Financial Institutions, Financial Contagion, and Financial Crises*

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Revised: May 2002

Abstract

In this paper financial contagion and crises are endogenized through the interactions among corporations, banks and the interbank market. We show that the lack of financial disciplines in a single-bank-financing economy generates informational problems and thus the malfunction of the interbank market, which constitutes a mechanism of financial contagion and may lead to a financial crisis. In contrast, financial disciplines in an economy with diversified financial institutions lead to timely information disclosure from firms to banks and improve the informational environment of the interbank market. With symmetric information in the interbank market, bank runs are contained to insolvent banks and financial crises are prevented. Our theory sheds light to the causes and timing

*We are grateful to William Alexander, Abhijit Banerjee, Peter Clark, Tito Cordella, Charles Goodhart, James Gordon, Nich Hope, R. Barry Johnston, Nobu Kiyotaki, Janos Kornai, Eric Maskin, John Moore, George Pennacchi, Dwight Perkins, Katharina Pistor, Yingyi Qian, Jean-Charles Rochet, and Jean Tirole for helpful comments; to the seminar and conference participants at AEA, EEA, HIID-Harvard, IMF, Illinois, LSE, Stanford, Southampton, USC and Toulouse; and to Nancy Hearst for editorial assistance. The second author thanks the hospitality of the Research Department of the IMF; the support of the CID and the HIID at Harvard, and the CEP at LSE. The usual disclaimer applies.

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of the East Asian crisis, it also has important policy implications on lender of last resort and banking reform.

1. INTRODUCTION

It has been documented that financial crises often accompany problems in financial institutions, probably even more so at some specific stages of development. The recent financial crisis in East Asia, 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, banks 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 constitutes a mechanism for financial contagion and creates conditions for a financial crisis.

Our theory emphasizes the role of financial institutions in explaining financial crises, in particular the recent East Asian financial crisis. Right before the crisis, the East Asian economies had been doing so well that there was a major debate among economists concerning the nature of the "miracle." The breaking out of financial crisis in East Asia presents great challenges to economists and policy makers. A particularly puzzling phenomenon regarding the crisis comes from the comparison between Korea and Taiwan. Korea and Taiwan were both regarded as the major phenomenon of the so-called "East Asia Miracle." However, while Korea was at the center of the East Asian crisis, Taiwan was much less affected — even though it too had been attacked by international speculators.

Is this difference an accident? Our analysis on the functions of corporate and banking institutions will provide an answer to this puzzling phenomenon. Consistent with observations that the financial crisis in East Asia were deeply linked to their corporate financial problems, our theory suggests that different financing structures in East Asian economies generate profound impacts to the information in their financial markets, which further affects financial stability.

Our theory can be summarized as follows. We endogenize information structures in two different kind of economies. In an economy where corporations are financed by multiple banks or through a syndicated loan, liquidation of bad projects/firms becomes a norm in the economy. Liquidation of bad projects makes information public so that the banks have better knowledge about each others' assets and solvency. In the rest of the paper, we term this kind of economy a multi-bank-finance (MBF) economy.

In an economy where financing decisions to corporations are concentrated (e.g. the Japanese main bank system or the Korean principal transaction bank system), however, liquidation of bad projects/firms becomes an exception. Without liquidation of bad projects, banks with bad projects can easily hide bad news from others. We show that in such an economy bad projects are not liquidated and thus the solvency of a financier is not known to other financiers. In the rest of the paper, we call this kind of economy as single-bank-finance economy (SBF).

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. Moreover, there is an interbank market which may solve liquidity shortage problems among banks. That is, when a bank faces a liquidity shock it may borrow from others in the market. The function of the interbank market depends on the information of borrowing banks' asset quality. When an equilibrium is such that bad projects are liquidated, which can be observed by other banks, the interbank can function well and through trading among banks it can solve the liquidity problem faced by illiquid banks.

However, if lending banks in the interbank market are unable to distinguish solvent and insolvent borrowing banks, i.e. there is a pooling equilibrium, all illiquid banks are treated in the same manner. In that case, asymmetric information between financiers will make the interbank lending market a "lemon" market. In this lemon market, all borrowing banks face the same nominal expected cost. This implies that solvent banks will have to subsidize the borrowing of insolvent banks. With private information about one's own solvency, a better-quality borrowing bank will face higher costs of borrowing due to this implicit subsidy.

When a liquidity shock is severe enough, such high borrowing costs can lead a solvent bank to choose between liquidating assets and facing a bank run. We assume that a liquidation implies a poor management while a well managed bank can still experience a bank run due to exogenous liquidity shocks; and bank managers have career concern. Thus, from a bank manager's perspective, a liquidation is worse than a bank run. As a result, illiquid banks with better-quality assets may not borrow and face a bank run earlier than other banks. Moreover, a bank run on better banks will deteriorate the quality of the lending market which may trigger more bank runs by the same logic. We then further demonstrate bank run contagious risks can lead to the collapse of the lending market and thus a financial crisis, in particular when the investment projects are heterogeneous in quality.

We also show that a pooling equilibrium in the interbank market does not always lead to a financial crisis when there are only idiosyncratic shocks and the projects are heterogeneous in quality. This is because the expected borrowing cost for good banks monotonically decreases with the average quality of the projects in the economy and the homogeneity of the projects' quality. If the average quality of the projects is high, and/or the projects are very homogeneous in quality, the interbank market works well and there is no bank run or financial crisis. But when the projects are heterogeneous, as long as the average quality of the projects is not very high, 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. An 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.[1] We show that a certain type of financial institutions (MBF) makes information in the market symmetric; in that case bank runs are contained. A contagious bank run in our model is a result of an interbank market failure due to informational problems, which are caused by the SBF institution. We endogenize the Akerlof's (1970) lemon problem and extend it from real markets to the liquidity market between lenders and borrowers. In a separate paper (Huang and Xu, 2001), we further extend our analysis of banks' liquidity management in a model with interbank market and liquidation of real assets.

von 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 financial crisis, Aghion, Bolton, and Dewatripont (1999) and Allen and Gale (2000) are related to our work, but their emphases are quite different from ours. Aghion, Bolton, and Dewatripont (1999) focus on systemic shocks to the entire banking system. In comparison, financial crises in our model can be caused by idiosyncratic as well as systemic shocks. We study a mechanism of negative externalities in the interbank market that transforms idiosyncratic shocks into a systemic liquidity shock, and thus bank failure contagion. Allen and Gale (2000) derive financial contagion from the incompleteness of the structure

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

of interregional claims. If we reinterpret our interbank market as a form of interconnectedness among all the banks in their model, then we show that even with a complete structure of interregional claims, informational problems in the market can still lead to financial contagion.

Moreover, 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 creditors" is more likely to liquidate bad projects ex-post. The reason is that the costs of renegotiation are higher when there are multi-creditor 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 creditors do not face such high renegotiation costs and thus are more likely to reorganize 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-creditor 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: a SBF economy whereby only a pure pooling equilibrium exists, and a MBF economy whereby only a pure separating equilibrium exists. 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 inspired by Dewatripont and Maskin (1995), Hart and Moore (1995), and Bolton and Scharfstein (1996).

The rest of the paper is organized as follows. Section 2 briefly overviews the financial institutions in Korea and Taiwan. Section 3 establishes the basic structure of the model. Section 4 endogenizes information distributions between banks and corporations and in interbank market. Section 5, in particular subsections 5.3 and 5.4, investigates how bank run contagion are created in a SBF economy and when it can lead to a financial crisis. Finally, section 6 concludes with some qualifications and elaborations of our theory in relation to the existing literature, and discussions of policy implications.

2. FINANCIAL INSTITUTIONS AND CORPORATE FINANCING IN KOREA AND TAIWAN

Korea and Taiwan are at similar development stages, geographically close, and they also have similar technologies, labor inputs, and high savings. In both economies the share of trade in GNP is much higher than the world average; and each economy has been transformed from traditional one into a high tech oriented one. Moreover, both were regarded as the major phenomenon of the so-called "East Asia Miracle." However, while Korea was at the center of the East Asian crisis, Taiwan was much less affected — even though it too has been attacked by international speculators. Is this difference an accident?

In this section we present brief overviews of the Korean and Taiwanese economies to illustrate that their financial institutions are quite different, and how this difference may related to their different performances in the East Asia Financial Crisis.

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. For example, in the 1970s the Korean government promoted investment in the heavy and chemical industries by selecting projects and providing subsidized loans. In the 1980s the government promoted specialization in the largest chaebols through a similar financing approach. In the two decades since the early 1970s, more than half of Korean domestic credits were distributed as government policy loans with low rates (Stern et al., 1995; Cho and Kim, 1995).[2] It is well documented that the decision making

[2] A closely related fact is that Korean firms were over-leveraged as their average debt-equity ratio was among the highest in the world since the 1970s (Borensztein and Lee, 1998; Lee, 1998). Before the outbreak of the 1997 crisis the average debt-equity ratio of thirty top chaebols was about 4.5.

of policy loans were concentrated in the hands of the government.

The subsidized government loans led to distortions in corporate capital structure: between 1965 and 1970, the debt-equity ratio of manufacturing firms in Korea increased from 0.94 to 3.29 (Nam and Kim). To reform the inefficient loan allocation scheme, the Korean government established a credit control system called a "principal transactions banking system" in the mid-1970s. Under this system, the bank which was most involved financially with each chaebol was designated as the principal transactions bank to coordinate all lending activities. Any new credit to be issued by a bank to the chaebol was supposed to be evaluated by the principal bank. However, this principal transactions banking system was not substantially different from the government-coordinated financing scheme. That is, financing decisions were concentrated to either the government or the principle bank.

Although there were complaints that with a predominance of government coordinated bank financing, credits were not allocated efficiently to Korean firms[3], the great success in the period of 1960s to the mid 1990s seems evident. Problems in corporate financing structure only become well noticed to outsiders when the East Asia Financial Crisis hit Korea. Some Korean economists claimed that excessive credit expansions caused 5 of the top 30 and 7 of the top 50 chaebols insolvent; it was documented that the insolvent chaebols had debt-equity ratios from 5.14 to 36 while the average of the 30 top chaebols was about 4.49 in April 1997 (Pak, 1997, p.1). A natural question to address is why creditors would be willing to continue providing credit to insolvent or nearly insolvent chaebols? A closely related fact to the high debt financing is that there was almost no bankruptcy in Korea before 1997

Moreover, a recent econometric work shows that a significant part of the total credit in Korea was not used productively (Demetriades and Fattouh, 1998).

[3] Using panel data of thirty-two Korean manufacturing sectors in the period from 1969 to 1996, Borensztein and Lee (1998) show that credit was allocated preferentially to the sectors with larger firms, with exports, and with worse economic performance. Examining firm level data for the 1984 - 86 period, Dailami and Kim (1994) discover that subsidized credit encouraged chaebols to hold more financial assets and real estate investments, but not actual productive assets.

(particularly for chaebols).

Major Insolvent Chaebols

	Hanbo	Usong	Sammi	Jinro	Taenong	Kia
Asset Ranking	14	27	26	19	33	8
Debt/Equity	6.75	17.1	32.3	36.0	18.2	5.14

Source: Kyong-so Pak (1997), p.1.[4]

Systematic evidence indeed suggests that closing down Korea plants were not related to financial disciplines. From panel data of more than 40,000 Korean manufacturing plants for the 1983 - 1993 period, Aw, Chung, and Roberts (1998) discover that the productivity of plants being closed down was about the same as those in operation. This suggests that decisions involving closure of plants were not related to efficiency considerations.

Comparing with Korea, Taiwan firms relied on much more diversified financial sources. Creditors in Taiwan were not coordinated by the government or other agents (Japanese type of main bank system does not exist in Taiwan). Even state-owned banks were supposed to make financing decisions by their own. Moreover, equity financing played a much larger role in Taiwan – the average debt-equity ratio of all Taiwan firms during the 1985 - 1992 period was about 1.4 and the ratio of the large firms was even lower (about 1.2) (Semkow, 1994, p.84).

Moreover, firms in Taiwan were subject to effective financial discipline and thus there had been frequent bankruptcies in the corporate sector in the past several

[4] Closely related to the inefficiencies of the projects being invested, the losses from projects financed by bank loans caused serious problems for Korean banks. At the end of 1986, nonperforming loans at the five largest commercial banks amounted to three times the total net worth of those banks (Park and Kim, 1994). To relieve the troubled banks, between 1985 and 1987 the Bank of Korea provided them with more than 3 trillion won in subsidized loans (Nam, 1994).

Implicitly complaining about the chronic problem of lack of financial discipline in Korean chaebols, some Korean economists claim that the excessive leveraged expansion ultimately resulted in the insolvency of five of the top thirty chaebols (Park, 1997), thus triggering the financial crisis.

decades. Inefficient firms were indeed disciplined: the productivity of closed-down (disciplined) firms was 11.4 percent to 15.5 percent lower than that of other firms (Aw et al., 1998).

In the rest of the paper, we are going to explain how corporate financing determines financial disciplines of the firms, and how this is related to financial stability.

3. THE MODEL

We consider a one-good economy, which has many entrepreneurs, M banks and bank managers, and $N \times M$ depositors. Entrepreneurs have ideas about new investment projects but no wealth to finance them. In this model any uncertain investment can be a project, such as an investment in technological innovation or imitation. Among all the projects proposed by entrepreneurs, λ percentage of the projects are of good type, and the rest are of bad type. Ex ante, neither entrepreneurs nor banks know which project is good and which project is bad, but they both are fully aware of the probability distribution.

A project takes three periods to finish, requiring a total investment of $I_1 + I_2 + I_3$, where I_t is the required investment in period t, and $I_t \gg 1$. 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.

For a project being financed, we assume that at date 1 an entrepreneur will learn its type, while the bank(s) still will not know the type. However, at date 2, the bank(s) will know the type of the project. If a project is of a bad type, it can be reorganized at date 2 and 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. Therefore, at date 2 a decision has to be made by the bank(s) regarding a bad project: either to reorganize it or to liquidate it.[5]

[5] The setup of the model shares some features with Qian and Xu (1998). But that paper is based on the Dewatripont-Maskin contractual foundation, while this paper establishes a different contractual foundation for the commitment problem.

Concerning reorganization, we assume that there are two strategies a and b to reorganize a bad project during the third period, but only one of them can generate a profit ex post. The decision on a specific strategy the bank(s) selects depends on their information. We suppose that in the case of co-financing, banks A and B will observe different information, represented by signals s_A and s_B respectively, where $s_J \in [\underline{s}, \overline{s}]$, $\underline{s} < \overline{s}$ and $J = A$, B, after I_3 is invested.

We suppose 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 $t = 1, 2, 3$.[6] Specifically, if the entrepreneur quits the project at date 1, he gets a low private benefit, $b_1 > 0$. At date 2, if a bad project is liquidated, the 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 the entrepreneur; in the case of a good project, it will generate a private benefit, $b_{3g} > b_{3b}$, to the entrepreneur. To summarize, we have $b_{3g} > b_{3b} > b_1 > b_{2b} \geq 0$.

In this economy, banks exist because they create liquidity and monitor investments on behalves of small depositors (Diamond, 1984; Gorton and Pennacchi, 1990). Bank managers are hired to manage banks, to make investment decisions, and to monitor bank investments in firms. They are risk-neutral, and do not want to be identified as bad managers (e.g., career concerns).

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; while without liquidation the nature of a project financed by a bank is not observable by another bank that is not involved in the investment and monitoring of the project.

In our economy there are two types of risk-averse depositors, as described by Diamond and Dybvig (1983): early consumers only consuming at $t = 1$, and late consumers only consuming at $t = 3$. Ex ante, all depositors are identical and do not

[6] We use the term private-benefit in such a general way that it includes both rewards and penalties.

become aware of their types until $t = 1$. Moreover, each depositor's \$1 endowment can be stored from one period to the next, without any cost, or it can be deposited in a bank which then invests in a project with stochastic technology, yielding a positive expected return in the future.[7] They make their investment decision based on an ex-ante belief about the riskiness of the banking system and about the market equilibrium return on deposit. They supposedly do not have the required expertise to be entrepreneurs or bank managers, nor do they monitor banks because of high surveillance costs.

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 of a depositor being a type 1 or type 2 consumers, 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 $(Cu^{'})^{'} = u^{'} + Cu^{''} < 0$.

Now we summarize the timing of the game as follows:

- Date 0: All parties know the probability distributions of projects and 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 the entrepreneur. If the contract is signed, the bank(s) will invest I_1 units of money into the project during period 1. Each depositor makes savings decision with a bank.

- Date 1: The entrepreneur learns the type of the project, and may stop the project in case of realizing a bad project. In that case the entrepreneur 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

[7] Note that unlike the Diamond and Dybvig model, which has a positive and deterministic return, in our model the return is stochastic, with an expected positive value.

(do) not know the type of the project and further I_2 units of money are invested into the project. Moreover, the bank(s) will know the probability distribution of their own projects better than other banks. Early consumers withdraw money from the banks, late consumers make their decisions wether to withdraw or to keep deposits in the banks. A bank facing too many early withdrawals has to borrow, otherwise it has to abort the project, resulting in no return.

- 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 it is a bad project, a decision whether to liquidate or to reorganize has to be made.
    - If a project is liquidated the bank(s) gets zero and the entrepreneur gets $b_{2b} < b_1$; otherwise,
    - if a project is reorganized, I_3 will be invested.
- After investing I_3, signals s_A and s_B are observed by the investor(s) and a reorganization strategy is chosen based on the signals.
- Date 3: All projects are completed,
  - for a good project, return Y goes to the bank(s), entrepreneur gets $b_{3b} > b_1$;
  - for a bad project, return X goes to the bank(s), entrepreneur gets $b_{3g} > b_{3b}$;
  - late consumers collect their rewards.

4. FINANCIAL INSTITUTIONS AND INFORMATION DISTRIBUTIONS

In this section we explain how financial institutions can cause informational problems in an interbank market. For more detailed technical results and their proofs, please see Huang and Xu (1999).

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:

- 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.[8]

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).

[8] 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).

5 FINANCIAL CONTAGION AND FINANCIAL CRISES

To make our basic point in the simplest possible way, we abstract government away from our model in the section. We will incorporate the role of government into our model later.

5.1 Deposit Contract

Similar to Diamond and Dybvig, in our model a market equilibrium in which all agents trade can Pareto dominate that of autarchy; but the market equilibrium does not necessarily provide a perfect insurance against liquidity shocks. The main reason in our model is that there may be information asymmetry in the interbank market which can give rise to contagious risks.

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

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

]}An ex-ante optimal market equilibrium can only be achieved by increasing C_1 and decreasing C_2, that is

$$\begin{aligned}
C_1^* &> 1, \\
C_2^* &< 1+R.
\end{aligned}$$

A bank can implement the market solution through a deposit contract a la Diamond and Dybvig. 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. For each dollar it receives as deposit, the bank holds $\pi_1 C_1^*$ (as cash) at no extra cost, and invests the rest in illiquid technology which yields a higher return. As banks are competitive in the economy, at C_1^* and C_2^* banks on average earn zero profit. That is {[

$$\pi_1 C_1^* + (1-\pi_1)C_2^*/(1+R) = 1.$$

]}This ex-ante optimal deposit contract is a pure strategy Nash equilibrium. That is, an early consumer always wants to consume at $t = 1$, but a late consumer has no incentive to withdraw early. This is because as long as $\rho(1 + R) > 1$, $u'(C_1^*) = \rho(1 + R)u'(C_2^*)$ holds if $C_1^* < C_2^*$, and any deviation does not pay, as long as other late consumers do not deviate.

However, there may be a bank run equilibrium, that is, a simultaneous deviation of all late consumers. In this case, the bank has to liquidate its project (which has zero value for simplicity) if borrowing from the interbank market is not possible or too expensive.[9] As a result, the bank will fail and nothing will be left for late consumers when they withdraw later than others. Anticipating this, all late consumers will withdraw at $t = 1$, and a bank run becomes self fulfilling. A key for the existence of a bank run equilibrium is the possibility that a bank cannot solve its liquidity shortage problem by borrowing from the interbank market. This turns out to be a key condition to extend Diamond and Dybvig's framework from a one-bank economy to a multi-bank economy.

In our multi-bank economy the total number of depositors is finite, with N depositors in each bank and the realized numbers of type 1 and 2 depositors for each bank are random draws from binomial distributions of π_1 and $\pi_2 = 1 - \pi_1$ respectively. In the next two subsections, we will analyze financial contagion in MBF and SBF economies. We start from the problem faced by the bank manager in a MBF economy.

5.2 Bank Run in a MBF Economy

Following our results for a MBF economy, at equilibrium all bad projects are stopped at date 1 and all good projects are completed. Therefore, every bank knows that all continued projects are good ones. The ex-ante expected deposit return in

[9] In a separate paper (Huang and Xu, 2001) we allow banks to liquidate illiquid assets to solve their liquidity shortage problems. See Diamond and Rajan (1998) for an analysis of liquidating illiquid assets.

such an economy is:

$$R^M = \frac{\lambda Y - [I_1 + \lambda(I_2 + I_3)]}{I_1 + \lambda(I_2 + I_3)} > 0.$$

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 a project. Every bank co-invests with another bank in one project, given the symmetry of the banks, and the investment is made in the following way,

$$N(1 - \pi_1 C_1^*) = \frac{1}{2}\left[I_1 + \lambda(I_2 + I_3)\right].$$

In the event that a project is a bad one and aborted at date 1, the realized value from the investment is zero. In this case, if there are more than $\pi_1 N + \frac{\lambda(I_2+I_3)}{C_1^*}$ depositors trying to withdraw at date 1, the bank will run out of cash because of the excessive demand for withdrawals. Because it is known that this bank has a bad project and will not be able to pay back its loan, it will not be able to borrow in the interbank market. Thus a bank run can occur with a positive probability in a MBF economy, when there are both technological shocks and liquidity shocks.[10]

Now let us look at the case where a bank manager is informed at date 1 that the project is a good one, which will generate a good positive return at date 3. In this case, when there is an unexpected excess early withdrawals, the bank can borrow from other banks.

As other banks in the interbank market also know that this bank has invested in a good project, they know this bank will definitely generate a return at

$$R_g^M = \frac{Y - (I_1 + I_2 + I_3)}{I_1 + I_2 + I_3} > R^M.$$

In this case, when the bank with a good project faces excess early withdrawals, it

[10] If late consumers can observe the liquidation of bad projects, a bank run will occur for sure after the bank's project is liquidated.

For the sake of simplicity, we do not allow the bank with a bad project to start another project at date 1. Moreover, this setup avoids giving an MBF economy too great an advantage over an SBF economy, which would also divert our focus in the analysis.

can borrow from other banks.[11] Therefore, a bank with good project can solve its liquidity shortage problem by borrowing from other banks so that a bank run is avoided.

Proposition 1 *In a MBF economy, because of symmetric information among banks, a bank run occurs when a bank faces both technological and liquidity shock; but bank-run contagion is not possible.*

The last point of the above proposition is more interesting. A MBF economy does not experience a contagious bank run simply because with symmetric information among banks, the interbank lending market is able to provide liquidity to all illiquid but solvent banks, these that are not hit by technological shocks. As a result, although there are still possible isolated bank runs in a MBF economy, bank-run contagion does not occur.

5.3 Bank Run in a SBF Economy

Following our earlier results, in a SBF economy without a commitment to liquidate bad projects at date 2, entrepreneurs with bad projects will cheat at date 1. Thus, at date 1 banks in a SBF economy do not know the exact type of a project that they are financing. However, we assume that every bank has a better understanding of

[11] The bank can issue a risk-free bond to borrow from other banks. The bond has a face value of \$1 and is sold at price p per share. p is determined by the competitive bank lending market. In equilibrium $R_g^H \geq 1/p$ and there is sufficient demand for such a bond.

From the supply side, since each bank stores $N\pi_1 C_1^*$ amount of cash, there is enough supply of liquidity to meet the total amount of withdrawals of $MN\pi_1 C_1^*$ as long as there is no bank run. Moreover, as some banks will have excess liquidity generated from the termination of bad projects, liquidity supply in the interbank market is plenty. Indeed, banks can improve their ex ante liquidity management because of the excess liquidity available due to termination of bad projects (Huang and Xu (2001) provides further analysis on liquidity management of banks and liquidity equilibrium in an interbank market).

Furthermore, because $C_1^* < C_2^*$, it is not worthwhile for any late consumers to withdraw deposits earlier (at date 1).

the risk of its own project. That is, at date 1, the manager of bank m ($m = 1, ..., M$), through her project-monitoring for one period of time, has better information than at date 0, such that she knows that the probability of her project being a good one is λ_m. But this is her private information. Suppose that the qualities of all banks can be ranked as $\lambda_1 < \lambda_2 < \lambda_3 < ... < \lambda_M$, which is not known by any bank manager, but the average quality of banks, $\overline{\lambda} = \frac{1}{M}\sum_{m=1}^{M}\lambda_m$, is known to all banks.

The ex-ante expected deposit return in such an economy is:

$$R^S = \frac{\lambda Y + (1-\lambda)X - (I_1 + I_2 + I_3)}{I_1 + I_2 + I_3} > 0.$$

Obviously we have $R^S < R^M$.

Anticipating the expected number of early consumers' withdrawal at date 1, a bank's optimal investment decision is to hold $N\pi_1 C_1^*$ in cash and invest $N(1-\pi_1 C_1^*)$. That is, the expected investment of a bank is

$$N(1 - \pi_1 C_1^*) = I_1 + I_2 + I_3.$$

Substituting {[$N = N\pi_1 C_1^* + N(1-\pi_1)C_2^* / (1+R)$ in the above condition, we have

$$N(1-\pi_1)C_2^* / \left(1 + R^S\right) = I_1 + I_2 + I_3.$$

]}

Therefore, if the number of depositors who withdraw at date 1 is no more than the expected number $\pi_1 N$, the bank will have enough cash to handle the withdrawals; however, if the number of early withdrawals is more than $\pi_1 N$, the bank will have to borrow from the interbank market through issuing bond to meet the depositors' demands.

We assume that a borrower has a limited liability. That is, an illiquid borrowing bank can only repay its borrowing 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 borrowing 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 all lending banks 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 $\frac{1}{\bar{\lambda}}$ shares of bonds in the interbank market. Thus, in order to deal with n excessive early withdrawal consumers for an amount of nC_1^*, a total of $\frac{nC_1^*}{\bar{\lambda}}$ 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 each dollar is $\lambda_m \frac{\lambda_m}{\bar{\lambda}}$; and the expected cost of raising liquidity to deal with n excessive early withdrawls is $\frac{\lambda_m^2}{\bar{\lambda}} \frac{nC_1^*}{\bar{\lambda}}$. Therefore, the higher the quality of a bank, or the higher the ratio $\eta_m \equiv \frac{\lambda_m}{\bar{\lambda}}$, the higher the borrowing cost for bank m. Not surprisingly, the ratio η_m should not be too high and $\bar{\lambda}$ should not be too low to make the expected profit of bank m non negative through borrowing.

Lemma 2 *With borrowing in the interbank market,*

1. *a bank with $\lambda_m \leq \bar{\lambda}$ is solvent regardless of number of early withdrawls if $(1 - \lambda_m)X + \lambda_m Y - (1-\pi_1)NC_2^* \geq 0$.*

2. *A good bank with $\lambda_m > \bar{\lambda}$, is insolvent if the total number of excess withdrawals n_m is large enough such that $n_m > \overline{n}_m$, where*
$$\overline{n}_m \equiv \frac{\bar{\lambda}\,(Y-X)\,(\eta_m - 1)\,N(1-\pi_1)\pi_1}{\eta_m^2\,(N-I)\,(1-\pi_1) - \pi_1\left(\bar{\lambda}Y + (1-\bar{\lambda})X\right)}.$$

Proof. A bank's non-negative expected return condition is

$$\begin{aligned} E\,(\mathfrak{R}) &= (1-\lambda_m)X + \lambda_m Y - \left[(1-\pi_1)N - n\right]C_2^* - \frac{\lambda_m^2}{\bar{\lambda}}\frac{nC_1^*}{\bar{\lambda}} \\ &\geq 0. \end{aligned}$$

If $\eta_m = \frac{\lambda_m}{\lambda} \leq 1$, we have $n\left(C_2^* - \eta_m^2 C_1^*\right) > 0$. Then $E\left(\Re\right) > 0$ as long as

$$(1-\lambda_m)X + \lambda_m Y - (1-\pi_1)NC_2^* \geq 0.$$

Second, if $\eta_m = \frac{\lambda_m}{\lambda} > 1$ then substituting η_m in (3), $E\left(\Re\right) = 0$ is equivalent to

$$X - (1-\pi_1)NC_2^* + \lambda_m(Y-X) = \overline{n}_m\left[\left(\frac{\lambda_m}{\bar{\lambda}}\right)^2 C_1^* - C_2^*\right]. \tag{1}$$

The we have the solution for $\overline{n}_m$,

$$\overline{n}_m = \frac{X + \eta_m\bar{\lambda}(Y-X) - (1-\pi_1)NC_2^*}{\eta_m^2 C_1^* - C_2^*}. \tag{2}$$

Recall

$$\begin{aligned} N(1-\pi_1 C_1^*) &= I_1 + I_2 + I_3, \\ N(1-\pi_1)C_2^* / \left(1+R^S\right) &= I_1 + I_2 + I_3. \end{aligned}$$

Or,

$$\begin{aligned} C_1^* &= \frac{1}{\pi_1}\left(1 - \frac{I}{N}\right) \\ C_2^* &= \frac{I\left(1+R^S\right)}{N(1-\pi_1)} \\ &= \frac{\bar{\lambda}Y + (1-\bar{\lambda})X}{N(1-\pi_1)}. \end{aligned}$$

where, $I = I_1 + I_2 + I_3$. Using these conditions in (2), we have

$$\begin{aligned} \overline{n}_m &= \frac{X + \eta_m\bar{\lambda}(Y-X) - (1-\pi_1)NC_2^*}{\eta_m^2 C_1^* - C_2^*} \\ &= \frac{X + \eta_m\bar{\lambda}(Y-X) - \left(\bar{\lambda}Y + (1-\bar{\lambda})X\right)}{\eta_m^2 \frac{1}{N\pi_1}(N-I) - \frac{\bar{\lambda}Y + (1-\bar{\lambda})X}{N(1-\pi_1)}} \\ &= \frac{(Y-X)\left(\eta_m\bar{\lambda} - \bar{\lambda}\right)}{\eta_m^2 \frac{1}{N\pi_1}(N-I) - \frac{\bar{\lambda}Y + (1-\bar{\lambda})X}{N(1-\pi_1)}} \\ &= \frac{\bar{\lambda}(Y-X)(\eta_m - 1)N(1-\pi_1)\pi_1}{\eta_m^2(N-I)(1-\pi_1) - \pi_1\left(\bar{\lambda}Y + (1-\bar{\lambda})X\right)} \end{aligned}$$

It is obvious that $E\left(\Re\right) < 0$ if $n_m > \bar{n}_m$. ■

The intuition behind this lemma is clear. Borrowing from the interbank is equivalent to a subsidy for a bank with $\lambda_m \leq \bar{\lambda}$, while the subsidies are provided by borrowers with $\lambda_m > \bar{\lambda}$. When the costs of subsidies become too high, a good bank becomes insolvent when facing too many early withdrawals.

{[it seems to me the following lemma is not directly related to the major results. if so, we may not include this in the paper]}

Lemma 3 *if $\eta_m^2 C_1^* > C_2^*$, $\partial\overline{n}_m/\partial\bar{\lambda} > 0$, but $\partial\overline{n}_m/\partial\eta_m$ can be positive or negative, depending on whether $n < n^*$ or $n > n^*$, where $n^* \equiv \bar{\lambda}(Y-X)/\left(2\eta_m C_1^*\right)$.*

Proof. $\eta_m = \frac{\lambda_m}{\bar{\lambda}} > 1$ then

$$(1-\lambda_m)X + \lambda_m Y - (1-\pi_1)NC_2^* > (1-\bar{\lambda})X + \bar{\lambda}Y - (1-\pi_1)NC_2^* \geq 0$$

always hold. An increase in λ_m increases the value of

$$X + \eta_m\bar{\lambda}(Y-X) - (1-\pi_1)NC_2^*$$

in a linear fashion on the one hand, but it also decrease the value of

$$n\left(C_2^* - \eta_m^2 C_1^*\right)$$

in a nonlinear fashion on the other hand. In this case there must be an upper bound for n before $E(\mathfrak{R})$ turns negative.

Indeed for $\eta_m = \frac{\lambda_m}{\bar{\lambda}} > 1$ such that $\eta_m^2 C_1^* > C_2^*$, $E(\mathfrak{R}) = 0$ is equivalent to

$$X - (1-\pi_1)NC_2^* + \eta_m\bar{\lambda}(Y-X) \geq \overline{n}_m\left(\eta_m^2 C_1^* - C_2^*\right). \tag{3}$$

The total differentiation of the above condition with respect to η_m leads to

$$\bar{\lambda}(Y-X) = \frac{\partial\overline{n}_m}{\partial\eta_m}\left(\eta_m^2 C_1^* - C_2^*\right) + 2\overline{n}_m\eta_m C_1^*.$$

This, if n is not too large so that $\bar{\lambda}(Y-X) > 2n\eta_m C_1^*$, i.e.,

$$n < n^* \equiv \frac{\bar{\lambda}(Y-X)}{2\eta_m C_1^*},$$

we have

$$\frac{\partial \overline{n}_m}{\partial \eta_m} > 0.$$

Otherwise, if n is so large that $n > n^*$, we have

$$\frac{\partial \overline{n}_m}{\partial \eta_m} < 0.$$

Thus, as long as the number is excess withdrawals is not too large ($n < n^*$), the better a bank's quality, the larger number of excess early withdrawals it can face. If the number is excess withdrawals is too large ($n > n^*$), however, the better a bank's quality, the smaller number of excess early withdrawals it can face. Notice further that n^* itself is a decreasing function in η_m. That is, a better quality bank has a lower threshold level of n^*.

Substituting $\eta_m = \frac{\lambda_m}{\bar{\lambda}}$ in (3), $E(\Re) = 0$ is equivalent to

$$X - (1-\pi_1)NC_2^* + \lambda_m(Y - X) = \overline{n}_m \left[\left(\frac{\lambda_m}{\bar{\lambda}} \right)^2 C_1^* - C_2^* \right]. \tag{4}$$

The total differentiation of the above condition with respect to $\bar{\lambda}$ leads to

$$\frac{\partial \overline{n}_m}{\partial \bar{\lambda}} \left[\left(\frac{\lambda_m}{\bar{\lambda}} \right)^2 C_1^* - C_2^* \right] - 2n \frac{\lambda_m^2}{\bar{\lambda}^3} C_1^* = 0,$$

that is

$$\frac{\partial \overline{n}_m}{\partial \bar{\lambda}} = \frac{2n\eta_m^2 C_1^*}{(\eta_m^2 C_1^* - C_2^*)\,\bar{\lambda}} > 0,$$

for $\eta_m = \frac{\lambda_m}{\bar{\lambda}} > 1$ such that $\eta_m^2 C_1^* > C_2^*$, $\partial \overline{n}_m / \partial \bar{\lambda} > 0$. Hence the better is the average quality of banks, the bigger is the number of excess withdrawals that a good bank can face. ■

It is interesting to notice that the better is the average quality of banks, the bigger is the number of excess withdrawals that a good bank can face. In other words, if the average quality of banks is deteriorated, a good bank with the same quality can only face a smaller number of excess withdrawals than before. This result will be important when we analyze contagious risks in the interbank market.

Notice further that the ratio $\eta_m = \frac{\lambda_m}{\bar{\lambda}}$, a measure of heterogeneity of the project pool in the economy, in turn determines the degree of information asymmetry. Suppose that $\lambda_m \in \left[\lambda_{\underline{m}}, \lambda_{\bar{m}}\right]$, then we can differentiate two extremes: a perfectly homogeneous case, where $\eta_m = 1$; and an extremely heterogeneous case, where $\lambda_{\bar{m}} \to 1$ and the ratio $\frac{\lambda_{\bar{m}}}{\bar{\lambda}}$ becomes $\frac{1}{\bar{\lambda}}$.

Lemma 4 *With borrowing in the interbank market, there exist a* $\widehat{\lambda} \in (0,\ 1)$ *and* $\lambda^* = \frac{N(1-\pi_1)+\left(\pi_1^2-3\pi_1+1\right)(I_1+I_2+I_3)}{\pi_1(Y-X)} - \frac{X}{Y-X}$ *such that:*

1. *if* $\bar{\lambda} \geq \widehat{\lambda}$*, all borrowing banks are solvent regardless of the degree of project heterogeneity in the economy;*

2. *if* $\bar{\lambda} \geq \lambda^*$*, then borrowing banks are solvent if the projects in the economy are perfectly homogeneous.*

Proof. Since we are concerned about the providers of subsidies, i.e., banks with good quality, pulling out of the interbank market, we can focus our attention to $\eta_m \in \left(1,\ \frac{1}{\bar{\lambda}}\right)$.

$$
\begin{aligned}
E(\mathfrak{R}) &= (1-\lambda_m)X + \lambda_m Y - \left[(1-\pi_1)N - n\right] C_2^* - \frac{\lambda_m^2}{\bar{\lambda}} \frac{nC_1^*}{\bar{\lambda}} \\
&= (1-\lambda_m)X + \lambda_m Y - \left[(1-\pi_1)N - n\right] \frac{\bar{\lambda}Y + (1-\bar{\lambda})X}{N(1-\pi_1)} - \frac{\lambda_m^2}{\bar{\lambda}^2} \frac{n}{\pi_1} \left(1 - \frac{I}{N}\right) \\
&\geq 0.
\end{aligned}
$$

or,

$$
\frac{1}{\bar{\lambda}} E(\mathfrak{R}) = (1-\eta_m)X + \eta_m Y - \left[(1-\pi_1)N - n\right] \frac{Y + (1/\bar{\lambda} - 1)X}{N(1-\pi_1)} - \eta_m^2 \frac{n}{\pi_1} \left(1 - \frac{I}{N}\right) \geq 0
$$

First, look at the case that $\eta_m = 1:$

$$
\frac{1}{\bar{\lambda}} E(\mathfrak{R}) \mid_{\eta_m = 1} = Y - \left[(1-\pi_1)N - n\right] \frac{Y + (1/\bar{\lambda} - 1)X}{N(1-\pi_1)} - \frac{n}{\pi_1} \left(1 - \frac{I}{N}\right) \geq 0
$$

$$
\Leftrightarrow \quad Y - ((1-\pi_1)N - n) \tfrac{Y + (1/\bar{\lambda} - 1)X}{N(1-\pi_1)} - \tfrac{n}{\pi_1} \left(1 - \tfrac{I}{N}\right) \geq 0,
$$

$\Leftrightarrow \quad Y - \frac{n}{\pi_1}\left(1-\frac{I}{N}\right) \geq ((1-\pi_1)N-n)\,\frac{Y+(1/\bar{\lambda}-1)X}{N(1-\pi_1)}$

$\Leftrightarrow \quad \frac{N(1-\pi_1)\left(Y-\frac{n}{\pi_1}\left(1-\frac{I}{N}\right)\right)}{((1-\pi_1)N-n)X} - \frac{Y}{X} + 1 \geq 1/\bar{\lambda}$

$\Leftrightarrow \quad \frac{N(1-\pi_1)\left(Y-\frac{n}{\pi_1}\left(1-\frac{I}{N}\right)\right)-Y((1-\pi_1)N-n)+((1-\pi_1)N-n)X}{((1-\pi_1)N-n)X} \geq 1/\bar{\lambda}$

$\Leftrightarrow \quad \frac{-N(1-\pi_1)\frac{n}{\pi_1}\left(1-\frac{I}{N}\right)+Yn+((1-\pi_1)N-n)X}{((1-\pi_1)N-n)X} \geq 1/\bar{\lambda}$

$\Leftrightarrow \quad \bar{\lambda} \geq \frac{((1-\pi_1)N-n)X}{Yn+((1-\pi_1)N-n)X-N(\frac{1}{\pi_1}-1)n\left(1-\frac{I}{N}\right)}$

From this we have

$$
\begin{aligned}
\lambda^* &= \frac{((1-\pi_1)N-1)\,X}{Y+((1-\pi_1)N-1)\,X-N(\frac{1}{\pi_1}-1)\left(1-\frac{I}{N}\right)} \\
&> \frac{((1-\pi_1)N-n)\,X}{Yn+((1-\pi_1)N-n)\,X-N(\frac{1}{\pi_1}-1)n\left(1-\frac{I}{N}\right)}
\end{aligned}
$$

for any $n > 1$

Thus when $\eta_m = 1$, $E(\mathfrak{R}) \geq 0$ for any $\bar{\lambda} \geq \lambda^*$.

Then look at the case that $\eta_m = \frac{1}{\lambda}$:

$$
\begin{aligned}
\frac{1}{\bar{\lambda}}E(\mathfrak{R}) \quad &|_{\eta_m=\frac{1}{\lambda}} = (1-\frac{1}{\bar{\lambda}})X + \frac{1}{\bar{\lambda}}Y - [(1-\pi_1)N-n]\,\frac{Y+(1/\bar{\lambda}-1)X}{N(1-\pi_1)} - \frac{1}{\bar{\lambda}^2}\frac{n}{\pi_1}\left(1-\frac{I}{N}\right) \\
&\geq 0
\end{aligned}
$$

Let $n = 1$, then $\frac{1}{\lambda}E(\mathfrak{R}) = 0$

$\Leftrightarrow \quad -\frac{1}{\lambda^2}\frac{1}{\pi_1}\left(1-\frac{I}{N}\right)+\left(-X+Y-((1-\pi_1)\,N-1)\,\frac{X}{(1-\pi_1)N}\right)\frac{1}{\lambda}+X-((1-\pi_1)\,N-1)\,\frac{Y-X}{(1-\pi_1)N} = 0$

$\Leftrightarrow \quad -\frac{1}{\lambda^2}\frac{(1-\pi_1)N}{\pi_1}\left(1-\frac{I}{N}\right)+((Y-X)\,(1-\pi_1)\,N-((1-\pi_1)\,N-1)\,X)\,\frac{1}{\lambda}+X\,(1-\pi_1)\,N-((1-\pi_1)\,N-1)\,(Y-X) = 0$

Let $(Y-X)\,(1-\pi_1)\,N-(1-\pi_1)\,NX = (Y-2X)\,(1-\pi_1)\,N = A < 0$, if $Y < 2X$

$((Y-X)\,(1-\pi_1)\,N-(1-\pi_1)\,NX)-X = A-X$

$X\,(1-\pi_1)\,N-(1-\pi_1)\,N\,(Y-X)+Y-X = Y-X-A$

$\frac{(1-\pi_1)N}{\pi_1}\left(1-\frac{I}{N}\right) = B.$

$$
\frac{1}{\bar{\lambda}}E(\mathfrak{R})\;|_{\eta_m=\frac{1}{\lambda}} = -\frac{1}{\lambda^2}B+(A-X)\,\frac{1}{\lambda}+Y-X-A = 0
$$

Its solutions are :

$$\lambda = \frac{1}{2\left(Y - X - A\right)}\left(\left(X - A\right) \pm \sqrt{\left(X - A\right)^2 + 4B\left(Y - X - A\right)}\right)$$

where, $A = \left(Y - 2X\right)\left(1 - \pi_1\right)N, B = \frac{(1-\pi_1)N}{\pi_1}\left(1 - \frac{I}{N}\right)$. ■

In the following we are going to analyze bank run equilibrium in a SBF economy. To make our point in a simpler way, we suppose that a bank manager has an incentive to avoid being identified as a poor manager. We also assume that a bank being liquidated is perceived by the economy as an indication of bad management; while a bank run is not perceived so since a well-managed bank may also suffer from a bank run. Thus, from the perspective of a bank manager, an expected liquidation at date 3 is worse than a bank run at date 1. Therefore, when a manager has to choose between facing an expected liquidation at date 3 and a bank run at date 1, she will choose the latter.[12] Given these assumptions applying the above Lemmas, we have the following results.

Proposition 2 *In a SBF economy*

1. *if $\bar{\lambda} \geq \widehat{\lambda}$, then a bank run never happens regardless of degree of project heterogeneity in the economy;*

2. *if $\bar{\lambda} \geq \lambda^*$, then bank run never happens if banks' projects are perfectly homogeneous;*

3. *if $\eta_m > 1$, for any bank m if $n_m > \overline{n}_m$, this bank will suffer from a bank run.*

The first result implies that if the uncertainty of projects financed by banks is very low, or if banks invest in very safe projects, there is no bank run in a SBF economy. This is because the average quality of the projects are good enough for lenders to

[12] The same qualitative result can be derived without this assumption but at the costs of a more complicated analysis.

lend to all the illiquid banks. That is, under that condition, asymmetric information in the interbank market is not a serious problem.

The second result says that if the uncertainty of projects is at a moderate level, then as long as projects are very homogeneous, there is still no bank run in the economy. This is so because when projects are highly homogeneous, the degree of asymmetric information is low (in the case of perfect homogeneous, there is no asymmetric information). Given that the average quality of the projects in the economy is not too bad, the interbank market functions well.

In contrast, in a MBF economy bad projects are always liquidated. Moreover, illiquid and insolvent banks may still suffer bank runs even when the project pool is relatively safe. That is, a SBF economy may appear better than a MBF economy in terms of financial stability when the project pool of the banks in the economy is less uncertain. This result sheds some light on the 'East Asian Miracle' which happened before the mid 1990s when the project pool in those economies featured less uncertain imitations.

The last result shows that when the best illiquid banks (banks with high $\frac{\lambda_m}{\lambda}$ ratio) face a large amount of excess withdrawals, these banks will be run by their depositors. This is because to avoid a consequence of liquidation these bank managers choose not to borrow. The implication of this result is grave to the economy. Because the bank run may generate negative externalities in the interbank market that it may induce a bank run contagion which can lead to a collapse of the banking system.

5.4 Bank-Run Contagion and Financial Crisis in a SBF Economy

Our analysis in the above subsection has shown that as long as the number is excess withdrawals is not too large ($n_m \leq \overline{n}_m$) for each bank, the banking system is also subject to contagious risks. However, if there are some large excess early withdrawals ($n_m > \overline{n}_m$) for some banks, these banks will face bank run. In this subsection, we show that if a bank run occurs to good quality banks, it can lead to a contagious massive bank failures, which can lead to a financial crisis.

For simplicity, we assume that the liquidity shock is exogenously given such that there are w illiquid banks that face the same amount of $\widehat{n}$ excess early withdrawals. And the quality of these w banks can be ranked such that each illiquid bank $i's$ quality is $\lambda_i = \lambda_{i-1} + \mu$ for all $i = 1, 2, ..., w$, and $\lambda_0 = \mu$. Based on this setup, the average quality of all illiquid banks is

$$\overline{\lambda}_w = \frac{1}{w} \sum_{i=1}^{w} \lambda_i = \frac{(1+w)\mu}{2}.$$

We also continue to assume that the average quality $\overline{\lambda}_w$ is known by all the banks, but each individual bank's λ_i is not known by other banks.

To facilitate our analysis, we group the w banks into two partitions: good (W_g) and bad (W_b). In W_b, a bank has a subscript i that $1 \leq i \leq w_b$; in W_g, a bank has a subscript i that $w_g < i \leq w$, where $w_g = w_b + 1$. The following shows the relationship between the ranking of the banks and the partition.

$$\underbrace{\lambda_1 < \lambda_2 < ... < \lambda_{w_b}}_{W_b} < \underbrace{\lambda_{w_g} < ...... < \lambda_w}_{W_g}$$

We further assume that $\widehat{n} \leq \bar{\lambda}^2 (Y - X) / (2\lambda_1 C_1^*)$. Since $n^* = \bar{\lambda}^2 (Y - X) / (2\lambda_i C_1^*)$ is a decreasing function of λ_i, following Lemma 4, $\widehat{n} > n^*$ and $\partial \overline{n}_i / \partial \eta_i < 0$ hold for all banks in the W_g and W_b partitions. Consequently, the upper portion of or all banks in the W_g partition decide to pull out from the interbank borrowing, because $\widehat{n} > \overline{n}_i$ holds. Following Proposition 4 these banks will suffer from bank runs.

Moreover, the runs on W_g banks generate externalities in the interbank market through lowering the average quality of banks that would still stay in the interbank market. If the W_g banks are run by their depositors, the average quality of the remaining banks in the economy, $\bar{\lambda}_{w_b}$, will decrease to

$$\bar{\lambda}_{w_b} = \frac{1}{w_b} \sum_{i=1}^{w_b} \lambda_i = \left(1 - \frac{w - w_b}{1 + w}\right) \bar{\lambda}_w < \bar{\lambda}_w.$$

Associated with a lower $\bar{\lambda}_{w_b}$, the deteriorated quality of the pool of borrowing banks to a lower $\overline{n}_i$, according to Lemma 4 (i.e., $\partial \overline{n}_i / \partial \bar{\lambda} > 0$). As a result, relatively better banks in the partition W_b stop from borrowing and face bank run. Let us group these banks into partition W_{b_1}. An illustration of partition W_{b_1} is as follows.

$$\underbrace{\lambda_1 < \lambda_2 < ... < \lambda_{w_{b2}}}_{W_{b_2}} < \underbrace{\lambda_{w_{b1}} < ... < \lambda_{w_b}}_{W_{b_1}} < \underbrace{\lambda_{w_g} < ... < \lambda_w}_{W_g}$$

Following Proposition 4, W_{b_1} banks are run by their depositors. As a result, the average quality of the remaining illiquid banks will be further lowered. This in turn will push the borrowing cost further up. The same process repeats that there will be additional bank runs, further deterioration of qualities of banks, and further lower bond prices until they reach a low enough level that no bank will issue a bond. Observing the low bond price later consumers will infer deep troubles in the banking system and they will all be induced to withdraw at date 1 – a run to the banking system. At this point, the entire banking system collapses. The above situation is summarized in the following proposition.

Proposition 3 *In a SBF economy if $\eta_i^2 C_1^* > C_2^*$ for some of the best banks and the excess early withdrawals $\widehat{n} \leq \bar{\lambda}^2(Y - X)/\left(2\lambda_i C_1^*\right)\bar{\lambda}^2$ for illiquid banks, there exists bank run contagions which starts from the best illiquid banks and can lead to a collapse of the banking system.*

The condition of bank run contagions in this result has implications for the timing of a financial crisis in a SBF economy. When an economy is technically less developed such that most investment projects are featured by imitations, the uncertainty of the projects is low and the bank run contagion condition is not satisfied. However, when a SBF economy is more developed such that a large proportion of investment projects are in high tech or R&D-intensive, the projects are more uncertain (lower $\bar{\lambda}$) and more heterogeneous (higher η_m). Then, the bank run contagion condition may be easily satisfied.

This result sheds lights to the timing of East Asia Financial Crisis, in particular why Korea was hit by the crisis, and the Japanese economy stagnation since the 1980s. Since the early 1990s (the 1980s for Japan), Korean economy became more developed and it moved onto technological frontiers and invested more in high-tech projects and in innovations, its project pool became more uncertain, i.e. $\bar{\lambda} < \lambda^*$, and more heterogeneous, i.e. η_m. So it began to meet the conditions for bank run contagion and could face a financial crisis when some liquidity shocks hit the economy.[13]

In sharp contrast, in a MBF economy information about bank investment quality is revealed to all banks at date 1 because of the liquidation of bad projects. As a result of the symmetric information, bank runs are always restricted to insolvent banks and the interbank market never degenerates. Therefore, bank run contagion will never occur when there are only idiosyncratic shocks!

To make our point in a simple way, our model is quite stylized. The model can be extended and modified to better capture the reality. For example, it can be readily modified by introducing imperfect monitoring from depositors in the sense of Postlewaite and Vives (1987) and Jacklin and Bhattacharya (1988). If depositors' monitoring is more blurred than that of bank managers' such that depositors can divide the banks' qualities into groups but are not able to further distinguish them within each group, then lower quality groups of banks are more likely to suffer liquidity shocks and bank runs. Moreover, the bank run contagion mechanism based on interbank lending market lemon problem can apply within each group of banks. From this we can show a bank run contagion extending from bad groups to better groups.

6. CONCLUDING REMARKS

This paper endogenizes contagious risks and financial crises from the perspective of financial institutions and corporate finance. We began our analysis by examining informational problems not only between entrepreneurs and banks but also in the in-

[13] Radelet and Sachs (1998) give detail accounts of "bank run" contagion in the East Asia financial Crisis.

terbank market. Then we showed how in a SBF economy the information asymmetry between entrepreneurs and banks leads to a “lemon” problem in the interbank lending market, which further impedes strong banks from securing loans to solve liquidity shortage problems when they face liquidity shocks. Thus, bank runs may break out, which further exacerbate the lemon problem and can lead to a collapse of the entire banking system. In contrast, under MBF economy entrepreneurs reveal their private information to banks timely, as a result information about the quality of the banks is disclosed to the whole banking system timely. This allows the interbank lending markets to function well in providing loans to illiquid but solvent banks. Thus, solvent banks will be rescued and financial crisis avoided.

Our theory sheds some light to reconcile the seemingly paradoxical phenomena between the “East Asian Miracle” in the three decades prior to 1997 and the East Asian financial crisis in the period after 1997. In the period of early development, that is, the catching-up period of the 1960s to the early 1990s, the uncertainty of projects was low due to the nature of technological imitation. In this situation, our theory predicts that tin a SBF economy there are no project liquidation and no bank run. That is, a SBF economy appears even to outperform a MBF economy, and it may attract many investments. However, if the uncertainty of projects rises precipitously, for example, when an economy moves on technological frontiers (e.g., South Korea since the early 1990s), the negative effects of a SBF economy will dominate, finally leading to trouble in the financial system.

Some final remarks about our theory are in order. Although our theory is motivated by observations of the East Asian financial crisis, it is a very basic model aiming to improve one’s general understanding of financial crises. In the real world, there may not exist a simple MBF economy such that all bad projects are liquidated as cleanly and early as in our model. That is, even in a well-developed market economy there exist some SBF financial and economic institutions which may cause bank runs or even financial crises, but at a lesser degree than in an economy where SBF predominate. However, the basic message of our theory is clear.

Moreover, in order to study financial crises from a purely economic perspective, we provide an institutional foundation of soft-budget constraints where there are no political problems and every agent maximizes his own economic gain. But our theory of financial crises is general enough that any institutional foundation of a soft-budget constraint economy (e.g. a foundation based on political considerations, Segal, 1998) applies and can produce the same qualitative results. For example, it is well documented that there are serious corruptions in some of the Asian economies, and it is a well held belief that corruptions in those economies, particularly in Philippines and Thailand, and probably also in Malaysia and even Korea, had affected their financial crises. Our model also allows us to examine how corruption affects financial institutions and changes the likelihood of financial crisis.

There are two aspects of corruption that can be introduced into our model. The first aspect is that corruption itself can be a mechanism of soft-budget constraint (Shleifer and Vishny, 1993). That is, when it is discovered that a project is a bad one at date 2, firms and financial institutions in a corrupted economy have options to bribe the government to bailout the project even if the project is not ex post profitable. That is, with corruption there will be less effective financial discipline in the economy.

In addition, another aspect of corruption can also be incorporated into our model. That is corruption can affect selection of projects. This aspect will significantly alter our results on the timing of financial crisis. To illustrate this, we suppose that at date 0 there is an asymmetric information that entrepreneurs know the distribution better; moreover, some risky projects may benefit some entrepreneurs. In a corrupted economy the entrepreneur may bribe the bank to get the project financed. Thus, on average projects selected in a corrupted economy will be riskier than in a corruption-free economy. Therefore, even in a less developed economy like Philippines and Thailand, many high risk projects can be chosen because of corruption. As corruptions not only degenerate financial disciplines but also make project selection towards more risky ones, Proposition 3 implies that a corrupted economy is more likely to have financial crisis.

Our theory has implications for many policy solutions proposed in the literature. For example, Dewatripont-Tirole (1994) propose the following policies to deal with bank failures: 1) to liquidate illiquid banks; 2) to allow solvent and liquid banks to take over illiquid banks; and 3) to provide loans to illiquid banks. Our theory demonstrates that in a MBF economy, with sufficient information about the solvency of illiquid banks, the government should consider the trade-off between closing down illiquid banks and letting solvent liquid banks take over illiquid banks; or to provide loans to solvent illiquid banks. However, in a SBF economy, without information about the solvency of the banks, the government has no other choice but to provide loans to all illiquid banks or to provide loans to a proportion of them randomly. With respect to nationalizing illiquid banks, our theory implies that this may work as an emergency measure if nationalization has an informational value such that with control rights the government may be able to identify solvent banks. However, this may not work in the long run because a nationalized bank will likely generate a SBF environment.

On the lender of last resort (LOLR) policy[14], since the government also faces an adverse selection problem in the sense in that it does not know the solvency of each bank at date 1, an implication of our theory is that the best that the government can do may be either to rescue all the banks regardless of their solvency, thus creating a bail-out trap, or to rescue none of them, thus leaving the banking system vulnerable to contagious risks and financial crisis. Thus focusing on the information asymmetry between the government and illiquid banks and effectively dealing with them are the key to the implementation of the LOLR policy.

Another important policy issue concerns the liberalization of financial markets and institutions, whose effects can be analyzed in our model by comparing a one bank economy (before liberalization) with an M-bank economy (after liberalization).

[14] See Goodhart and Huang (1998) for a model of LOLR and Huang and Xu (2000) for further discussions on contagious risks and the LOLR policy.

According to our theory, a one-bank economy must be a SBF economy. Moreover, because all the deposits in the economy are pooled in one bank, the risk of facing a liquidity shock or a bank run will be greatly reduced. Theoretically, if the economy has a sufficiently large number of depositors, then the probability of an excessive early withdrawals from the bank will be negligible. That is, although inefficient, this one-bank economy is almost immune to bank runs or financial crisis. In contrast to a one-bank economy, an M-bank SBF economy is very sensitive to a bank run contagion due to the lemon problem in the interbank lending market.

This comparison has important implications for banking policies and reforms. The basic message is that a liberalization of financial institutions must be conditional on measures to harden the budget constraints. If liberalized banks are operating under SBF and measures to harden the budget constraints are not in place, a liberalization policy may greatly destabilize the financial system!

This simple analysis captures some characteristics of banking systems reform and liberalization. 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) into a multi-bank system. Many of the banking system liberalization reforms in East Asia before 1997 shared this spirit as well. According to our theory, a banking system reform designed to enhance competition as described above can create huge contagious risks to the system, if additional measures to harden budget constraints in the system are not implemented simultaneously.

Another important policy implication from our theory for financial system reform and for financial-crisis-prevention is that the transparency of the banking system is critical. However, transparency cannot be achieved by imposing government regulations alone. In fact, with wrong targets in transparency a regulation can cause a back fire in the sense that the commitment device of banks can be destroyed even in a MBF economy. That is because the commitment device relies on information asymmetry between banks. Therefore, an effective reform can only be achieved by reforming the financial institutions to tighten budget constraints at the micro level.

Finally, our work compliments the existing literature on banking and financial crisis, and this can be seen more clearly through a comparison of our work with some of the existing literature. Allen and Gale (2000) in the Diamond and Dybvig one-bank framework show that bank runs are related to the business cycle, rather than being the results of simple "sunspots." We are in agreement with their view in that fundamentals affect financial crises, and we argue that financial institutions are just such a fundamental factor, especially in a multi-bank banking system. Chang and Velasco (1998) extend the Diamond and Dybvig model into an open economy model. They show that the illiquidity of the domestic financial system is at the center of the financial crisis in emerging markets. We regard the Chang and Velasco model to complement our theory. In fact, we can readily apply their approach to extend our model and explain how domestic financial institutions interact with international financial issues and how an over-borrowing syndrome in the sense of McKinnon and Pill (1997) is generated.

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