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Self-Fulfilling Credit Market Freezes

Lucian A. Bebchuk and Itay Goldstein[✧]

Abstract

This paper develops a model of a self-fulfilling credit market freeze and uses it to study alternative governmental responses to such a crisis. We study an economy in which operating firms are interdependent, with their success depending on the ability of other operating firms to obtain financing. In such an economy, an inefficient credit market freeze may arise in which banks abstain from lending to operating firms with good projects because of their self-fulfilling expectations that other banks will not be making such loans. Our model enables us to study the effectiveness of alternative measures for getting an economy out of an inefficient credit market freeze. In particular, we study the effectiveness of interest rate cuts, infusion of capital into banks, direct lending to operating firms by the government, and the provision of government capital or guarantees to finance or encourage privately managed lending. Our analysis provides a framework for analyzing and evaluating the standard and nonstandard instruments used by authorities during the financial crisis of 2008-2009.

Key words: Credit freeze, self-fulfilling crisis, run on the economy, global games, coordination failure, capital injection, government policy, lender of last resort.
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[✧] Bebchuk is from the Harvard Law School and the NBER; e-mail: bebchuk@law.harvard.edu. Goldstein is from the Wharton School, University of Pennsylvania; e-mail: itayg@wharton.upenn.edu. We thank Paolo Pesenti, Jakub Steiner, and Andrew Winton for insightful comments. We also thank seminar and conference participants at the American Economic Association Annual Meeting, the Bank of Portugal Conference on Financial Intermediation, the Federal Reserve Bank of Philadelphia, Harvard University, the IMF Annual Research Conference, the Wharton School, and Temple University. Bebchuk would like to thank the John M. Olin Center for Law, Economics, and Business for financial support.

1. Introduction

An important aspect of the economic crisis of 2008-2009 has been the contraction or "freezing" of credit to nonfinancial firms.[1] During the crisis, financial firms have displayed considerable reluctance to extend loans to nonfinancial firms (as well as households). Some observers attributed the reluctance of financial firms to lend to irrational fear, while others attributed it to a rational assessment of the fundamentals of the economy, which can be expected to reduce the number of operating firms with good projects worthy of financing.

We analyze in this paper another factor that may contribute to the contraction of credit in such circumstances. In particular, we show how coordination failure among financial institutions can lead to inefficient "credit markets freeze" equilibria. In such equilibria, financial institutions rationally avoid lending to nonfinancial firms (operating firms) that have projects that would be worthy if banks did not withdraw from the lending market en masse. They do so out of self-fulfilling fear, validated in equilibrium, that other financial institutions would withhold loans and that operating companies would not be able to succeed in an environment in which other operating firms fail to obtain financing.

The primary contribution of the paper is in analyzing the effectiveness of various government policies in getting the economy out of such a self-fulfilling credit-freeze equilibrium. The analysis identifies the role and potential limitations of standard instruments such as interest rate cuts and infusion of capital into the financial sector. It also considers less traditional forms of intervention – including direct intervention in lending to nonfinancial companies, provision of incentives to financial firms to lend to such companies, and supplying government capital to private funds dedicated to such lending – and analyzes why and when they may be needed. Our analysis provides a framework for understanding and assessing the range of instruments used by authorities to revive credit markets in the course of the financial crisis.

Our analysis is based on the premise (put forward in earlier work such as Cooper and John (1988)) that operating firms, or at least a significant fraction of such firms, benefit from the success of other operating firms in the economy, and the returns they

[1] For a description of the crisis and the events leading to it, see Brunnermeier (2009).

will make on borrowed capital thus will increase if other operating firms are able to obtain financing. This interdependence can be generated by multiple channels. A firm's success depends on the success of firms who use its products, of those who supply its inputs, and of those whose employees buy its products. As a result of this interdependence, the decision of any given financial institution whether to lend to a given operating firm depends not only on the financial institution's assessment of the firm's project but also on its expectations as to whether other financial institutions will lend money to other operating firms. (Below we refer to financial institutions as banks for simplicity.)

If fundamentals are sufficiently poor, it may be rational for banks not to lend regardless of what they expect other banks to do. And if fundamentals are sufficiently good, it may be rational for banks to lend regardless of what they expect other banks to do. However, given the positive spillovers among firms, there is an intermediate range of fundamentals that can give rise to multiple equilibria. In an efficient lending equilibrium, banks expect other banks to lend to operating firms with worthy projects, and these expectations are self-fulfilling. In an inefficient credit freeze equilibrium, banks have self-fulfilling expectations that other banks will withdraw from the lending market, and they rationally avoid lending to operating firms. We use the global-games methodology, where banks observe noisy signals about the macroeconomic fundamentals – which affect the profitability of real projects – to identify when an inefficient credit freeze arises in equilibrium. We also analyze the effect of various government policies on the probability of an inefficient freeze and on the overall wealth in the economy.

One standard policy measure to encourage lending is interest rate reduction. During the recent financial crisis, the Fed and other central banks around the world slashed interest rates. In our model, interest rate cuts by the central bank make an inefficient credit market freeze less likely by reducing the payoff to banks that avoid lending and invest in government bonds. Such cuts, however, still leave a range of fundamentals where the economy remains in an inefficient credit-freeze equilibrium, in which banks' self-fulfilling expectations that other banks will not lend lead them to avoid lending to firms that would be worth funding if other banks were expected to lend.

Another prominent course of government policy works via capital infusion. Our analysis indicates that a shock to the banking system that depletes the amount of capital banks have makes an inefficient credit market freeze equilibrium more likely. Such depletion in the financial sector's capital makes each bank more concerned that operating firms in the economy will not receive sufficient capital and therefore more reluctant to lend the capital it has to operating firms. As a result, intervention through the infusion of capital into banks, which governments in the US, UK, and other countries did throughout the financial crisis, can be beneficial and reduces the probability of a freeze in our model. However, we show that this measure, again, has limited effectiveness. Even when banks know that the banking sector's capital is no longer depleted, there is still a range of macroeconomic fundamentals in which the economy remains in an inefficient credit freeze and banks avoid lending to operating firms that they would fund if other banks were expected to lend.

We then turn to examine the possibility of the government providing capital directly to operating firms. In macroeconomic circumstances in which an inefficient credit freeze arises, should the government serve as "lender of last resort" to operating firms? That is, should the government provide capital directly to *Main Street* rather than provide it to *Wall Street* with the hope that the banks will in turn lend it to operating firms? This has been attempted during the financial crisis when the government bought commercial paper of some firms. In our model, direct lending to operating firms is more effective in reducing the probability of a credit freeze, as it avoids the coordination problem among banks in lending the money. However, as long as the government does not have the same ability as banks to distinguish between operating firms with good and bad projects, direct lending to operating firms, without screening of such firms by intermediating banks, can waste resources by channeling capital to some firms with bad projects.

Thus, in some circumstances, providing the government's capital to banks will fail to break an inefficient credit freeze, but providing this capital directly to operating firms will fail to take advantage of the screening expertise of private parties and hence to allocate capital among productive operating firms. Therefore, our analysis devotes considerable attention to alternative mechanisms under which the government harnesses the screening expertise of financial firms but also provides them with incentives to lend. For example, during the financial crisis, the US government has used the Term Asset-Backed Securities Loan Facility (TALF) to provide government capital, while limiting the downside risks of funds that extended certain types of credit to the nonfinancial economy. We analyze and compare the consequences of several alternative mechanisms. We identify their potential advantages and disadvantages relative to standard policy instruments as well as to each other. This analysis provides a rationale and framework for assessing and designing government-supported mechanisms to encourage lending while harnessing financial firms' expertise.

Although we shall explicitly discuss lending by financial firms to nonfinancial operating firms, it will be clear to the reader that the basic insights of our analysis also apply to some lending by the financial sector to other nonfinancial borrowers, namely, individuals and households. That will be the case whenever there is interdependence among borrowers that makes the ability of some nonfinancial borrowers to repay loans to a given bank dependent on the ability of other nonfinancial borrowers to obtain financing from other banks. This might be the case, for example, in the housing market, where the expected resale value of any given house for which a loan is sought from a bank depends on future housing prices and thus might depend on the willingness of other banks to finance house purchases. Our focus in this paper, however, is on lending to business operating firms, and we leave the extension and adaptation of our analysis to other lending to nonfinancial borrowers for subsequent work.

Our paper is related to the large literature on bank runs, where depositors rush to demand early withdrawal from the bank because they believe that other depositors are going to do the same. The seminal paper on bank runs is by Diamond and Dybvig (1983), and it was followed by much subsequent work on the subject (see, e.g., Allen and Gale (1998), Peck and Shell (2003), and Goldstein and Pauzner (2005)). The ideas in the bank-run literature have subsequently been applied to also describe runs by investors on currencies (Morris and Shin (1998)), financial markets (Bernardo and Welch (2004) and Morris and Shin (2004a)), and other contexts. Our paper, which builds on the analytical insights of this literature, focuses on a different context. We do not consider a run by depositors or investors on financial institutions, financial markets, or governments, but rather a run by financial institutions on the nonfinancial firms of the real economy. More importantly, our contribution is in analyzing alternative government responses that can be used in this context.

Several papers analyze policies of deposit insurance or 'lender of last resort' to prevent runs on financial institutions. These include the papers by Rochet and Vives (2004), Corsetti, Guimaraes, and Roubini (2006), and Morris and Shin (2006). The policy problem we consider here is fundamentally different. In these papers, the analysis revolves around capital infusion to an institution that might be subject to a run because it lacks capital. In our model, on the other hand, coordination failures arise among financial institutions in their decision to lend to operating firms. Hence, capital infusion to financial institutions might not be sufficient to eliminate an inefficient credit market freeze, as they might fail to coordinate on lending this capital. This leads to our discussion on the role of direct government intervention in lending to operating firms, and the various ways of implementing it without losing the informational advantage that banks have in lending to such firms.[2]

The source of coordination failures among banks in our model is the interdependence among firms in the real economy that makes the investment in a firm profitable only if other firms are able to invest and produce. Such strategic complementarities in the macro economy were motivated in an influential paper by Cooper and John (1988), and have been used in other papers (e.g., Goldstein and Pauzner (2004)). Our paper complements this literature by showing how such complementarities can cause an inefficient credit freeze and analyze government policy in such context.

Models of strategic complementarities usually yield multiple equilibria and thus do not lend themselves naturally to policy analysis. To overcome this problem, we follow recent work on self-fulfilling crises and rely on global-games techniques. The global-games literature has been pioneered by Carlsson and van Damme (1993) and Morris and Shin (1998) and is reviewed in Morris and Shin (2003)). In particular, we build here on the model in Morris and Shin (2004b).

The recent financial crisis has generated a surge of theoretical research on the performance of markets during the financial crisis. Let us mention a few papers that are more related to ours. Acharya, Gale, and Yorulmazer (2009) analyze the debt rollover problem, where the fact that debt needs to be rolled over frequently reduces the debt

[2] A recent paper by Sakovics and Steiner (2009) analyzes a related question of subsidizing agents who participate in a coordination game. While their paper focuses on who should be subsidized, ours focuses on how to subsidize.

capacity of firms with little credit risk. Diamond and Rajan (2009) argue that the possibility of future fire sales makes banks want to hoard on cash instead of extending new loans. Benmelech and Bergman (2009) analyze government policies in a model where credit traps evolve as a result of reduction in collateral value. Philippon and Schnabl (2009) analyze government policy in a model where credit does not flow because firms suffer from a debt overhang problem.

The remainder of this paper is organized as follows. Section 2 describes our framework of analysis. Section 3 provides an equilibrium analysis, identifying the conditions under which inefficient credit freeze equilibria will arise. Section 4 analyzes alternative governmental policies that may be used to produce a credit thaw, identifying their potential benefits and limitations. Section 5 concludes.

2. The Model

There is a continuum $[0,K]$ of identical financial firms, which we call banks for simplicity. Each bank has 1 dollar of capital. Banks can choose whether to invest their capital in a risk-free asset, such as a deposit with the central bank, generating $1+r$ (>1) dollars next period, or lend it to operating (nonfinancial) firms. Banks are risk neutral and hence make their choices so as to maximize expected payoffs.

Operating firms have access to investment projects that require investment of 1 dollar, but do not have any capital to finance them. They rely on bank lending to invest in their projects. There are two types of operating firms. Some operating firms have bad projects that always generate a gross return of 0. Others have good projects, generating a gross return of $1+R$ ($>1+r$) when the macroeconomic fundamentals are strong and a sufficient number of operating firms get the required financing to invest. Specifically, the return on a good project is assumed to take the following form:

$$\begin{cases} 1+R & if \quad aL+\theta \geq b \\ 0 & if \quad aL+\theta < b \end{cases}. \tag{1}$$

Here, θ is a macroeconomic fundamental that can represent various factors, such as firms' productivity, consumers' demand, the cost of imported oil, etc. The variable L represents the mass of firms that received loans from banks to invest in their projects. In the basic model, $L = nK$, where $n \in [0,1]$, whose value is determined endogenously in the model, is the proportion of banks that decide to lend to firms. Hence, the macroeconomic fundamentals and the proportion of firms investing in their projects are together responsible for the profitability of good projects. a is a parameter capturing the importance of complementarities vs. fundamentals in making projects profitable, and b is a parameter capturing the threshold needed to become profitable.[3]

The effect of L reflects the interdependence in payoffs among operating firms in the economy. This interdependence can be due to several reasons. For example, many firms can prosper only when there are other firms in the economy that can provide them with adequate inputs. In addition, many firms sell some or all of their output to other firms, and thus depend on the operation of other firms. Even firms that sell their output solely to individuals might suffer from declining sales if other firms are not able to employ these individuals. In sum, the success of the economy in our model requires the coordination among various operating firms and the banks that finance them. Such coordination issues in the macro economy were proposed before by other authors, e.g., by Cooper and John (1988).[4]

We assume that banks can tell the difference between firms with bad projects ("bad firms") and firms with good projects ("good firms"), and thus can choose to lend only to firms with good projects. The firms with bad projects will have an explicit role in the model later when we consider the possibility of the government extending direct loans to operating firms. We assume for simplicity that the mass of firms with good projects is greater than the mass of banks K, and thus banks are able to extract the full return R from lending to good firms, whose projects were successful. Given this assumption, we will be able to show that an inefficient credit-freeze equilibrium may arise even when the competitive conditions enable banks to extract the full surplus from lending and are thus as favorable to lending activity as possible.

[3] Note that we use a discontinuous return function (i.e., projects either succeed or do not succeed) for simplicity of exposition. Our results would hold in a model where the return on projects is a continuous function of θ and L.

[4] Clearly, there are some firms (e.g., firms providing services to firms in bankruptcy) that can become better off when other firms are hurting. Our analysis applies to the universe of nonfinancial firms where positive complementarities are the dominant force.

We assume that the fundamental θ is not publicly known. It is normally distributed around a mean of y. We consider y to be public news available to everyone about the strength of the economy. The standard deviation of θ around y is σ_θ, and we use $\tau_\theta = \frac{1}{(\sigma_\theta)^2}$ to denote the precision of the distribution of θ. Each bank i receives a private signal regarding the value of θ, given by $x_i = \theta + \varepsilon_i$. Here, the individual specific noise terms ε_i are independently normally distributed with mean 0 and standard deviation σ_p. We use $\tau_p = \frac{1}{(\sigma_p)^2}$ to denote the precision of banks' signals. Banks make their decisions whether to invest in the riskless asset or to lend to operating firms after observing these signals.

Because the profitability of operating firms depends on macroeconomic conditions and the availability of financing to other firms, a bank's incentive to lend to a given operating firm with a good project is higher when the economy's fundamentals are favorable and when the number of banks who are going to lend is high. While the optimal behavior of a bank usually depends on its belief regarding the behavior of other banks, there are ranges of macroeconomic fundamentals in which banks have a dominant strategy. More specifically, when the fundamental θ is above b, a bank will prefer to lend to an operating firm no matter what it believes other banks will do. This is because in this range the return on lending is guaranteed to be $1+R$. Similarly, when the fundamental is below $b - aK$, the bank will invest in a government bond even if it believes that all the other banks will lend to operating firms.

Since θ is drawn from an unbounded distribution, there are signals at which banks choose to lend to operating firms independently of their beliefs regarding other banks' behavior, as well as signals at which they choose not to lend independently of their beliefs. As for banks that receive a signal in the intermediate range, however, their optimal decision depends on their expectations about whether other banks will lend to operating firms. This calls for an equilibrium analysis to which we turn next.

3. Equilibrium Analysis

3.1. Credit Freeze

We solve the model using global-games techniques. In particular, we follow here Morris and Shin (2004b). Proposition 1 states the basic equilibrium result.

Proposition 1: *Suppose that the information in banks' signals is precise relative to prior information, so that* $\frac{\tau_\theta}{\sqrt{\tau_p}} \leq \frac{\sqrt{2\pi}}{aK}$. *Then, there is a unique Bayesian Nash Equilibrium in which all banks lend to operating firms if they observe a signal above* x^* *and withdraw from lending if they observe a signal below* x^*. *Investment projects then succeed if and only if the fundamentals are above the threshold* θ^*, *between* $b - aK$ *and* b, *which is characterized by the following equation:*

$$\theta^* = b - aK + aK\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+r}{1+R}\right)\right)\right), \qquad (2)$$

where $\Phi(\cdot)$ *is the cumulative distribution function for the standard normal.*

Remarks: (i) *Intuition:* The intuition behind the result of Proposition 1 can be explained as follows. Due to strategic complementarities, when banks do not know that the fundamentals are below $b - aK$ or above b, they do not have a dominant action to choose. In this case, they simply want to do what other banks do. In a model with common knowledge about the fundamental θ, this would result in multiple equilibria, as both the case where all banks lend to operating firms and the case where none of them does so can be supported by equilibrium beliefs. The assumption that banks observe slightly noisy information about θ combined with the presence of extreme regions where they have dominant actions pins down the threshold equilibrium characterized by equation (2) as the unique equilibrium here.

Intuitively, with noisy information, banks that observe a signal slightly below the upper dominance region know that the fundamental may well be higher than their signal and thus choose to lend. Knowing this, banks with even lower signals will also choose to lend. This rationale can be repeated again and again, guaranteeing a range of signals below the upper dominance region, where banks choose to lend. Similarly, due to the noisy information, there will be a range of signals above the lower dominance region, where banks will choose to invest in government bonds. The proof of equilibrium with global-game techniques demonstrates that this procedure exactly separates the real line, so that banks lend above x^* and do not lend below it, leading to success of real projects above θ^* and failure below it.

(ii) *The No-Lending Threshold:* Equation (2) characterizes the threshold fundamental θ^* below which investment projects fail. To gain some intuition for what determines this threshold, it is useful to consider the limit, as banks' private signals become infinitely precise, i.e., as τ_p approaches infinity. In this case, x^* and θ^* converge to the same value, which is given by:

$$\theta^* = b - aK + aK\frac{1+r}{1+R} \tag{3}$$

Intuitively, a bank observing the signal θ^* is indifferent between lending to operating firms and investing in the risk-free asset under the belief that the proportion of other banks lending to operating firms is uniformly distributed between 0 and 1.[5] This implies that lending to operating firms will be profitable with probability $\left(1 - \frac{b-\theta^*}{aK}\right)$, which yields the following indifference equation:

$$1 + r = \left(1 - \frac{b-\theta^*}{aK}\right)(1 + R).$$

Rearranging this equation, we get (3).

Because banks' signals have infinitesimally small noise, the equilibrium result is that all banks lend when the fundamental is above θ^* and do not lend when the fundamental is below θ^*. Hence, below θ^*, the economy ends up in a no-lending equilibrium.

(iii) *Efficient and Inefficient No-Lending Equilibria:* When macroeconomic fundamentals are so bleak that we are below $b - aK$, the refusal of banks to lend is efficient because firms' projects will not produce payoffs exceeding the economy's

[5] The rationale behind the uniform-distribution belief is that each bank perceives a uniform distribution on the proportion of banks getting lower signals than its own. Given that the bank observed θ^* and that other banks lend if and only if they obtained a signal above θ^*, the bank perceives a uniform distribution on *n*.

riskless rate even if no banks withdraw from the lending market. When fundamentals lie between $b - aK$ and θ^*, however, the economy is in an inefficient no-lending equilibrium. In this interval, banks withdraw from lending even though, were banks all willing to lend, firms' projects would produce returns exceeding the riskless rate and the banks would be all better off relative to the no-lending equilibrium. We refer to such an inefficient equilibrium as a *credit freeze*.

(iv) *Credit Freezes as a Coordination Failure*: When fundamentals lie tween $b - aK$ and θ^*, the credit freeze can be viewed as due to coordination failure. Here, banks do not lend to operating firms just because they fear that other banks will not lend to operating firms. The fundamentals uniquely determine banks' expectations regarding what other banks are going to do and thus (indirectly) uniquely determine whether a credit freeze will arise; however, the credit freeze is still inefficient. If the banks could have concluded among themselves an enforceable agreement on how they would act, they would have agreed on a coordinated strategy of lending to firms. However, as long as the banks make their decisions separately, based on their expectations as to how other banks will act, an inefficient credit freeze equilibrium may ensue. Interestingly, this inefficiency could have been avoided if the available capital was held by one large bank (or a few large banks) instead of many small ones. Thus, from the point of view of avoiding coordination failures, having large financial institutions may be an advantage.

(v) *The 2008-2009 Credit Crunch:* The analysis above indicates that a credit freeze can arise in a certain range of fundamentals and that an economy may fall into such an equilibrium when fundamentals worsen. The credit crunch of 2008-2009 was preceded by the arrival of bad economic news about macroeconomic fundamentals. For one thing, the substantial decline in housing prices considerably reduced the wealth of households, and such a reduction could have been expected to produce a subsequent decrease in consumer spending and thus the demand for firms' output. Our model indicates that the arrival of bad macroeconomic news might trigger a credit freeze that will lead to the refusal of banks to lend to firms, even though the firms would still be worth financing notwithstanding the deterioration in macroeconomic fundamentals absent a self-fulfilling withdrawal of banks from the lending market. Such triggering of a credit freeze will of course further reinforce and exacerbate the effects of the deterioration in fundamentals that triggered it in the first place.

3.2. Can Reduction in Banks' Capital Trigger A Credit Freeze?

The credit crunch of 2008-2009 was preceded not only by deteriorating macroeconomic fundamentals but also by a deterioration in the capital positions of financial institutions as a result of losses from real estate mortgage assets. This subsection examines whether a reduction in the banks' capital can trigger a credit freeze, even holding the fundamental θ constant.

To study this issue, let us introduce the parameter l (between 0 and 1), which denotes the proportion of capital lost by banks in the economy due to bad past investments. For simplicity of exposition, we assume that capital has been lost uniformly across banks, that is, each bank in the economy lost a fraction l of its capital. With this parameter introduced into the model, the capital of a single bank ($1-l$) does no longer suffice to finance a firm's project. Hence, each firm will have to pool resources from more than one bank. Eventually, if a fraction n of banks decide to lend the capital they have to operating firms, the total capital that will be provided as loans to such firms will be only a fraction $n(1-l)$ of K, and hence $L = n(1-l)K$.

Proposition 2 characterizes the new equilibrium results and the effect that the parameter l may have on the realization of a credit freeze.

Proposition 2: *(a) In the unique Bayesian Nash Equilibrium, investment projects succeed if and only if the fundamentals are above the threshold $\theta^*(l)$. The threshold $\theta^*(l)$ is characterized by the following equation:*

$$\theta^* = b - aK(1-l) + aK(1-l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right), \quad (4)$$

(b) The threshold $\theta^*(l)$ is an increasing function of the parameter l; hence, an increase in the fraction of bank capital that was lost, l, with no change in the fundamental θ, can shift the economy from an efficient lending equilibrium to an inefficient credit freeze.

Remark: The intuition behind the result of Proposition 2, which indicates that a reduction in the banking sector's capital raises the threshold, below which banks elect to withdraw from lending, is as follows. A reduction in the banking sector's capital makes each bank "less sure" that other banks will provide enough capital to operating firms to guarantee adequate return from extending loans to operating companies. Hence, such a reduction makes each bank more concerned that, in the event it provides a loan to a given operating company, the firm will nonetheless suffer from the inability of many other operating companies to obtain financing. Technically, in equilibrium, a higher fundamental θ is required to make banks indifferent between providing credit to operating companies and investing in the riskless asset, which leads to an increase in the threshold θ^*, and thus in turn to a larger range of fundamentals at which an inefficient credit freeze ensues.

Thus, our results indicate that banking losses can drive the economy into a credit freeze even without any accompanying change in other macroeconomic fundamentals. What is important to stress is that such reduction in capital will make operating firms less likely to receive financing not only because of the direct effect that some capital which could have been available for loans is no longer in place, but also because of the indirect effect, which our result identifies, that it might deprive operating firms even of the capital that remains in place. By influencing banks' expectations as to how many operating firms will be able to obtain financing, the disappearance of some capital can make banks more reluctant to lend the capital that still remains.

4. Government Policy

The focus of our paper is on analyzing and comparing various government policies intended to reduce the inefficiency from credit-freeze equilibria. This analysis, building on the setup and equilibrium analysis of the preceding two sections, is provided in this section.

4.1. Interest Rate Reduction

One governmental measure that is natural to examine as an instrument for addressing a credit freeze is a cut in interest rates. During the credit crisis of 2008, governments around the world have made substantial use of interest rate cuts. During 2008, in a series of moves, the Federal Reserve Board cut the federal rate considerably, bringing the Federal funds rate down from 4.25% in January to 1% in October. Similar steps have been taken by other central banks around the world. In October 2008, for example, facing a worldwide contraction in lending, twenty one countries around the world, including the US and the UK, simultaneously cut interest rates.

Under normal market conditions, a cut in a country's interest rate can be expected to spur lending. To what extent can a cut in interest rate, however, be relied on to eliminate a coordination failure that results in an inefficient credit freeze equilibrium? As we show below, a cut in interest rate (i.e., reducing r) may – but does not have to – produce a credit thaw. The following proposition summarizes the results.

Proposition 3: *(a) For every level of bank losses l, a decrease in the interest rate r on government bonds reduces the threshold θ^*, below which a credit freeze occurs, and hence reduces the likelihood of a credit freeze.*
(b) Yet, for every $r \geq 0$ and l (between 0 and 1), there are realizations of the fundamental θ, at which an inefficient credit freeze occurs.

Remarks: (i) *The Reduction in the Likelihood of Credit Freeze*: A reduction in r makes investment in the riskless asset less attractive and thus lowers the expected return that will be necessary to induce banks to lend to operating firms, which in turn lowers the threshold θ^* above which banks will lend to such firms rather than withdraw from the lending market. It is interesting to note that the effect of the reduction in r on the decision of an individual bank is more than just the direct effect on this bank's payoff. Because the reduction in interest rate can be expected to affect other banks' decisions, it also affects the individual bank's decision through its effect on the bank's expectation concerning how other banks will act.

(ii) *The Limits of Interest Rate Cuts*: The second part of the proposition says that interest rate reductions cannot eliminate all inefficient credit freezes. Even if the government reduces *r* all the way to 0 (or to a very low level just above zero), θ^* will remain above $b - aK(1-l)$, which implies that inefficient credit freezes may occur in the interval between $b - aK(1-l)$ and θ^*. The intuition goes back to the coordination-failure aspect of credit freezes in our model. Even if the net return on the riskless asset is close to zero, banks will prefer to invest in it rather than lending to operating firms when they expect that other banks will all do so. Thus, while governmental reduction in interest rates can shift the threshold that triggers coordination failure and credit freezes, it cannot completely eliminate such coordination failures. This result might be thought of as similar in spirit to the well-known liquidity trap in monetary economics.

4.2. Infusion of Capital to the Banking System

During the financial crisis of 2008-2009, governments around the world infused very large amounts of capital into banks to shore up banks' capital positions, which have eroded due to losses from real estate mortgage assets and other investments. In the fall of 2008, for example, the US Troubled Asset Relief Program (TARP) provided about $250 billion in capital to banks, and the UK invested about $90 billion in several major banks.

Infusion of capital into banks is a policy measure that is natural to consider in financial crises. Infusion of capital, e.g., in the form of a lender of last resort, has been used to prevent or stop bank runs in which depositors seek to withdraw their deposits en masse from a bank. When a solvent bank faces a problem of a bank run, providing the bank with capital may ensure depositors that their money is safe and prevent a run on the bank. Infusion of capital has also been used in the case of insolvent banks when governments felt that making sure such banks can meet their obligations to depositors is necessary to prevent a contagion effect that would lead to runs by depositors on other banks.

The subject we examine using our model is different because it does not involve potential runs by depositors on banks (or financial institutions more generally). Rather, it is the banks that may "run on the economy" by not extending loans to operating firms. In our context, therefore, capital infusion will not be designed to enable banks to meet their obligations toward their creditors. Rather, in our context, capital infusion may be used to facilitate lending by banks to operating firms in two ways: first, the direct and straightforward way of providing banks with additional capital that they may use for the purposes of extending loans; and, second, the indirect effect, which our model highlights, of encouraging banks to lend to operating firms capital that they already have but that they might elect not to lend in the absence of the capital infusion to the banking sector and the shift in expectations produced by it.

To analyze governmental infusion of capital into the banking sector, let us assume that the government has or can obtain capital that would be sufficient to cover part of banks' losses. In particular, let us assume that the government has an amount $Z = \alpha l K$, enabling it to inject a proportion α of the lost capital l to all banks in the economy. If the government injects the capital, each bank will have a total capital of $1 - (1 - \alpha)l$.

Banks will again make a decision whether to lend to operating firms or invest in the riskless asset. The first option yields a gross return of $1 + R$ if firms' investment projects succeed, which happens as long as the proportion of banks lending to firms is above $\frac{b-\theta}{a(1-(1-\alpha)l)K}$, while the second one yields a certain gross return of $1+r$. To focus on capital infusion, we will assume from now that r=0, so that the government has already reduced the interest rate as much as possible. The following proposition analyzes the effect of injecting capital to the banking system.

Proposition 4: *(a) The threshold θ^*, below which a credit freeze occurs when the government covers proportion α of bank losses is implicitly determined by:*

$$\theta^* = b - aK(1 - (1 - \alpha)l) + aK(1 - (1 - \alpha)l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1}{1+R}\right)\right)\right), \qquad (5)$$

(b) The threshold θ^* decreases in α .Yet, for every α ≤l, there are realizations of the fundamental θ at which an inefficient credit freeze will occur.

Remarks: (i) *The Reduction in the Likelihood of Credit Freeze*: By providing capital to the banking system, the government creates externalities that make the projects of operating firms more profitable. This is because banks have more capital to lend to operating firms, and so when they decide to lend, operating firms will produce greater returns. This encourages banks to lend to operating firms, making a credit thaw more likely to occur. Importantly, the effect of capital infusion is not merely due to the fact that the government's capital flows to operating firms, but rather mostly due to the fact that the availability of this capital makes banks more likely to lend capital that they already have. This is thus the mechanism behind the effect of TARP if the underlying problem was indeed a coordination problem.

Technically, at the threshold, below which a credit freeze occurs, banks will require a lower fundamental θ to be indifferent between lending and not lending to operating firms when the government injects more capital to the banking system (α is higher). This is because a higher α implies that under a uniform distribution of banks that decide to lend, the returns from lending increase. This pushes the threshold θ^* lower and increases the likelihood of a credit thaw.

(ii) *The Limits of Capital Infusion:* Even when the government covers all the losses that banks accumulated, banks will be reluctant to lend if they believe other banks are not going to lend. Hence, this policy of the government cannot fully eliminate coordination-based credit freezes. This sharpens the difference between infusion of capital to banks in our model, where crises reflect a run of banks on operating firms, and infusion of capital in a model of a run on the bank. Because, in our model, coordination failures arise among banks in their decision to lend to operating firms, banks end up not using capital that they have for lending purposes. Hence, capital infusion might not be sufficient to eliminate an inefficient credit market freeze.

4.3. Direct Lending to Operating Firms

As explained above, the difficulty that the government faces in breaking a credit freeze by providing capital to banks is that banks might take the capital and not lend it to operating firms due to the fear that other banks will not lend. An alternative to providing capital to banks is for the government to forgo the intermediation by banks and lend directly to operating firms. This approach could be viewed as extending the government's role as a lender of last resort from the financial sector to the nonfinancial sector. During the financial crisis of 2008-2009, governments provided some direct financing to operating firms. In the US, for example, the government made an unprecedented entry into the market for commercial paper and purchased the commercial paper of some nonfinancial firms.

While such an approach avoids the coordination problems that might impede lending by banks, it suffers from the disadvantage that the government does not have the ability that banks have to screen operating firms. Thus, providing capital to firms without using the intermediation services of banks would lead to lending to some firms that have bad projects and should not get financing.

To examine the efficiency of direct lending formally, we have to explicitly describe the bad operating firms in our model. So far, there was no need to consider them and how many of them exist, as the assumption was that banks can tell good firms from bad firms, and thus bad firms would always be avoided. If the government attempts to lend to operating firms directly, however, it will have to consider the consequences of not being able to tell good firms from bad firms.

For the formal analysis, let us denote the mass of bad (good) operating firms in the economy as B (G). Recall that G is greater than K (the mass of banks). Suppose that the government has capital at the amount of $Z = \alpha l K$ (as in Section 4.2) and it has to decide whether to inject it directly to operating firms or to the banks. When the government lends capital to operating firms, the capital is randomly allocated between good or bad firms. We denote the proportion of the capital that finds its way to bad firms as $\beta \equiv B/(B+G)$. For simplicity, we assume that the government does not know the realization of the fundamental θ (and does not get any signal about it). Initially, we will assume that the operation of firms with bad projects, while producing no returns for the lending bank, still provides a positive externality for other operating firms (as firms with bad projects do purchase inputs from other firms etc.); below we will discuss how our conclusions will change if we were to assume that such externalities flow only from the operation of firms with good projects.

We begin the analysis by comparing the likelihood of a credit freeze under direct lending to operating firms vs. under infusion of capital to banks. The result is summarized in the following proposition.

Proposition 5: *If the government lends $\alpha l K$ directly to operating firms, there is a credit freeze equilibrium if and only if the fundamental θ is below the threshold θ^*, which is implicitly defined by:*

$$\theta^* = b - aK(1-(1-\alpha)l) + aK(1-l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1}{1+R}\right)\right)\right), \quad (6)$$

Denoting the threshold under capital injection to banks (defined in equation (5)) as θ^*_{Bank} and the one under direct lending to firms (defined in equation(6)) as θ^*_{Direct}, we get that for every α and l, $\theta^*_{Bank} > \theta^*_{Direct}$, implying that the probability of a credit freeze is higher under capital injection to banks than under direct lending to operating firms.

Remark: The intuition for why directly lending the government's capital will reduce the lending threshold more than infusing the capital into banks is simple. When the government injects capital to banks, some of this capital might remain "stuck" in the banking system as banks fail to coordinate on lending it to operating firms. When the government lends the capital directly to operating firms, banks know that it will generate the desired externalities. As a result, lending directly to operating firms more effectively increases the returns to banks from lending and encourages banks to lend, and thus is more likely to bring the economy to a credit thaw.

Focusing attention on the limit case where banks' private signals become infinitely precise, i.e., as τ_p approaches infinity, the comparison between the two cases becomes very transparent. Following (3), we can express the thresholds under the two regimes in the limit case as:

$$\theta^*_{Bank} = b - aK(1-(1-\alpha)l) + aK(1-(1-\alpha)l)\frac{1}{1+R} \quad (7)$$

$$\theta^*_{Direct} = b - aK(1-(1-\alpha)l) + aK(1-l)\frac{1}{1+R} \quad (8)$$

Equations (7) and (8) clearly reveal that $\theta^*_{Bank} > \theta^*_{Direct}$.

But, as noted above, the fact that direct lending is more likely to generate a credit thaw is not enough to make this policy measure more efficient. We now carry out a full comparison between the two measures. For a sharp comparison, we focus attention on the limit case considered above. This is easier to work with because at the limit either all banks lend or none of them does, and then we do not have to consider cases where some banks lend but projects fail and vice versa. The following proposition characterizes which policy ends up producing better results for different levels of the fundamentals.

Proposition 6: *(a) When the fundamental θ is below θ^*_{Direct} or above θ^*_{Bank}, the overall wealth in the economy is higher under injection of capital to the banking system than under direct lending to operating firms.*
(b) When the fundamental θ is between θ^*_{Direct} and θ^*_{Bank}, the comparison between the two regimes yields ambiguous results. For a sufficiently large β and/or small R the wealth is higher under injection of capital to the banking system.
(c) Ex-ante, when choosing the policy, the government should choose to inject capital to the banking system when β is sufficiently high, R is sufficiently low, and y is either sufficiently high or sufficiently low (i.e., outside an intermediate range).

Remarks: (i) *When θ is below θ^*_{Direct} or above θ^*_{Bank}*: In these circumstances, direct lending is clearly undesirable, as it does not turn a credit freeze into a thaw, but still generates the costs of lending by the government. In particular, when θ is above θ^*_{Bank}, a credit thaw is produced under both policies, but direct lending involves lending money to bad borrowers. When θ is below θ^*_{Direct}, there is a credit freeze under both policies, but direct lending involves lending to bad borrowers and also to good borrowers, whose projects fail because there is a credit freeze.

(ii) *When θ is between θ^*_{Direct} and θ^*_{Bank}*: In these circumstances, infusion of capital into the banks will fail to induce banks to lend efficiently. Direct lending by the government will accordingly have two benefits: first, it will provide financing to some operating firms with good projects; second, direct lending will induce banks to lend to operating firms. On the other hand, direct lending by the government will involve the wasteful provision of financing to firms with bad projects. If β is sufficiently large – that is, when the government's screening ability is sufficiently poor – this cost of a direct lending program may make it overall undesirable. The same is true when the return on successful good projects R is sufficiently low.

(iii) *Ex-ante choice between the two policy measures*: As noted above, the government does not know the realization of θ. Hence, it should make its decision between the two policy measures based on the characterization provided above of what will happen for different realizations of θ and on the prior distribution of θ. Clearly, based on the above, we can see that for sufficiently high β and/or low R, the government should not choose direct lending. In addition, y – the mean of the fundamentals, which can be interpreted as public news – matters for the decision. Given that direct lending may only be desirable at an intermediate range of the fundamentals, the government should not choose it when y is either too high or too low, only when it is in an intermediate range.

This result can be tied to the policy debate that came up in the recent crisis about whether the government should bail out *Wall Street* or *Main Street*. Infusing money to banks can be interpreted as helping Wall Street, while lending directly to operating firms can be interpreted as helping Main Street. Our results suggest that the latter is desirable when public news about the fundamentals of the economy is in some intermediate range, and not desirable when it is too bad or too good.

(iv) *The Case in which only Operating Firms with Good Projects have Beneficial Spillover Effects*: Finally, we remind the reader that our analysis was conducted under the assumption that capital that is lent to bad firms still creates positive externalities to other firms even though it generates no direct return. It might be argued, however, that some bad projects create no or lower spillover benefits for other firms. To examine the consequences of this factor, let us assume that the payoffs of operating firms do not depend on the number of other firms in operation but on the number of other firms in operation with good projects. Making this assumption weakens the attractiveness of direct lending to operating firms by the government.

Formally, note that if only good firms getting capital from the government created synergies to other firms, than the equation that determined the threshold θ^*_{Direct}, below which a credit freeze occurs in a regime of direct lending, would change from equation (8) to the following (we consider the limit again, for simplicity):

$$\theta^*_{Direct} = b - aK\big(1 - \big(1 - \alpha(1-\beta)\big)l\big) + aK(1-l)\frac{1}{1+R} \qquad (9)$$

Clearly, this would increase the likelihood of a credit freeze under direct lending, making this regime overall less desirable.

4.4. Government Funds Managed by Private Firms

While the direct lending program analyzed in the preceding section could ensure that the government's capital will flow to operating firms, it is disadvantaged by the government's inability to distinguish between operating firms with good and bad projects. Accordingly, a direct lending program could benefit if it were designed to utilize the expertise of private parties in screening operating firms with good projects from operating firms with bad projects.

Consider the following mechanism. The government places the capital $Z = \alpha lK$ in a number of funds, which are managed by banks or by other private agents that have the same expertise. The managers of the funds will be paid a proportion γ on any profit that they generate on the capital invested by the fund they manage – that is, the excess of the return they generate over the riskless return. However, like hedge fund managers, they will not bear any share of the losses generated, if any, and such losses will be borne by the government.[6] The following proposition characterizes the consequences of this mechanism.

Proposition 7: *(a) If the government invests $Z = \alpha lK$ in funds dedicated to lending to operating firms, and managed by private agents promised a proportion γ on any return they generate above 1, then (i) the funds' capital will be fully lent to operating firms with good projects, and (ii) the threshold defining whether banks will lend to operating firms will be θ^*_{Direct}, as characterized in equation (6).*

(b) Consider the case where τ_p approaches infinity: Compared with infusing the capital Z into banks, the setting of government funds proposed here will (i) produce the same total wealth if θ exceeds θ^*_{Bank}, (ii) produce a higher total wealth if θ is between θ^*_{Direct} and θ^*_{Bank}, and (iii) produce a lower total wealth if θ is lower than θ^*_{Direct}.

(c) Ex-ante, when choosing the policy, the government should choose to inject capital to the banking system, rather than to place it with private funds, when R is sufficiently low, and γ is sufficiently low.

[6] For a fuller discussion of the institutional details involved in implementing this mechanism, see Bebchuk (2008b). The mechanism is similar to the one proposed by Bebchuk (2008a) for the government's purchase of troubled assets through funds using governments funds and run by private agents compensated with a cut of the profits generated by the funds.

Remarks: (i) *The Decisions of the Government Funds' Managers*: The design of the mechanism ensures that the government's capital invested in the funds will be fully provided to operating firms with good projects. Because the government will fully bear the losses, the managers will have no reason to avoid lending the funds given to them. Furthermore, because the managers will be promised a cut of the profits, they will have an incentive to screen operating firms with good projects from operating firms with bad projects, and their dominant strategy will be to lend funds only to firms with good projects.

(ii) *The Effect on Banks' Lending Threshold*: Because the government funds program, like the direct lending program, will ensure that an amount of $Z = \alpha l K$ will be lent to operating firms, the threshold for banks' lending to operating firms will be the same as the threshold, defined in equation (6), that would result from the direct lending program under the assumption that all operating firms have positive externalities for other operating firms.

(iii) *Comparison with the Direct-Lending Program*: Relative to the direct-lending program, the government funds mechanism has the advantage of not involving loans to operating firms with bad projects; as a result, the government funds program performs better in a comparison with infusion of capital into banks. While the government funds program does not have this cost of the direct-lending program, it does, like the direct-lending program, provide capital to firms in circumstances in which θ *is below* θ^*_{Direct}, which are circumstances in which even funding good operating firms is inefficient (because not enough of them are being funded).

(iv) *Comparison with Infusion of Capital into Banks:* In circumstances in which θ *exceeds* θ^*_{Bank} , where infusion of capital will be sufficient to produce a credit thaw, the government funds mechanism will perform neither better nor worse than infusion of capital. In this case, both mechanisms will lead to providing *K* to operating firms with good projects. (In these circumstances, the direct-lending program performs worse than capital infusion into banks, because it involves lending to operating firms with bad projects.)

In circumstances in which θ is between θ^*_{Direct} and θ^*_{Bank}, the government funds mechanism will be superior to infusion of capital to banks. In these circumstances, the infusion of capital will not eliminate an inefficient capital freeze, and no funding will be provided to operating firms. In contrast, in these circumstances, under the government funds mechanism, both the capital in the government funds and the capital in the hands of the banks will be provided to operating firms.

Finally, when θ is lower than θ^*_{Direct}, the government funds mechanism will produce inferior results. In this case, the operation of government funds will not lead banks to lend to operating firms, and the lending by the government funds will produce losses.

(v) *Ex-ante choice between the two policy measures*: Given that the government funds mechanism is worse than infusion of capital to banks only when the fundamental is relatively low, the government would prefer injecting capital to banks only when y – its prior expectation about the fundamental – is sufficiently low.

4.5. Government Guarantees

The problem with the mechanisms discussed in the previous two sections is that they create excessive waste by having capital lent to operating firms when their projects fail. Under direct lending by the government (Section 4.3), the problem is most severe because the government, who is uninformed about borrowers' type, blindly lends to firms who have no access to potentially successful projects. Under privately-managed government funds (Section 4.4), the government uses the expertise of private agents in avoiding bad borrowers, but the incentives for private agents to lend are so strong that they lend even in a credit freeze when good projects fail because of the lack of lending by banks. We consider now an alternative mechanism that attempts to encourage lending without wasting government resources. Here, the government just provides banks with guarantees in case their loans to operating firms fail. During the financial crisis of 2008-2009, governments such as those of the US and the UK used the mechanism of guarantees, though they used it primarily (as in the case of Citigroup) to limit the potential losses of banks on existing loan portfolios. In contrast, our focus is now on encouraging new lending by providing guarantees that limit the losses from new loan portfolios.

Specifically, suppose that the government guarantees a proportion δ of a bank's losses. In this case, a lending bank will receive the return $1+R$ when projects succeed and $\delta < 1$ when projects fail. The following proposition characterizes the consequences of using this mechanism.

Proposition 8: *(a) Suppose that the government provides a guarantee covering a proportion δ (between 0 and 1) of banks' losses, that is, the government pays δ when a bank lends and real projects fail. Then, the threshold θ^*, below which a credit freeze occurs is given by:*

$$\theta^* = b - aK(1-l) + aK(1-l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1-\delta}{1+R-\delta}\right)\right)\right), \qquad (10)$$

which is decreasing in δ.

(b) At the limit, as τ_p approaches infinity, the threshold (denoted as $\theta^*_{Guarantees}$) is given by:

$$\theta^*_{Guarantees} = b - aK(1-l) + aK(1-l)\frac{1-\delta}{1+R-\delta} \qquad (11)$$

Then, when the government provides full guarantees ($\delta = 1$), all banks lend and projects fail only when they are inefficient ($\theta < b - aK(1-l)$). Otherwise, banks do not always lend, and projects sometimes fail even though they are efficient ($\theta > b - aK(1-l)$).

Remarks: (i) *The Nature of the Mechanism:* Government guarantees reduce the threshold below which crises occur because they make it more attractive for banks to lend. Considering the case where banks' signals are very precise (consider the limit case of part (b)), the attraction in this mechanism is that the government essentially does not need to provide any capital. Above $\theta^*_{Guarantees}$, where banks lend, the government's guarantee of providing capital if loans fail is sufficient to get the economy out of a credit freeze. Hence, banks lend and loans do not fail, so the government does not need to provide the capital. Below $\theta^*_{Guarantees}$, where banks do not lend, there are no loans made, and hence no loans that fail. This implies that the government's guarantees again do not lead to any capital being spent. In sum, this mechanism leads to an improvement in the threshold below which a credit freeze occurs without any actual cost.

(ii) *Comparing this Mechanism with Previous Ones*: It is hard to provide a sharp comparison. Such comparison depends on the extent to which the guarantees can reduce the threshold θ^*. This, in turn, depends on the level of the guarantees δ. It would be tempting to conclude that the government should increase δ very close to 1,[7] but this is not so easy. Essentially, while the mechanism does not lead to actual costs, its validity depends on the credibility of the government in providing the guarantees. That is, banks have to believe that the government will indeed be able to pay back a proportion δ of the losses. Hence, there is a budget constraint in the background that has to be considered. The solution is for the government to increase δ (still below 1) until this budget constraint becomes binding. A reasonable case to consider is where the maximum guarantee provided by the government is equal to its available capital $Z = \alpha l K$. The maximum that the government will have to pay is when all banks lend and fail. This will cause a liability of $\delta(1-l)K$, implying that δ cannot exceed $\frac{\alpha l}{(1-l)}$. The following proposition compares the government guarantees mechanism with the government funds mechanism (considered in the previous section) for this level of guarantees (assuming that $\frac{\alpha l}{(1-l)} < 1$, i.e., that the government's available capital is smaller than the capital left in the banking sector).

Proposition 9: *(a) Suppose that the government provides a guarantee* $\delta = \frac{\alpha l}{(1-l)} < 1$*, and that* τ_p *approaches infinity. Then the threshold under the guarantee regime* ($\theta^*_{Guarantees}$) *is higher than under the funds regime* (θ^*_{Direct})*, implying that the latter is more effective in preventing a credit freeze.*
(b) Compared with the government funds regime, providing guarantees as proposed here will (i) produce a lower total wealth if θ *exceeds* $\theta^*_{Guarantees}$*, (ii) produce a lower total wealth if* θ *is between* θ^*_{Direct} *and* $\theta^*_{Guarantees}$*, and (iii) produce a higher total wealth if* θ *is lower than* θ^*_{Direct}*.*

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[7] There is a problem in setting $\delta = 1$, because at that level of guarantees, banks always lend and the government will have to bail them out sometime. Setting δ very close but still below 1 ensures that banks (who have infinitesimally precise signals) never lend when projects fail.

(c) Ex-ante, when choosing the policy, the government should choose to provide guarantees, rather than to place capital with private funds, when y is sufficiently low.

Remark: The advantage of the guarantees regime over the funds regime is that it avoids the waste of government's capital when there is a credit freeze. This is because in the guarantees regime, the government's capital does not get invested, while in the funds regime it gets invested in projects that end up failing because of the coordination failure. The disadvantage, however, is that under the guarantees regime, there are overall more realizations of the fundamental with a credit freeze, since the government's investment is more efficient in breaking the coordination failure. Also, under a credit thaw in the guarantees regime, the government's capital does not get invested. Overall, government guarantees offer a better solution when y is relatively low. In that, the guarantees regime is closer to the injection of capital to banks considered in Section 4.2. Direct comparison between the two (not reported here, for brevity) reveals that capital injection to banks dominates the guarantees regime when $R > \delta$, while the guarantees regime may be preferred when $R < \delta$.

4.6. Government Funds Managed by Private Firms Exposed to Downside Risk

In this section, we search for a mechanism that will combine the advantages of previously discussed mechanisms and thus achieve better results. Such a mechanism should make the government's capital available to the economy so as to incentivize banks to lend their capital above θ^*_{Direct} (like the mechanisms in Sections 4.3 and 4.4), and at the same time it should avoid lending the government's capital to bad projects or to good projects in a credit freeze (like the mechanisms in Sections 4.2 and 4.5).

Suppose that, like in Section 4.4, the government sets up a continuum *[0,K]* of private funds, each one receiving αl of government capital, but unlike in that section, the government imposes some downside risk on the managers of these funds. Specifically, assume, like in Section 4.4, that managers get $\gamma > 0$ on any dollar return they achieve above *1*, but, unlike in Section 4.4., they are penalized by *c>0* on any dollar return they achieve below *1*.

The mechanism examined in this section is similar to that of the Term Asset-Backed Securities Loan Facility (TALF) developed by US authorities during the 2008-2009 crisis. Under this government program, public capital was provided to finance certain portfolios of new loans on a non-recourse basis. Under the terms of financing, the private manager was able to capture the upside in the event the loans turned out to be profitable and had to bear only part of the downside, with the remainder absorbed by the government's capital.

In the game we are now considering, there are effectively two types of players: banks and fund managers.[8] Banks face the same tradeoff as before: if they lend to operating firms, they will get a net return of R if their projects succeed and *-1* if they fail. For fund managers, lending to operating firms will yield a net return of γR if their projects succeed and $-c$ if they fail. The amount of capital managed by banks is $(1-l)K$, while the amount that is managed by the funds is αlK. Hence, denoting the proportion of banks that decide to lend to operating firms as n_B and the proportion of funds that decide to lend to operating firms as n_F, the mass of operating firms L that will receive lending is given by $L = n_B(1-l)K + n_F \alpha lK$.

The following proposition summarizes the equilibrium results under this policy mechanism.

Proposition 10: *(a) Suppose that the government invests $Z = \alpha lK$ in funds managed by private agents, who receive a proportion γ on any return they generate above 1 and a penalty of proportion c on any return they generate below 1, and consider the case where τ_p approaches infinity. Then, banks and funds will lend to (good) operating firms and projects will succeed when θ is above:*

$$\theta^*_{RiskyFunds} = b - aK\left(\frac{R}{\frac{c}{\gamma}+R}\alpha l + \frac{R}{1+R}(1-l)\right) \qquad (12)$$

[8] Note that the same agent can act both as a bank and as a fund manager. His incentives to lend will be different between the two roles due to the compensation structure. Moreover, due to risk neutrality, lending decisions will be completely independent between the two roles, and hence we can effectively analyze the game as having two types of agents.

(b) As the penalty c approaches 0, the threshold $\theta^*_{RiskyFunds}$ converges to θ^*_{Direct} and so the solution of setting privately-managed government funds with downside risk dominates the solutions proposed in Sections 4.2-4.5.

Remarks: (i) *Fund Managers' Incentive Structure*: Inspecting Equation (12), we can see that when the fundamental is at the threshold $\theta^*_{RiskyFunds}$, proportion $\frac{R}{1+R}$ of banks lend to operating firms. This is similar to the behavior of banks in any of the previous mechanisms.[9] At the same time, the proportion of fund managers that lend when the fundamental is $\theta^*_{RiskyFunds}$ is $\frac{R}{\frac{c}{\gamma}+R}$. Hence, the ratio between the downside penalty c and the upside gain γ that fund managers are exposed to changes their incentive to lend relative to banks. Reducing this ratio makes fund managers more eager to lend, and this lowers the threshold $\theta^*_{RiskyFunds}$.

(ii) *Optimal Level of Downside Risk*: In general, there is a tradeoff in setting the level of downside risk c (or more precisely, the ratio $\frac{c}{\gamma}$). Reducing the exposure of fund managers to downside risk makes credit freezes less likely, but also increases the likelihood that fund managers will lend the government's capital to failing projects. Hence, reducing the downside risk gets us closer to the mechanisms discussed in Sections 4.3 and 4.4. Interestingly, in the limit of precise private information (as τ_p approaches infinity), it is optimal to set the downside risk to be infinitesimally small. Since fund managers have very precise information, they know almost surely when the economy is going to be in a credit freeze, and thus even a tiny downside risk is sufficient to deter them from lending in a credit freeze. At the same time, the incentive effect of cutting the downside risk to be infinitesimally small encourages banks to lend, so that the credit-freeze threshold is pushed down to θ^*_{Direct}. Hence, in the limit of precise information, setting up government funds managed by private agents who are exposed to minimal downside risk emerges as the optimal solution combining the advantages of the mechan-

[9] This behavior stems from the fact that banks find it optimal to lend only if they think that the probability of success, i.e., the probability that the fundamental is above the threshold, is at least $\frac{1}{1+R}$, while at the threshold, the posterior probability that the fundamental is above the threshold is uniformly distributed across agents between 0 and 1.

isms analyzed in previous sections. Away from the limit of precise private information, the cost of reducing downside risk is likely to have more effect, leading to an interim solution with regard to the optimal level of downside risk.[10]

(iii) Equivalence to direct infusion with certain lending commitment: The key of the mechanism described here is that private agents with lending expertise get to lever up their profit from lending to operating firms by using government capital. An alternative way to achieve the same outcome is to have the government allocating its capital to banks under the condition that they lend this capital in addition to a certain specified amount of their own capital to operating firms. We analyzed this alternative mechanism and found that it can achieve the outcome in this section, no matter what is the amount of banks' own capital that must be lent together with the government's capital. Essentially, increasing the amount required from banks ensures more private money is lent when the government's money is lent, but reduces banks' incentives to lend. These two effects cancel out with each other, leading always to the same outcome, which is the outcome in Proposition 10b. Details of this analysis are available upon request.

5. Concluding Remarks

In financial crises, banks may contract credit to nonfinancial borrowers as a product of rational and efficient response to the deterioration in the future repayment ability of such borrowers. This paper shows, however, how rational choices by banks may produce an inefficient outcome. It develops a model of credit freezes that are inefficient but arise from the rational and self-fulfilling expectations of financial institutions. In this equilibrium, banks would be collectively better off if they were all willing to extend loans to a set of operating firms, but each of them avoids doing so out of self-fulfilling expectations that others will do as well. Our model enables identifying the circumstances in which an inefficient credit freeze can be expected to arise. In such circumstances, efficiency will be served by getting the economy out of the inefficient credit freeze equilibrium, and the

[10] As is usually the case in global-games models, the expressions for the thresholds away from the limit do not lend themselves to tractable comparative-statics analysis (see the expression in the proof of Proposition 10).

developed model has been seen to be useful for studying and assessing government policies that can be considered for this purpose.

Our analysis has shown that interest rate cuts and infusion of capital into the financial sector can be expected to eliminate an inefficient credit freeze in certain circumstances but not in others. Even with ample capital and with low return on hoarded cash, banks may fail to extend loans to operating firms when they believe that their projects, even though worthy in an environment in which other such firms obtain financing, will fail in an environment in which credit to other firms is frozen. If such circumstances arise, governments may look beyond interest rate cuts and capital enhancement to get the economy out of the credit freeze.

Our analysis has examined several supplemental or alternative measures, including ones used by authorities in the course of the recent financial crisis. While direct lending by the government to nonfinancial borrowers can address certain problems resulting from coordination failure among banks, it forgoes the benefits of expert screening of such borrowers by private parties. We have accordingly analyzed mechanisms that harness the screening expertise of private agents and identified features that determine their effectiveness. Our analysis provides a framework for assessing the benefits and limits of using standard and nonstandard policies to address a self-fulfilling credit market freeze.

Appendix

Proof of Proposition 1: The proof follows Morris and Shin (2004b). The arguments in their proof (which we don't repeat here, for brevity) establish that there can only be a threshold equilibrium, where banks lend if and only if their signal is above some common x^*. Given this result, we now characterize the threshold equilibrium and show that it is unique.

Given x^*, there is a unique threshold fundamental θ^*, at which investment projects are on the margin between failure and success. This is given by:

$$\theta^* = b - aK\left(1 - \Phi\left(\sqrt{\tau_p}(x^* - \theta^*)\right)\right)$$

Here, $\Phi\left(\sqrt{\tau_p}(x^* - \theta^*)\right)$ is the proportion of banks receiving a signal below x^* and withdrawing from lending when the fundamental is exactly θ^*.

This gives us the first equation for the two unknowns x^* and θ^*. The second equation comes from the fact that at the threshold signal x^* a bank has to be indifferent between lending to firms and investing in the risk-free asset. When bank i observes signal x_i, his posterior distribution of θ is normal with mean $\frac{\tau_\theta y + \tau_p x_i}{\tau_\theta + \tau_p}$ and precision $\tau_\theta + \tau_p$. He knows that lending to firms yields $(1 + R)$ if and only if the fundamental is above θ^*, while not lending yields $(1 + r)$ with certainty. The indifference condition is then given by:

$$\left(1 - \Phi\left(\sqrt{\tau_\theta + \tau_p}\left(\theta^* - \frac{\tau_\theta y + \tau_p x^*}{\tau_\theta + \tau_p}\right)\right)\right)(1 + R) = 1 + \mathrm{r}$$

Which can be developed as follows:

$$\theta^* - \frac{\tau_\theta y + \tau_p x^*}{\tau_\theta + \tau_p} = \frac{\Phi^{-1}\left(1 - \frac{1 + \mathrm{r}}{1 + R}\right)}{\sqrt{\tau_\theta + \tau_p}}$$

Leading to:

$$\theta^* - x^* = \frac{-\tau_\theta(\theta^* - y)}{\tau_p} + \frac{\sqrt{\tau_\theta + \tau_p}\,\Phi^{-1}\left(1 - \frac{1 + \mathrm{r}}{1 + R}\right)}{\tau_p}$$

Plugging this in the first equation, we get:

$$\theta^* = b - aK\left(1 - \Phi\left(\sqrt{\tau_p}\left(\frac{\tau_\theta(\theta^* - y)}{\tau_p} - \frac{\sqrt{\tau_\theta + \tau_p}\,\Phi^{-1}\left(1 - \frac{1 + \mathrm{r}}{1 + R}\right)}{\tau_p}\right)\right)\right)$$

Which yields the equation in the proposition statement:

$$\theta^* = b - aK + aK\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1 + \mathrm{r}}{1 + R}\right)\right)\right)$$

The left-hand side is the 45-degree line with respect to θ^*, and the right-hand side is increasing in θ^*, and is bounded between $b - aK$ and b. A unique solution for θ^* is guaranteed when the right-hand side has a slope of less than 1 everywhere. The slope of the right-hand side is given by $aK\phi(\cdot)\frac{\tau_\theta}{\sqrt{\tau_p}}$, where $\phi(\cdot)$ is the density of the standard normal evaluated at the appropriate point. Since $\phi(\cdot) \leq \frac{1}{\sqrt{2\pi}}$, a sufficient condition for a unique solution is $\frac{\tau_\theta}{\sqrt{\tau_p}} \leq \frac{\sqrt{2\pi}}{aK}$. **QED**. ■

Proof of Proposition 2: Proving the first part of the proposition is straightforward given the proof of Proposition 1. The proof just replaces K with $K(1-l)$ to reflect the fact that when a proportion *n* of the banks lend, only $nK(1-l)$ capital makes its way to operating firms. Note that the condition for uniqueness is now $\frac{\tau_\theta}{\sqrt{\tau_p}} \leq \frac{\sqrt{2\pi}}{aK(1-l)}$, which always holds when the condition in Proposition 1 holds.

The second part is proved with the implicit function theorem. Denote

$$F(\theta^*, l) = \theta^* - b + aK(1-l) -$$
$$aK(1-l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right) = 0$$

Then,

$$\frac{d\theta^*}{dl} = -\frac{dF(\theta^*, l)\big/_{dl}}{dF(\theta^*, l)\big/_{d\theta^*}}$$

We know that

$$\frac{dF(\theta^*, l)}{dl} = -aK\left(1 - \Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right)\right) \leq 0$$

$$\frac{dF(\theta^*, l)}{d\theta^*} = 1 - aK(1-l)\frac{\tau_\theta}{\sqrt{\tau_p}}\phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right)$$

$$\geq 1 - aK(1-l)\frac{\tau_\theta}{\sqrt{\tau_p}}\frac{1}{\sqrt{2\pi}} \geq 0$$

It follows that $\frac{d\theta^*}{dl} \geq 0$. **QED**. ■

Proof of Proposition 3: Proving the first part of the proposition is again done using the implicit function theorem. Denote:

$$F(\theta^*, r) = \theta^* - b + aK(1-l) - aK(1-l)\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta + \tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right) = 0$$

Then,

$$\frac{d\theta^*}{dr} = -\frac{dF(\theta^*, r)\big/_{dr}}{dF(\theta^*, r)\big/_{d\theta^*}}$$

Given that $\frac{dF(\theta^*,r)}{dr} \le 0$ and $\frac{dF(\theta^*,r)}{d\theta^*} \ge 0$, it follows that $\frac{d\theta^*}{dr} \ge 0$.

To see why the second part holds, note that, given the capital available to banks $K(1 - l)$, not lending to operating firms is efficient only when the fundamental θ is below $b - aK(1-l)$. Since $\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^* - y + \frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1+\mathrm{r}}{1+R}\right)\right)\right) > 0$ (unless y approaches infinity), $\theta^* > b - aK(1-l)$. Hence, there is a range of fundamentals for which banks do not lend and projects fail, even though this is inefficient. **QED**. ■

Proof of Proposition 4: The proof is analogous to the proof of Proposition 3, and thus omitted. **QED** ■

Proof of Proposition 5: Equation (6) is based on the same principles behind the construction of equilibrium in Propositions 1 and 2. The only thing to note in equation (6) is that all the government's capital is lent and generates the positive externality. Hence, investment projects fail when the proportion *n* of banks that decide to lend is below $\frac{b-\theta-a\alpha lK}{a(1-l)K}$. Having established equation (6) and comparing it with (5) (using the implicit function theorem, as in Propositions 2 and 3) reveals that $\theta^*_{Bank} > \theta^*_{Direct}$. **QED** ■

Proof of Proposition 6: The overall wealth in the economy under injection of capital to the banking system is given by $(1-(1-\alpha)l)K$ when the economy is in a credit freeze, and by $(1-(1-\alpha)l)K(1+R)$ when the economy is in a credit thaw.

The overall wealth in the economy under direct lending to operating firms is given by $(1-l)K$ when the economy is in a credit freeze, and by $\big(1-l+\alpha l(1-\beta)\big)K(1+R)$ when the economy is in a credit thaw. Note that in a credit thaw, only $(1-\beta)$ of the projects financed by the government succeed, as the government cannot tell the difference between good firms and bad firms. In a credit freeze, all the projects financed by the government fail, as even the good firms cannot succeed given that too many of them do not receive financing (if this was not the case, then banks would lend, and there would not be a credit freeze).

Based on these results, we now prove the different parts of the proposition.

(a) Now, when the fundamental θ is below θ^*_{Direct}, we know that there is a credit freeze under both regimes. Then, since $(1-(1-\alpha)l)K > (1-l)K$, the wealth in the economy is higher under infusion of capital to the banking system than under direct lending to firms.

When the fundamental θ is above θ^*_{Bank}, there is a credit thaw under both regimes. Then, since $(1-(1-\alpha)l)K(1+R) > \big(1-l+\alpha l(1-\beta)\big)K(1+R)$, the wealth in the economy is again higher under capital injection to banks than under direct lending to operating firms.

(b) When the fundamental θ is between θ^*_{Direct} and θ^*_{Bank}, the economy is in a credit thaw under the regime of direct lending and in a credit freeze under the regime of injection of capital to banks. Then, there is no obvious ranking between the levels of wealth in the two regimes: Capital injection to banks yields $(1-(1-\alpha)l)K$ and direct lending yields $\big(1-l+\alpha l(1-\beta)\big)K(1+R)$. Overall, a high enough β and/or a small enough R makes capital injection better than direct lending.

(c) For the choice of regime, the government should consider all possible realizations of θ, weighted by their prior probabilities, and the difference in wealth they generate between the two policy measures. Based on the results above, the expected difference between wealth under capital injection and wealth under direct lending can then be expressed as:

$$
\alpha l K \Phi\left(\frac{\theta^*_{Direct} - y}{\sigma_\theta}\right)
$$

$$
+ \left(\alpha\beta l - \left(1 - l + \alpha l(1-\beta)\right)R\right)K\left[\Phi\left(\frac{\theta^*_{Bank} - y}{\sigma_\theta}\right) - \Phi\left(\frac{\theta^*_{Direct} - y}{\sigma_\theta}\right)\right]
$$

$$
+ \alpha\beta l K(1+R)\left[1 - \Phi\left(\frac{\theta^*_{Bank} - y}{\sigma_\theta}\right)\right]
$$

The statement in (c) then follow directly based on (a) and (b). **QED**. ■

Proof of Proposition 7: (a) When choosing whether to lend the government's capital to operating firms or not, banks managing the government's funds always prefer to lend. This is because their only chance to get a return above 1, on which they are compensated, is when they lend. Moreover, given that the noise, with which the banks observe the fundamentals is unbounded (even though it can be very small), they always perceive some probability that lending will generate a return above 1, which will provide compensation for them, while they know that there is no cost in generating a return below 1. Hence, the government's capital always flows to operating firms, generating the threshold θ^*_{Direct} characterized in equation (6). Finally, it is straightforward that banks lend to good firms and not to bad firms, as a positive return only comes from the former and the banks can distinguish between the two types.

(b) The second part of the proposition follows similar lines to those used in the proof of Proposition 6. The difference is that when the government sets private investment funds, as opposed to when it lends directly to operating firms, the government's capital does not go to bad firms. Hence, the overall wealth in the economy when the government lends the money via private funds is given by $(1-l)K$ when the economy is in a credit freeze (here the government's capital still gets wasted because even good firms fail to produce returns), and by $(1-(1-\alpha)l)K(1+R)$ when the economy is in a credit thaw. Then, comparing this with the overall wealth levels under infusion of capital to the banks, we get the result stated in part (b) of the proposition.

(c) Based on the results above, the expected difference between wealth under capital injection to banks and wealth under lending via private funds can be expressed as:

$$
\alpha l K \Phi\left(\frac{\theta^*_{Direct} - y}{\sigma_\theta}\right) - (1-(1-\alpha)l)RK\left[\Phi\left(\frac{\theta^*_{Bank} - y}{\sigma_\theta}\right) - \Phi\left(\frac{\theta^*_{Direct} - y}{\sigma_\theta}\right)\right]
$$

The statement in (c) then follow directly. **QED**. ■

Proof of Proposition 8: The proof follows similar steps to those in Propositions 1, 2, and 3. **QED**. ■

Proof of Proposition 9: (a) We need to show that:

$$b - aK(1-(1-\alpha)l) + aK(1-l)\frac{1}{1+R} < b - aK(1-l) + aK(1-l)\frac{1-\delta}{1+R-\delta}$$

This can be developed as follows:

$$-(1-(1-\alpha)l) + (1-l)\frac{1}{1+R} < -(1-l) + (1-l)\frac{1-\delta}{1+R-\delta}$$

$$-\alpha l + (1-l)\frac{1}{1+R} < (1-l)\frac{1-\delta}{1+R-\delta}$$

$$(1-l)\left(\frac{1+R-\delta-(1+R)(1-\delta)}{(1+R)(1+R-\delta)}\right) < \alpha l$$

$$\frac{\delta \mathrm{R}}{(1+R)(1+R-\delta)} < \frac{\alpha l}{(1-l)}$$

Plugging in $\delta = \frac{\alpha l}{(1-l)}$, we get:

$$\mathrm{R} < (1+R)(1+R-\delta)$$

$$0 < (1+R)(1-\delta) + R^2$$

which is always true.

(b) The government guarantees regime generates an overall wealth of $(1-(1-\alpha)l)K$ when the economy is in a credit freeze (here the government's capital doesn't gets wasted), and of $\big((1-l)(1+R)+\alpha l\big)K$ when the economy is in a credit thaw (here the government's money doesn't get invested in the real projects). Then, comparing this with the overall wealth levels under the government funds program (in Proposition 7), we get the result stated in part (b) of the proposition.

(c) Based on the results above, the expected difference between wealth under the funds regime and wealth under the guarantees regime can be expressed as:

$$-\alpha lK\Phi\left(\frac{\theta^*_{Direct}-y}{\sigma_\theta}\right) + (1-(1-\alpha)l)RK\left[\Phi\left(\frac{\theta^*_{Guarantees}-y}{\sigma_\theta}\right) - \Phi\left(\frac{\theta^*_{Direct}-y}{\sigma_\theta}\right)\right] + \alpha lRK\left[1-\Phi\left(\frac{\theta^*_{Guarantees}-y}{\sigma_\theta}\right)\right]$$

The statement in (c) then follows directly. **QED**. ■

Proof of Proposition 10: (a) Based on results in the global-games literature (e.g., Goldstein and Pauzner (2004)), the equilibrium will be characterized by two threshold signals: Banks will lend to operating firms if and only if their signal is above x_B^*, while fund managers will lend if and only if their signal is above x_F^*. Then, there would be a unique cutoff θ^*, such that projects fail below the cutoff and succeed above it. Extending the logic in the proof of Proposition 1, the three thresholds x_B^*, x_F^*, and θ^* are determined by the following three equations:

$$\theta^* = b - aK\left((1-\mathrm{l})\left(1-\Phi\left(\sqrt{\tau_p}(x_B^*-\theta^*)\right)\right)+\alpha\mathrm{l}\left(1-\Phi\left(\sqrt{\tau_p}(x_F^*-\theta^*)\right)\right)\right)$$

$$\left(1-\Phi\left(\sqrt{\tau_\theta+\tau_p}\left(\theta^*-\frac{\tau_\theta y+\tau_p x_B^*}{\tau_\theta+\tau_p}\right)\right)\right)=\frac{1}{1+R}$$

$$\left(1-\Phi\left(\sqrt{\tau_\theta+\tau_p}\left(\theta^*-\frac{\tau_\theta y+\tau_p x_F^*}{\tau_\theta+\tau_p}\right)\right)\right)=\frac{\frac{c}{\gamma}}{\frac{c}{\gamma}+R}$$

Then, θ^* is implicitly determined by the following equation:

$$\theta^* = b - aK\left(\begin{array}{c}(1-\mathrm{l})\left(1-\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^*-y+\frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{1}{1+R}\right)\right)\right)\right)\\ +\alpha\mathrm{l}\left(1-\Phi\left(\frac{\tau_\theta}{\sqrt{\tau_p}}\left(\theta^*-y+\frac{\sqrt{\tau_\theta+\tau_p}}{\tau_\theta}\Phi^{-1}\left(\frac{\frac{c}{\gamma}}{\frac{c}{\gamma}+R}\right)\right)\right)\right)\end{array}\right)$$

In the limit of precise information, denoting the threshold as $\theta^*_{RiskyFunds}$, we get:

$$\theta^*_{RiskyFunds} = b - aK\left(\frac{R}{\frac{c}{\gamma}+R}\alpha l+\frac{R}{1+R}(1-l)\right)$$

(b) From (8) and (12) it is clear that as c approaches 0 $\theta^*_{RiskyFunds}$ approaches θ^*_{Direct}. Then, because this mechanism achieves the lowest threshold for lending, and does not have government funds lent to failing projects, it maximizes wealth. **QED**. ■

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