribe the bank so that the project will be financed. In that case, the selected projects will be more heterogeneous than the corruption-free projects. Thus, many high-risk projects may be selected even in a less developed economy. When corruption not only results in

more serious SBC problems but also results in the selection of more risky projects, then our theory predicts that the economy will be more likely to encounter a financial crisis than a corruption-free economy regardless of the stage of development. This may help explain the financial crisis in some economies where corruption is regarded as a serious problem, such as Thailand.

VI. Conclusions

This paper endogenizes contagious risks and financial crises from financial institutions. We begin our analysis by deriving a pooling equilibrium in the interbank market from single-bank financing and a separating equilibrium in the interbank market from multi-bank financing. Then we show how a pooling equilibrium in the interbank market generates a "lemon" problem. The lemon problem in the interbank market makes the costs of borrowing high for strong banks when they face liquidity shocks. This leads them to leave the interbank market and to rely on liquidating premature assets to solve their problems. However, with their withdrawals from the interbank market the quality of the market will deteriorate, further exacerbating the lemon problem, and leading more good banks to withdraw from the interbank market – further worsening the quality of the market. This process can lead to a collapse of the entire interbank market. In contrast, financial institutions involved in joint financing generate a separating equilibrium in which information about the quality of the banks is disclosed to the entire banking system in a timely manner. This allows the interbank market to function effectively in providing loans to illiquid but solvent banks. Thus, solvent banks will be rescued and financial crisis avoided.

Our model extends Diamond-Dybvig's seminal insight regarding a run on a single bank to a contagious banking crisis in the banking system of multi-banks. To our knowledge, our paper is the first to model a contagious banking crisis mechanism through an interbank market failure caused by endogenized informational problems.

The presence of insolvent banks, as well as an informational problem in the banking system, pose a great challenge to the government's lender-of-last-resort policy. From our theory, we derive that the best a government can do to prevent a financial crisis in an economy with a pooling equilibrium in the interbank market is to bail out all illiquid banks. However, this will lead the economy to a bail-out trap. Another important policy implication from our theory for financial system reform and for a financial-crisis-prevention policy concerns the transparency of the banking system. However, transparency cannot be achieved by imposing government regulations alone; instead, it can only be achieved by reforming the financial institutions to harden budget constraints at the micro level.

The recent Asian financial crisis, in particular the sharp comparison between Taiwan (POC) and Korea, provides evidence consistent with our theory on the importance of financial institutions in generating or containing financial crisis. Moreover, our theory helps to reconcile the ostensible paradox between the East Asian "miracle" in the three decades prior to 1997 and the East Asian "financial crisis" in the period after 1997. Our theory provides a formal explanation for the observations and insights of the East Asian financial crisis as runs to the economies, like bank runs, made by Radelet and Sachs (1998). Chang and Velasco (1998b) also treat the East Asian financial crisis as runs to the economies and they focus on systemic shocks in an open economy model with one bank. In contrast we focus on institutional conditions leading to these kinds of runs when there are only idiosyncratic shocks. It turns out that some of the conditions are related to a banking moral hazard problem, which is consistent with Krugman's (1998) intuition regarding the Asian crisis. However, we also show that a banking moral hazard problem alone does not create a financial crisis.

Our model deals with financial crisis in a closed economy. By incorporating exchange regimes, Chang and Velasco (1998a) examine an open economy with the banking sector which is also based on the Diamond and Dybvig framework. They show that some random systemic exogenous shocks can cause a financial crisis. We regard that model as complementary to ours. We hope to extend our model to an open economy in our future research.

Appendix

Proof of Lemma 2: A bank's non-negative expected return condition is

$$E(\mathfrak{R}) = (1-\lambda_m)X + \lambda_m Y - I_1 - I_2 - I_3 - [(1-\pi_1)N - n]\, C_2^* - \frac{\lambda_m}{\bar{\lambda}} \frac{nC_1^*}{p^S} \geq 0.$$

Thus the lower bound of the bond price is,

$$\underline{p} = \lambda_m n C_1^* / \left\{ \bar{\lambda} \left[(1-\lambda_m)X + \lambda_m Y - I_1 - I_2 - I_3 - ((1-\pi_1)N - n)\, C_2^* \right] \right\}.$$

Given that all the returns of a bank will be distributed to its late consumers, that is,

$$(1-\lambda)X + \lambda Y - I_1 - I_2 - I_3 = (1-\pi_1)NC_2^*,$$

we have,

$$\begin{aligned} \underline{p} &= \lambda_m n C_1^* / \left\{ \bar{\lambda} \left[(1-\lambda_m)X + \lambda_m Y - I_1 - I_2 - I_3 - ((1-\pi_1)N - n)\, C_2^* \right] \right\} \\ &= \lambda_m n C_1^* / \left\{ \bar{\lambda} \left[(\lambda_m - \lambda)(Y-X) + nC_2^* \right] \right\}. \end{aligned}$$

Using the following relationships,

$$C_1^* > 1, C_2^* < 1 + R^S(\lambda), \text{ and } R^S(\lambda) = \frac{\lambda Y + (1-\lambda)X}{I_1 + I_2 + I_3} - 1,$$

we have

$$\begin{aligned} \underline{p} &= \frac{\lambda_m C_1^*}{\bar{\lambda}} \frac{n}{nC_2^* + (\lambda_m - \lambda)(Y-X)} \\ &\geq \frac{\lambda_m}{\bar{\lambda}} \frac{n\,(I_1 + I_2 + I_3)}{n\,(\lambda Y + (1-\lambda)X) + (\lambda_m - \lambda)(Y-X)} \\ &\approx \frac{\lambda_m\,(I_1 + I_2 + I_3)}{\bar{\lambda}\,(\lambda Y + (1-\lambda)X)}. \end{aligned}$$

Only when $\underline{p} \leq \bar{\lambda} = p^S$ the illiquid bank will have a non-negative expected profit after borrowing. This will be satisfied if

$$\begin{aligned} \bar{\lambda}^2 &\geq \frac{n\lambda_m\,(I_1 + I_2 + I_3)}{n\,(\lambda Y + (1-\lambda)X) + (\lambda_m - \lambda)(Y-X)} \\ &\approx \frac{\lambda_m\,(I_1 + I_2 + I_3)}{\lambda Y + (1-\lambda)X}. \end{aligned}$$

■

Proof of Lemma 3: With $\lambda_m = \lambda_{m-1} + \mu$ and $\underline{\lambda} = \lambda_1$, we have

$$\begin{aligned} &\lambda_m = \underline{\lambda} + (m-1)\,\mu; \\ &\textstyle\sum_{m=1}^{\bar{m}} \lambda_m = \underline{\lambda}\bar{m} + \frac{1}{2}\mu\,(\bar{m}-1)\,\bar{m}; \\ &\bar{\lambda}_{\bar{m}} = \frac{1}{\bar{m}} \textstyle\sum_{m=1}^{\bar{m}} \lambda_m = \underline{\lambda} + \frac{1}{2}\mu\,(\bar{m}-1). \end{aligned}$$

Thus,

$$\begin{aligned} \frac{\lambda_{\bar{m}}}{\bar{\lambda}_{\bar{m}}^2} - \frac{\lambda_{\bar{m}-1}}{\bar{\lambda}_{\bar{m}-1}^2} &= \frac{\underline{\lambda} + (\bar{m}-1)\,\mu}{\left[\underline{\lambda} + \frac{1}{2}\mu\,(\bar{m}-1)\right]^2} - \frac{\underline{\lambda} + (\bar{m}-2)\,\mu}{\left[\underline{\lambda} + \frac{1}{2}\mu\,(\bar{m}-2)\right]^2} \\ &= -\frac{(2\bar{m}-3)\underline{\lambda}\mu^2 + (\bar{m}-2)(\bar{m}-1)\mu^3}{(2\lambda + \mu\bar{m} - \mu)^2\,(2\lambda + \mu\bar{m} - 2\mu)^2} \\ &< 0, \end{aligned}$$

for any $\bar{m} \geq 2$, and $\mu > 0$. ■

Proof of Lemma 5: First, let us look at the case where $j = k\lambda$. When $n \leq n^*$ the zero expected return condition, i.e.,

$$k\lambda Y - 2n^* C_1^* \left(\frac{1}{p^*} - \frac{C_2^*}{C_1^*}\right) = k\left(I_1 + \lambda\left(I_2 + I_3\right)\right)$$

will hold, where

$$n^* = N(1 - \pi_1 C_1^*)\frac{\lambda Y - I_1 - \lambda\left(I_2 + I_3\right)}{\lambda Y C_1^* - C_2^*\left(I_1 + \lambda\left(I_2 + I_3\right)\right)}.$$

Moreover, given $\frac{\lambda Y - I_1 - \lambda(I_2+I_3)}{\lambda Y C_1^* - C_2^*(I_1+\lambda(I_2-I_3))} \geq \frac{(1-\pi_1)}{(1-\pi_1 C_1^*)}$, which implies that $\frac{N(1-\pi_1 C_1^*)\lambda Y - I_1 - \lambda(I_2+I_3)}{\lambda Y C_1^* - C_2^*(I_1+\lambda(I_2-I_3))} \geq N(1-\pi_1)$, we have

$$n^* \geq N(1 - \pi_1).$$

Therefore, the bank is solvent for any $n \leq N$.

Then, let us look at the case where $n = 0$. If $j \geq j^*$ then the zero expected return condition, i.e.,

$$\left(j^*\left(Y\Psi - b\right) + k\lambda b\right) = \Psi,$$

will hold, where

$$j^* = \Psi\left(1 - \lambda^2 2N(1 - \pi_1 C_1^*)\frac{Y\left(I_2 + I_3\right)}{\left(I_1 + \lambda\left(I_2 + I_3\right)\right)^2}\right),$$

and $\Psi = \frac{I_1 + \lambda(I_2 - I_3)}{\lambda Y}$. However, $j^* \leq 0$ given $\lambda^2 2N(1 - \pi_1 C_1^*) \geq 1$. Thus, for any $j \geq 0$ the bank is solvent. ■

Proof of Lemma 6: Under the condition that there is no good project, $j = 0$, but some excessive early withdrawals, $n > 0$, the expected rate of return is

$$R_1^H\left(j = 0\right) = \frac{1}{k[I_1 + \lambda(I_2 + I_3)]}\left(\frac{1}{p^*}k\lambda(I_2 + I_3) - 2nC_1^*\left(\frac{1}{p^*} - \frac{C_2^*}{C_1^*}\right)\right) - 1.$$

It is easy to see that the critical value of n^* which makes $R_1^H\left(j = 0\right) = 0$ is,

$$n^* = \frac{1}{2}k\frac{\lambda\left(1 - p^*\right)\left(I_2 + I_3\right) - p^* I}{C_1^* - C_2^* p^*},$$

where, $C_1^* - C_2^* p^* > 0$ since $C_2^*/C_1^* < 1/p^*$. Since n^* increases in λ, the highest $n_{\max}^*$ is the one at $\lambda = 1$. By substituting p^* and k, we have

$$n_{\max}^* = \frac{I\left(Y(I_2 + I_3) - I^2\right)}{2\left(YC_1^* - C_2^* I\right)}.$$

Thus, for $\lambda \leq 1$, when $n \geq n_{\max}^*$ the expected rate of return is negative. ■

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