Information Acquisition, Coordination, and Fundamentals in a Financial Crisis *

Maxim Nikitin

Department of Economics
University of Alberta
Edmonton, Alberta
Canada T6G 2H4
maxim.nikitin@ualberta.ca

November 2004

Abstract

This paper reconciles the two explanations of a financial crisis, the self-fulfilling prophecy and the fundamental causes, in an empirically-relevant framework, by explicitly modeling the costly voluntary acquisition of information about fundamentals in a variant of Diamond and Dybvig (1983). In the "run" equilibrium investors engage in costly evaluation of projects, so that banks with lower-return projects fail. In the "no-run" equilibrium there is no project evaluation. Investors' coordination on a specific equilibrium is triggered by a self-fulfilling prophecy. So, financial crises are seen as both, fundamentals-based and self-fulfilling prophecies-based phenomena.

Keywords: financial crisis, banks, self-fulfilling prophecy

JEL classification: F34, G21

*I am grateful to Kanhaya Gupta, Alexandra Lai, R. Todd Smith, participants of the 2002 Canadian Economic Association Meetings in Calgary, seminar participants at the Bank of Canada and especially, to Claudia M. Landeo, for their helpful comments on earlier drafts of this paper. All remaining errors are my own.

1 Introduction

Theoretical analysis of recent financial crises in Mexico in 1994, South-East Asia in 1997, Russia in 1998, Argentina in 2001-2002 emphasizes the international illiquidity of the domestic financial system. Chang and Velasco (2000, 2001) extend the Diamond and Dybvig (1983) closed-economy bank run model to an open economy setting and show how a sudden capital outflow brings about costly liquidation of investment projects rendering the domestic banks insolvent. Chang and Velasco's approach focuses on self-fulfilling prophecies as the main cause of financial crises. However, empirical studies of financial crises suggest that normally banks or currencies with certain "fundamental" problems are the ones that suffer from a sudden loss of confidence by investors, and that financial crises are preceded by shocks to fundamentals.

The "global games" literature, pioneered by Morris and Shin (2000) and Goldstein and Pauzner (2000), represents a way to introduce fundamentals in a Diamond-Dybvig style coordination model of a financial crisis. Indeterminacy of equilibrium is eliminated by assuming that some agents receive a noisy signal about fundamentals. This assumption allows the modelers to calculate the probability of the run equilibrium for each set of values of fundamentals. These models imply a relatively low precision of the public information about economic fundamentals relative to the private information and exogenous and free interim information acquisition. However, in real-world settings virtually all the information received by economic agents is available to other agents and is costly.[1]

Our paper reconciles the two explanations of a financial crisis, the self-fulfilling prophecy and the fundamental causes in an empirically-relevant framework, by explicitly modeling the costly voluntary acquisition of information about fundamentals. Our framework is a variant of the Diamond and Dybvig's model with an open-economy interpretation. While Diamond and Dybvig consider one bank in a closed-economy setting, we consider a continuum of countries, each with one bank. Our model allows for two types of banks: "good" banks with a high rate of return to illiquid asset (project), and "bad" banks with a low return. We find conditions under which three different equilibria are possible: the "verification" equilibrium in which all global investors verify types of banks, and withdraw funds from the bad ones, leaving them insolvent, the no-run equilibrium in

[1] Even if the data is available free of charge (for example, released by government statistics offices), investors need time (and other resources, e.g. computers) to process it. Furthermore, most of the economic and financial research is conducted by the private sector and is available for a fee.

which all banks remain solvent, and the full-run equilibrium, in which investors withdraw funds from all the banks.[2] On the one hand, in the verification equilibrium only bad banks go bust, so the run on them has a fundamental cause. On the other hand, a switch from the no-run to the verification equilibrium can be triggered by a self-fulfilling prophecy. Therefore the financial crisis is inherently *fundamentals-based and panic-based* at the same time.

A stylized fact that supports our model is the alternation of periods of lending booms and busts, with dramatically different approaches towards risk. During lending booms, investors' enthusiasm for particular segments of the domestic or the world economy, or for particular financial instruments, brings about a narrowing of spreads and lack of concern for credit quality, as funds flow indiscriminately to all borrowers in these segments. The busts are accompanied by the "flight to quality," and a widening of spreads, which are devastating to borrowers with particularly weak fundamentals.[3]

The remainder of the paper is structured as follows. Part 2 is a presentation of the basic setup of the model. Part 3 comprises the derivation of the model solution. Part 4 concludes the analysis.

2 Model Setup

Consider a world economy populated by a continuum of agents (global investors) of measure one. All agents live for three periods: 0, 1, and 2. Each agent is endowed with one unit of divisible good in period 0. However, he derives his utility from consumption in periods 1 or 2 (depending on his type). In order to transfer wealth across time, he has two options. The first option is storage. The storage is liquid and risk-free, and its gross rate of return is one in both periods.[4]

Alternatively, the agent can use an illiquid productive technology (illiquid projects), which requires two periods to yield a return. However, and this is a departure from the original Diamond-Dybvig setup, there is a continuum of country-specific illiquid projects, also of measure one. The projects are risky: α projects yield the gross return $R > 1$, and $(1 - \alpha)$ projects yield q, such that $1 \leq q < R$. There is no aggregate uncertainty about the productivity: α is non-stochastic. If

[2]The last two equilibria are similar to the two equilibria of the Diamond and Dybvig's model.

[3]Schadler et al.(1993) document periods of overlending and capital outflow in emerging markets. The Economist(1998) describes how changes in investors' sentiments made risk "a four-letter word" in the aftermath of the Russian default in September 1998.

[4]A possible interpretation of storage in the open-economy context is the investment in government securities of the OECD countries.

interrupted during period 1, the illiquid technology yields only $r < 1$.

Productivity shocks are realized in period 1. In that period an agent can learn which country projects are highly productive, and which are not, at a cost ϵ per unit of investment.

Similarly to the original Diamond-Dybvig setup, agents face a preference risk. With probability λ, their utility function is $u(C_1) = \frac{C_1^{1-\sigma}-1}{1-\sigma}$, i.e. they derive utility from consumption in period 1 only. Henceforth we will refer to them as impatient agents. With probability $(1-\lambda)$, their utility function is $u(C_2) = \frac{C_2^{1-\sigma}-1}{1-\sigma}$. We will refer to them as patient agents. We assume that σ, the coefficient of relative risk aversion, is greater than or equal to 1.[5] The preference shock is realized during the first period, i.e. after agents have made their investment decisions. Moreover, the shock is not publicly observable.

3 Model Solution

3.1 Social Optimum

The problem of the (world) social planner is to maximize the expected welfare of a representative agent.

The assumption $r < 1 \leq q < R$ implies that the social planner should never interrupt illiquid technology investment in period 1, i.e. even inefficient projects should be completed and resources on verification should not be spent. The social planner should use storage to provide for consumption of impatient agents. The planner maximizes:

$$EU = \lambda u(X) + (1-\lambda)u(Y), \tag{1}$$

subject to

$$\lambda X \leq b \tag{2}$$

$$(1-\lambda)Y = \tilde{R}k + (b - \lambda X) \tag{3}$$

$$k + b = 1 \tag{4}$$

$$X \leq Y, \tag{5}$$

where b is the amount invested in storage, k is the amount invested in illiquid technology, X is the consumption of impatient agents, Y is the consumption of patient agents, and $\tilde{R} = \alpha R + (1-\alpha)q$ is the expected return on illiquid projects. Maximization is with respect to X, Y, k and b.

[5] Virtually all empirical estimates of σ lie between 1 and 10 (Auerbach and Kotlikoff, 1987, p.50.)

The objective function (1) is the expected utility of an agent. Inequality (2) is the first-period resource constraint. It states that the consumption of impatient agents comes from storage, b. Equation (3) is the second-period resource constraint. It shows that the consumption of the patient agents comes from the illiquid technology, k, and the storage of the good that is available but not consumed in period 1, $(b-\lambda X)$. Equation (4) is the budget constraint of period 0. It demonstrates that the social planner must either store or invest all the endowment. Finally, inequality (5) is the incentive-compatibility constraint. The patient agent should not have the incentive to mimic the behavior of the impatient agents and attempt to acquire the consumption good in period 1.

Proposition 1: The problem (1)-(5) has the following solution:

$$b^* = \frac{\lambda \tilde{R}^{(\sigma-1)/\sigma}}{1-\lambda+\lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{6}$$

$$k^* = 1 - b^* = \frac{1-\lambda}{1-\lambda+\lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{7}$$

$$X^* = \frac{b^*}{\lambda} = \frac{\tilde{R}^{(\sigma-1)/\sigma}}{1-\lambda+\lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{8}$$

$$Y^* = \frac{\tilde{R}(1-b^*)}{1-\lambda} = \frac{\tilde{R}}{1-\lambda+\lambda \tilde{R}^{(\sigma-1)/\sigma}}, \tag{9}$$

where the asterisk denotes the socially optimal values of the variables.

The proof is straightforward and is omitted for brevity.

Proposition 1 says that the social planner should invest in storage just enough to satisfy the impatient agents and not store anything between periods 1 and 2. Over two periods the return on illiquid technology dominates the return on storage.

In the particular case of $\sigma = 1$ (the case of the logarithmic utility function) $b^* = \lambda$, $X^* = 1$, $k^* = 1-\lambda$, $Y^* = \tilde{R}$. In words, the share of investment in storage should be equal to the share of impatient agents in the economy, and they should get exactly the return on storage. Patient agents earn the average return on illiquid technology. The social planner does not redistribute investment earnings from the patient to impatient agents, or vice versa.

If $\sigma > 1$, that is, if agents are *more* risk-averse than the agents with logarithmic utility, the social planner should reduce the difference between the earnings of patient and impatient agents. Hence $X^* > 1$, and $Y^* < \tilde{R}$.

3.2 Decentralized Equilibria and Runs

Decentralization of the socially optimal allocation can be achieved in the same way as in the original Diamond-Dybvig model. Each bank issues demand deposits. These deposits pay $X^* = \frac{b^*}{\lambda}$ if withdrawn in the first period, provided that the bank is solvent. In the second period all remaining assets are liquidated and allocated among deposit holders on *pro rata* basis.

Each bank stores the b^* share of the period 0 deposit, and invests the rest in the illiquid technology. The amount of storage should suffice to just satisfy the liquidity needs of impatient agents. If there is no run, i.e., if in period 1 patient agents do not attempt to withdraw, then impatient agents get X^*, and patient agents get Y^*, i.e., the socially optimal allocation is attained.

The demand deposit contract is the optimal arrangement because the type of the agent is his private information. The bank is unable to condition the first-period payout on the type of the agent.

Given that agents are risk-averse, and the bank type may be revealed only in period 1, it is optimal for agents to spread their deposits across the banking system, i.e. to make an equal deposit in every bank.

The decentralized equilibrium is prone to runs. If a sufficient number of patient agents decide to withdraw in period 1, it is indeed optimal for *all* patient agents to withdraw in period 1. The run becomes self-fulfilling, because $X^* > r$, and hence the banks have to destroy illiquid investment to meet the unexpected withdrawal demand. Therefore the return on deposits in period 2 can fall below X^*.

In this setup three different equilibria are feasible: a no-run equilibrium, or an equilibrium in which the socially optimal allocation is achieved, a "verification," or "partial run," equilibrium, and a "full-run" equilibrium. In the full-run equilibrium, agents do not verify the type of banks, but attempt to withdraw their deposits from all of them. Hence all the banks liquidate all their investment and shut down. In the verification equilibrium, all patient agents verify the type of the banks and withdraw from the inefficient ones. Hence the inefficient banks, though not the efficient ones, have to liquidate all their investment and shut down in the first period.

Proposition 2 below describes conditions for existence of equilibria. The proof is relegated to the Appendix.

Proposition 2: Under conditions (10)-(15) below there exist three Nash equilibria of the coordination game: the no-run equilibrium, the verification equilibrium, and the full-run equilibrium:

$$[b^* + k^* r](1 - \alpha) > \epsilon \tag{10}$$

$$\frac{k^*}{1-\lambda}\alpha R - \epsilon > \alpha X^* \tag{11}$$

$$(1-\alpha)(X^* - \frac{k^*}{1-\lambda}q) < \epsilon \tag{12}$$

$$\frac{k^*}{1-\lambda}\tilde{R} > X^* \tag{13}$$

$$X^* > r \tag{14}$$

$$X^*(1-\alpha) > (1-\alpha)q - \epsilon \tag{15}$$

where b^*, k^* and X^* are determined by equations (6)-(8).

Remark: Conditions (10)-(15) do not depend on whether the sequential service constraint applies. This is true for two reasons. First, the sequential service constraint does not affect the *expected* return on a bank deposit in case of a run on this bank. The expected return depends only on the amount of resources available at the bank in period 1.[6] Second, given that agents diversify their portfolios and hold their deposits in a continuum of banks, by the law of large numbers, the return on a portfolio is non-stochastic in any of the three equilibria even if the sequential service constraint applies.

Conditions (10)-(11) ensure that if all patient agents play the verification equilibrium, it is not optimal for any agent to deviate. If an agent verifies the type of banks and withdraws from inefficient ones, his expected return is $\left[\alpha R\frac{k^*}{1-\lambda} + (1-\alpha)[b^* + k^* r] - \epsilon\right]$. If he does nothing, and waits until the second period, the inefficient banks go bust and his return is $\left[\alpha R\frac{k^*}{1-\lambda}\right]$ (he earns the return on deposits in efficient banks only). Hence inequality (10) guarantees that the patient agent does not wait until period 2. Inequality (11) ensures that an indiscriminate withdrawal from all the banks in period 1 would not benefit a patient agent either. In case of an indiscriminate withdrawal, the patient agent gets only $\{\alpha X^* + [b^* + k^* r](1-\alpha)\}$ per unit of investment. But if he verifies

[6] The following example clarifies the idea. Assume that the demand deposit rate is X, and the amount of resources (per depositor) available at the bank in period 1 is $m < X$. Then, if the sequential service constraint is present, and all depositors run (which is the only equilibrium outcome, if there is a run), a depositor will get X with probability m/X and 0 with probability $1 - m/X$. Therefore, the expected return is m, the same as if the bank first collects all the withdrawal requests, and then makes an equal payment to every depositor.

the type of banks and withdraws from inefficient ones, he gets $\{\alpha R\frac{k^*}{1-\lambda} - \epsilon + [b^* + k^* r](1-\alpha)\}$. Inequalities (12)-(15) are the conditions for the two other Nash equilibria.[7]

3.3 Implications of the Verification Equilibrium.

A first implication of our model is that the partial run, i.e. the verification equilibrium, is fundamentals-based and panic-based at the same time. During a partial run only inefficient banks suffer from the run and shut down in the first period. This does not mean that bad fundamentals of these banks *per se* cause the run. Their fundamentals are as bad as in the no-run equilibrium. However, in the partial run equilibrium it is optimal for the agents to investigate the fundamentals of the banks just because other agents do that.

Second, empirical studies show high correlation between banking crises and recessions/economic slowdowns. This has been sometimes interpreted as the evidence that banking crises are just a natural outgrowth of the business cycle (Gorton, 1988, Allen and Gale, 1998). An alternative view states that the causality goes from the banking crisis to the economic slowdown (Chang and Velasco, 1998). Our model is consistent with this latter view. In the verification equilibrium, the GDP (global income) is:

$$I_v = \alpha[b^* + (1-b^*)R] + (1-\alpha)[b^* + (1-b^*)r] - (1-\lambda)\epsilon = b^* + (1-b^*)(\alpha R + (1-\alpha)r) - (1-\lambda)\epsilon \quad (16)$$

In the no-run equilibrium the global income is:

$$I_{nr} = b^* + (1-b^*)\tilde{R} = b^* + (1-b^*)[\alpha R + (1-\alpha)q] \quad (17)$$

From equations (16) and (17) it follows that the global income is always greater in the no-run equilibrium than in the verification equilibrium.

Therefore the model allows for the perfect correlation of GDP and bank runs. But the causality goes from the bank run to GDP and not the other way around. The direction of causality is assured, because aggregate uncertainty is ruled out by assumption.

[7]The following numerical example shows that conditions (10)-(15) are not mutually exclusive for at least some positive values of the model parameters. If $\sigma = 1$, $R = 2, r = q = 0.9, \lambda = \alpha = 0.5$, then conditions (10)-(15) are satisfied for any $\epsilon \in (0.05, 0.5)$.

4 Conclusions

The paper presents a coordination game in which there is a strategic complementarity between agents' decisions regarding fundamentals verification. Our paper reconciles the two explanations of a financial crisis, the self-fulfilling prophecy and the fundamental causes in an empirically-relevant framework, by explicitly modeling the costly voluntary acquisition of information about fundamentals. Agents verify the type of banks and withdraw funds from inefficient ones if and only if other agents do the same. Therefore runs on inefficient banks have a fundamental cause, although they are triggered not by an exogenous shock, but by a self-fulfilling prophecy.

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Appendix

Proof of Proposition 2:

Conditions (10)-(11) ensure that if all patient agents play the verification equilibrium, it is not optimal for any agent to deviate. If an agent verifies the type of banks and withdraws from inefficient ones, his expected return is $\left[\alpha R\frac{k^*}{1-\lambda} + (1-\alpha)[b^* + k^*r] - \epsilon\right]$. If he does nothing, and waits until the second period, the inefficient banks go bust and his return is $\left[\alpha R\frac{k^*}{1-\lambda}\right]$ (he earns the return on deposits in efficient banks only). Hence inequality (10) guarantees that the patient agent does not wait until period 2. Inequality (11) ensures that an indiscriminate withdrawal from all the banks in period 1 would not benefit a patient agent either. In case of an indiscriminate withdrawal, the patient agent gets only $\{\alpha X^* + [b^* + k^*r](1-\alpha)\}$ per unit of investment. But if he verifies the type of banks and withdraws from inefficient ones, he gets $\{\alpha R\frac{k^*}{1-\lambda} - \epsilon + [b^* + k^*r](1-\alpha)\}$.

Inequalities (12) and (13) ensure that a patient agent has no incentive to deviate in the no-run equilibrium. If he waits until the second period, he earns $\left[\tilde{R}\frac{k^*}{1-\lambda}\right]$ per unit of investment, but attains only X^* if he withdraws in period 1. If he verifies the type of banks and withdraws from inefficient ones, his gain, $\left[(1-\alpha)(X^* - \frac{k^*}{1-\lambda}q)\right]$, will be lower than the verification cost, ϵ.

Inequality (14) ensures the existence of the full-run equilibrium. This condition guarantees that if all the patient agents decide to withdraw in the first period, neither efficient nor inefficient banks have enough resources to pay X^* to all the agents wishing to withdraw. Therefore the payout to the patient agents waiting until the period 2 is 0. On the other hand, the return to the patient agents joining the full run is $b^* + k^*r > 0$. If a patient agent verifies the type of banks during the full run, he still loses his investment in efficient banks, and his payout is $\{(1-\alpha)[b^* + k^*r] - \epsilon < (b^* + k^*r)\}$.

Finally, inequality (15) rules out the fourth equilibrium. In that equilibrium the patient agents verify the type of banks in period 1, but withdraw from the *efficient* banks only. Condition (15) ensures that a patient agent can do better if he withdraws indiscriminately, even though all agents play that peculiar equilibrium. Q.E.D.

Appendix for Referees

Proof of Proposition 1:

It is never optimal for the social planner to store between periods 1 and 2. In that case the cumulative 2-period return will be exactly unity, while the two-period return on illiquid technology is $\tilde{R} > 1$. Hence:

$$b = \lambda X \tag{18}$$

and

$$(1 - \lambda)Y = \tilde{R}k \tag{19}$$

Maximization of (1) subject to (4), (18), and (19) with respect to b, k, X, and Y is straightforward. The first-order condition of the problem is:

$$u'(X) = \tilde{R}u'(Y), \tag{20}$$

where:

$$X = \frac{b}{\lambda}$$

and

$$Y = \frac{\tilde{R}(1 - b)}{1 - \lambda}$$

Taking into account the assumed functional form of the utility function, and equation (4), we get:

$$b^* = \frac{\lambda \tilde{R}^{(\sigma-1)/\sigma}}{1 - \lambda + \lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{6}$$

$$k^* = 1 - b^* = \frac{1 - \lambda}{1 - \lambda + \lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{7}$$

$$X^* = \frac{b^*}{\lambda} = \frac{\tilde{R}^{(\sigma-1)/\sigma}}{1 - \lambda + \lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{8}$$

$$Y^* = \frac{\tilde{R}(1 - b^*)}{1 - \lambda} = \frac{\tilde{R}}{1 - \lambda + \lambda \tilde{R}^{(\sigma-1)/\sigma}} \tag{9}$$

A comparison of (8) and (9) reveals that inequality (5) is satisfied if and only if $\sigma \geq 0$. Q.E.D.