Coordinated Strategic Defaults and Financial Fragility in a Costly State Verification Model

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Abstract

It is well know that diversification through a financial intermediary has the benefit of transforming loans that need costly monitoring into bank deposits that do not. We show that financial intermediation in a costly state verification model has a cost not yet analyzed: it allows for the existence of multiple equilibria, some of which are characterized by borrowers defaulting on their loans because they expect other borrowers to do the same (i.e.: bad equilibria arise due to the strategic complementarities among the entrepreneurs' decisions to default). We propose two mechanisms that fully implement the desired equilibrium allocation.

Keywords: Costly State Verification, Multiple Equilibria, Coordinated Default, Full Implementation.

J.E.L. Classifications: D82 (Asymmetric and Private Information), D86 (Economics of Contract Theory), G21 (Banks; Other Depository Institutions), M42 (Auditing).

Introduction

Diamond's (1984) seminal paper establishes that the exercise of economies of scale in monitoring calls for lending to take place through a financial intermediary (e.g., a bank), who is delegated the task of monitoring the set of fully diversified loans it extends. In this paper, we argue that if, on the one hand, delegation can save on monitoring costs, it, on the other hand, exposes the bank to the possibility of borrowers (explicitly or implicitly) coordinating on *strategic* defaults.[1] In fact, we show that whenever the bank's resources to monitor are bounded, on top of a "good" equilibrium, there may also exist equilibria in which borrowers, regardless of the profitability of their projects, find it optimal to default on loans because they expect other borrowers to do the same. While sources of financial fragility – namely, the possibility of bank runs – stemming from the banks' short term *liabilities* have been extensively studied, we identify a novel source of fragility in this paper– coordinated strategic defaults – that stem from the banks' *asset* structure.

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[1] A strategic default occurs when the debtor has the financial means to pay off his debt, but chooses not to. It is thus an issue of the debtor's willingness to pay, not of his capability to do so.

In our model, a single financial intermediary lends to a continuum of ex-ante symmetric entrepreneurs, each of which is endowed with a project with stochastic return. Projects' returns are independent and identically distributed, so, as in Diamond (1984), the bank's loans are fully diversified. In consonance with costly verification models à la Townsend (1979) and Gale and Hellwig (1985), there is asymmetry of information between each entrepreneur and the financial intermediary after the realization of the project: the entrepreneur observes his project's return, while the financial intermediary must perform a costly audit if he wishes to become informed.

We start our analysis by looking at a bank's problem when it ignores (or is unaware of) the possibility of strategic defaults by borrowers. In such a case, the bank's problem amounts to maximizing its expected profits subject to individual incentive compatibility constraints. With a continuum of borrowers with iid projects, the law of large numbers applies and the bank knows the realized aggregate returns. Hence, conditional on *all* borrowers being truthful, the bank can proceed as if it was dealing with a single representative borrower. Not surprisingly, the optimal mechanism is the standard debt contract derived by Gale and Hellwig (1985). With such a contract, the proceeds collected from the set of entrepreneurs with creditworthy projects are used to audit those in default. Moreover, the constant payment requirement, along with the credible threat of seizure of all of the project's returns when there is misreporting, induces truthtelling from entrepreneurs who are not in default.

While truthtelling is an equilibrium of the optimal mechanism in which the bank finances projects through a debt contract, it is by no means the only one. After all, the default by a group of debtors weakens the bank's financial position, hurting his monitoring capabilities. This makes the decision to default by any other entrepreneur more attractive. Such strategic complementarities in the entrepreneurs' decisions to default lead to multiple equilibria, as a debtor declares default because he expects other debtors to do the same. We first establish that, on top of the truthtelling equilibrium, there is always an equilibrium in which *all* entrepreneurs default strategically. We refer to such outcome as fully coordinated default. It may be argued that, due to communication and coordination costs, one should not be particularly concerned with deviations by the whole set of entrepreneurs. We show, however, that, when the bank adopts a symmetric auditing strategy, partially coordinated default equilibria always exist as well. In such equilibria, although some entrepreneurs truthfully report their realized returns, strategic default by subsets of entrepreneurs takes place.

The possibility of coordinated defaults is yet another source of financial fragility: a bank with a fully diversified portfolio of loans that finances projects with positive net present values – and who, therefore, would look completely sound ex-ante – may be exposed to default by individual borrowers that could pay their loans but choose not to because they expect others to default as well. Accordingly, in addition to establishing that banks are subject to such defaults, one second goal of this paper is to consider alternatives they may have to rule out bad equilibria.

We propose two main solutions for banks to insure against coordinated defaults.[2] Both of them share the following features: (i) to break the strategic complementarities among borrowers, the bank must use what

[2] One could think that a solution might be for the bank to hold, instead of debt, an alternative security issued against the proceeds to be collected by the entrepreneurs. As it turns out, this is of no help. In fact, in our costly state verification setting, if the bank were to hold, say, equity, it would need to monitor the entrepreneur in all states of the world, rather than just in a subset of states as with debt. Clearly, if anything, this would *magnify* the bank's exposition to a coordinated default. While we have used equity as an example, the same would be true for any alternative security. Indeed, among all securities, debt is the one that minimizes the bank's monitoring costs (and, consequently, its exposure to coordinated defaults).

we call a *sequential audit strategy*, (ii) in order to be able to audit a given group that plays a special role in the sequential audit strategy, the bank must secure a given amount of resources. The solutions differ mainly in the way the bank secures such resources.

The sequential audit strategy consists of dividing the entrepreneurs in groups, which are then randomly ordered. Once the investor starts auditing, he will do so sequentially according to such an order. *If* the bank can fully commit to audit the entrepreneurs in the first group, such entrepreneurs will find it optimal to report truthfully regardless of the announcements made by the others. With the payments collected from the first group, the bank´s monitoring resources increase and he can credibly commit to audit the entrepreneurs in the second group as well. Proceeding inductively, we show that no one will have incentives to misreport, so truthtelling is the only equilibrium.

To guarantee the needed resources to audit the entrepreneurs in the first group with probability one, the bank can set aside a small amount of capital. Since holding capital is costly, this solutions does come at a cost. However, we show that the amount of capital the bank must set aside can be made arbitrarily small. The use of exogenous resources to audit the first group guarantees truthtelling by the entrepreneurs through a process that resembles the iterative deletion of strictly dominated messages proposed by Bergemann and Morris (2009). As a consequence, truthtelling is the only rationalizable strategy for the entrepreneurs and, as Bergemann and Morris (2009) call it, implementation is robust.

We also show that a debt contract coupled with a properly designed forgiveness clause can, in an endogenous fashion, provide the bank with the initial resources that are necessary to implement the sequential audit strategy. As assumed in Gale and Hellwig (1984), the bank can impose a non-pecuniary cost on an entrepreneur that has declared default. Hence, to discourage participation of any given entrepreneur in a coordinated default, the bank can grant him full debt forgiveness, and charge him a fraction of the monetary equivalent of the non-pecuniary cost of default. This allows the bank to make use of the forgiveness clause on a group of entrepreneurs to raise a positive amount of resources. In equilibrium, the entrepreneurs realize that, if a fully strategic default is iminent, a group of entrepreneurs will renegotiate its debt with the bank providing him with the necessary capital to implement the sequential audit strategy. Therefore, all entrepreneurs will have incentives to report truthfully and debt forgiveness will only take place off-equilibrium. Since no capital needs to be put aside to implement such a solution, it is less costly than the first one (in fact, it involves no cost whatsoever). The drawback of this solution is that the strategy adopted by each individual entrepreneur depends on his (correct) beliefs about the other entrepreneurs' strategies, as opposed to what happens in the first solution.

Related Literature. We now discuss how our findings compare to the existing literature. There are a large number of papers showing that, in a world in which proceeds are not verifiable, debt contracts, by granting creditors the right to liquidate assets in case of default, reduce an entrepreneur's incentives to default strategically in period t when the assets generate value in $\tau > t$. Although ex-ante efficient, (since it allows for some loans to take place), Hart and Moore (1998) show that the provision of incentives for an entrepreneur to repay may call for inefficient liquidation on the equilibrium path. Noticing such ex-post inefficiency, Gromb (1994) points out that the incentives to renegotiate after default may limit the creditor´s ability to get his funds back. Berglof and von Thadden (1994) and Bolton and Scharfstein (1996), in turn, analyze the role played by multiple investors and different maturities in solving the creditor's commitment problem when confronted with the need to inefficiently liquidate. In our model, in contrast to all such papers, upon being able to pay a cost, the lender can make proceeds verifiable. Hence, it is the possibility of (coordinated) strategic defaults – which impair the ability of a creditor with bounded resources to monitor its loans – that make proceeds (endogenously) non-verifiable in our setting, rather than the other way around. In particular, although, debt contracting is still desirable due to the fact that it minimizes the need to monitor, it cannot per se avoid strategic defaults in our model. Also, rather than the choice of the number of creditors and the debt maturity structure, a distinctive aspect of debt design, namely a clause for forgiveness, is shown to play a key role in reducing the incentives for strategic defaults in our model.

In our setting, the complementarities in the entrepreneurs' default decisions are the main source of coordinated defaults. Using survey data on US households, Guiso, Sapienza and Zingales (2009) document that an agent who is aquainted with someone who has defaulted is (for moral reasons, they argue) more likely to declare his/her intention to default. Hence, at least for mortgages, there seems to be evidence of strategic complementarities in the agents' willingness to default. Constraints that induce complementarities in financial decisions also play a key role in Farhi and Tirole (forthcoming). In their paper, the inability of financial authorities to commit not to bail out institutions after the realization of a negative shock creates, ex-ante, complementarities in their leveraging (and other balance sheet) choices. In our paper, the potential inability of a bank to monitor all the projects it extends funding to creates complementarities in the entrepreneurs default decisions.

Our paper shares with Bassetto and Phelan (2008) and Bond and Hagerty (2010) the idea that bad equilibria may emerge as a result of a principal's limited resources to elicit untruthful reporting. In a crime prevention setting, Bond & Hagerty (2010) analyze how the optimal punishment intensity varies along the various existing equilibria, without addressing implementation issues. In an optimal taxation setting, Bassetto and Phelan (2008) show that, when the tax authority can only audit a fixed proportion of households (presumably due to budgetary issues), the optimal mechanism also has equilibria in which households misreport. In our paper instead, the amount of resources the bank has available for auditing purposes is endogenous, as proceeds collected from entrepreneurs who pay up can be used to monitor other entrepreneurs. The possibility of the bank "to expand" its monitoring budget is key to all the solutions we propose to eliminate bad equilibria. In fact, the form by which our sequential audit strategy endows the bank with additional resources to monitor remaining entrepreneurs guarantees that bad equilibria can be ruled out with arbitrarily small costs (or, in fact, no costs whatsoever for the case of partially coordinated defaults).

Finally, the way by which our sequential audit strategy induces truthtelling from the entrepreneurs is somewhat related to the ideas of Bergemann and Morris' (2008) robust implementation. In fact, such strategy guarantees that the first group of entrepreneurs find it dominant to report truthfully. Therefore, the second group will find it optimal to report truthfully regardless of the behavior of the entrepreneurs who will be monitored next. Proceeding inductively, one finds that truthtelling is obtained as the unique equilibrium through a process of iterated deletion of strictly dominated strategies.

Organization. In section 1, we lay down the model and establish that coordinated defaults can ensue in our costly state verification setting. Section 2 introduces what we call the sequential audit strategy and presents two possible solutions for the problem of bad equilibria. Section 3 draws the concluding remarks.

1 The Model

The model is an adaptation of Gale and Hellwig (1985) for the case in which there is a continuum of mass one of entrepreneurs. Each entrepreneur is endowed with the technology for a project with random returns. The entrepreneurs have no wealth of their own, so they must borrow from a wealthy investor – which we will call bank throughout the paper – to undertake the project. Projects' returns are iid across entrepreneurs, so the possibility of diversification makes it optimal for financial intermediation to take place through an agent who is delegated the task of monitoring, as in Diamond (1984).

An investment of $I > 0$ is taken to be the input to the production process, which involves two dates. At $t = 0$, the investment is made and at $t = 1$ production is realized. Let $f(s)$ denote the return of the risky project at $t = 1$ when state s is realized. We assume that $f(0) = 0$ and $\frac{\partial f(s)}{\partial s} > 0$. Hence, states are ordered so that higher states imply higher returns. The probability distribution of the states is given by an absolutely continuous cumulative distribution function H, with density h and support in a compact interval $[0, \overline{s}]$. The capital markets are perfectly competitive so the bank's expected profit is zero. Without loss, the interest rate is normalized to zero.

There's asymmetry of information between entrepreneurs and the investor. At $t = 1$, each entrepreneur observes his own project return free of charge, but the investor can observe the return only at some cost. This cost to observe the state is given by $c(s)$, where $\frac{\partial c(s)}{\partial s} \geq 0$.

A constant non pecuniary cost of c_0 can be imposed on the entrepreneur at the discretion of the investor, after default is declared. We do not require that the investor audit a given entrepreneur's project in order to impose this non-pecuniary cost on him. The imposition of this cost can be interpreted in a number of ways, one being as the investor's decision to inform a credit bureau of the entrepreneur's failure to comply with the debt contract.

When signing a contract, an entrepreneur and the bank must agree upon several issues. The first is on the audit region $B([0, \overline{s}]) \subseteq [0, \overline{s}]$, which determines when the bank will pay the observation costs. The second is on how to share, at each state, the return of the project, namely $f(s) - B(s)c(s)$. Therefore, a contract can be represented by an array (R_l, R_b, B), where R_l and R_b are respectively the return to the lender and borrower, and $B(s)$ is an indicator function taking value 1 at states where audits occur.

It is easy to see that a contract is incentive compatible if, and only if,

(i) There exists a constant D such that $R_l(s) = D$ whenever $B(s) = 0$;

(ii) for any states $s, \widehat{s}$ such that $B(s) = 1$ and $B(\widehat{s}) = 0$, we have $D \geq R_l(s) + c(s)$.

Condition (i) specifies a constant repayment schedule for the entrepreneur in the no-audit region. Condition (ii) guarantees that it is never in the entrepreneur's interest to report a non-audit state, when the true state specifies that an audit be realized.

Using the above characterization of the set of Incentive Compatible contracts, Gale & Hellwig (1985) show that in the case of a single entrepreneur-investor pairing, the optimal contract takes the form of what they call a *standard debt contract*, which is characterized by:

$$B = \begin{cases} 0 \text{ if } f \geq D \\ 1 \text{ if } f < D \end{cases} \quad R_l = \begin{cases} D \text{ if } B = 0 \\ f - c \text{ if } B = 1 \end{cases}$$

where D is the face value of the debt contract, which is chosen so as to guarantee a competitive return to the bank. Letting s^D be such that $f(s^D) = D$, then D is implicitly defined by

$$D(1 - H(s^D)) + \int_0^{s^D} [f(s) - c(s)]h(s)ds = I \tag{1}$$

In our setting, there is a continuum of entrepreneurs with iid projects and, by the law of large numbers, the bank knows the realized aggregate returns. Hence, conditional on *all* entrepreneurs being truthful, it is as if the bank were dealing with a single representative borrower. It follows that the same standard debt contract of Gale and Hellwig (1985) is optimal with a continuum of entrepreneurs.

Proposition 1 *The standard debt contract of Gale and Hellwig (1985) is an optimal mechanism when a single bank deals with a continuum of entrepreneurs with iid projects.*

1.1 Coordinated Default:

There is one caveat to the above analysis, which has been ignored by the literature up to now. In the mechanism of Proposition 1, the investor must have enough capital to pay for the auditing costs, at the time the audit is to take place. We now consider the case in which the bank must either set aside resources to cover those audit costs or use the proceeds collected from creditworthy entrepreneurs to monitor those in default.

Timing is as follows. At $t = 0$, the investor chooses an initial capital level E, which is common knowledge among every agent in the economy. We assume that equity capital is costly, so that the investor will choose the lowest level of capital in accordance with equilibrium behavior. The investor then signs a standard debt contract with all entrepreneurs, with face value D. At $t = 1$, each entrepreneur observes his project's return, and chooses a repayment strategy. Let Λ denote the group of entrepreneurs who choose to pay D. The group Λ^c chooses not to pay, and declares default. An entrepreneur may declare default for two reasons. He might be unable to pay his debt if the return from his project is lower than D, or he might be unwilling to do so, choosing a strategic default. The investor must then decide which projects to audit, subject to his budget constraint. We assume that the investor can only use his capital E and the proceeds from the creditworthy entrepreneurs, given by $D\int_\Lambda dH$, to pay for the audit costs.

In this section, we assume that the investor commits to the following auditing strategy, which is also common knowledge before the time of contracting :(i) only projects in default are audited, (ii) the investor always chooses to audit a project in default if he has enough resources to do so (iii) and the investor randomizes among projects in default when his budget constraint is binding.

We adopt the following assumption

$$D\left(1 - H\left(s^D\right)\right) > \int_0^{s^D} c\left(s\right)h\left(s\right)ds \tag{A1}$$

This means that the amount the investor collects when all entrepreneurs report truthfully is more than enough to cover his auditing costs. This appears to be a sensible assumption if the investor is willing to extend the standard debt contract to all entrepreneurs. In fact, using the investor's budget constraint given by (1), assumption (A1) is equivalent to

$$\int_0^{s^D} f(s)h(s)ds < I$$

which states that the mean return in default states is insufficient to cover the initial investment.

When entrepreneurs adopt a truth-telling strategy, the investor's auditing costs will be $\int_0^{s^D} c(s)ds$. Some points are in order. First, note that this is a deterministic amount, since the Law of Large Numbers eliminates aggregate uncertainty. Even tough the investor is unknowledgeable about an individual project's return, he does know the entire distribution of returns. Second, once the time arrives to audit the projects in default, the amount per project that the investor must come up is lower in the case of a continuum of entrepreneurs than with only one entrepreneur. This is due to the benefits of diversification.

We now analyze the set of equilibria of the game induced by the standard debt contract and the bank's audit strategy. We first characterize the entrepreneurs' strategy.

Proposition 2 *When confronted with a probability p of audit and a debt level D, there is a cutoff state s^* such that the entrepreneur i declares default if and only if $s_i \leq s^*$.*

Proof. The entrepreneur i declares default if and only if $(1-p)f(s_i) - c_0 \geq f(s_i) - D$ which is equivalent to $D - c_0 \geq p \cdot f(s_i)$. If $D - c_0 > p \cdot f(\overline{s})$, then $s^* = \overline{s}$. If $D - c_0 = p \cdot f(s)$ for some s, define $s^* = s$. Uniqueness is due to the fact that $f(.)$ is increasing. The result then follows. ■

The intuition for the above result is clear. As the realized return of the project increases, so does the cost to the entrepreneur of being fully expropriated if found out to have reported untruthfully. We assume that $c_0 \leq D$, so that costly auditing must be realized with positive probability in order to provide incentives for the entrepreneur to pay off his debt.

We analyze now how the probability p of each entrepreneur being audited is affected by the entrepreneurs' reports, given that the investor has fully committed to the audit strategy already described. Suppose there's a cutoff state s^*, such that every entrepreneur with $s_i \leq s^*$ declares default, while the remaining entrepreneurs pay off their debt. The investor will have $E + D(1 - H(s^*))$ to audit $H(s^*)$ projects. If $E + D(1 - H(s^*))$ is greater than $\int_0^{s^*} c(s)h(s)ds$, then all entrepreneurs are audited. If, given the initial capital E, the investor does not collect enough resources from the creditworthy entrepreneurs to audit all projects in default, then he randomly chooses which projects to audit. Therefore, the audit probability faced by each entrepreneur is given by:

$$p(E, s^*) = Min \left\{ \frac{E + D(1 - H(s^*))}{\int_0^{s^*} c(s)h(s)ds}, 1 \right\}$$

We are now ready to define an equilibrium to the entrepreneur game induced by the mechanism.

Definition 1 *For a given E, a repayment equilibrium is given by an ordered pair (s^*, p) such that:*

1. *$p = p(E, s^*)$*
2. *The entrepreneur i defaults $\Leftrightarrow s_i \leq s^*$*

The definition of a *repayment equilibrium* implies that entrepreneurs form beliefs about the cutoff state s^*, and then choose a repayment strategy accordingly. In addition, these beliefs must be correct in equilibrium.

We have the following:

Proposition 3 *Under (A1), for any given level of capital E (in particular, $E = 0$) chosen by the bank, there exists a truth-telling equilibrium given by $(s^*, p) = (s^D, 1)$. Hence, the optimal mechanism in Proposition 1 has a truthtelling equilibrium regardless of the amount of capital the bank hoards to pay for the auditing costs.*

Proof. If (A1) holds, $p(s^D) = 1$, and the investor can credibly commit to audit all projects in default. If default automatically triggers an audit, then the best response for each entrepreneur is to report truthfully. Therefore $s^* = s^D$. This holds for any capital level E. ■

While truthtelling is *one* equilibrium of the mechanism induced by the standard debt contract and the bank's audit strategy, it is by no means the only one when the bank has capital below a certain threshold. Entrepreneurs can default strategically, impairing the investor's financial position, and his auditing capability. This is formally stated in the following result:

Proposition 4 *If the conditions under (A1) are met, and $E < \overline{E} = \frac{(D-c_0)\int_0^{\overline{s}} c(s)h(s)ds}{f(\overline{s})}$:*
i) There is a fully coordinated default equilibrium where all entrepreneurs declare default, that is $s^* = \overline{s}$;
ii) There is a partially coordinated default equilibrium where $s^* \in (s^D, \overline{s})$.

Proof. i) If $E < \overline{E}$, and $s^* = \overline{s}$ then $p(E, \overline{s}) < \frac{D-c_0}{f(\overline{s})}$. Therefore, $p(E, \overline{s}) \cdot f(\overline{s}) - (D - c_0) < 0$. From Proposition 1, it is optimal for every entrepreneur to declare default. So $(\overline{s}, p(E, \overline{s}))$ is a repayment equilibrium.

ii) We now show the existence of a partially coordinated default. Define

$$\Gamma(s) = p(E, s) \cdot f(s) - (D - c_0)$$

$\Gamma(s)$ is a continuous function. At a partially coordinated default, an entrepreneur with $s_i = s^*$ should be indifferent between repayment and declaring default. So we must have $\Gamma(s^*) = 0$. Let $s^L = sup\{s; p(E, s) = 1\}$. From (A1), we have $s^L > s^D$. Since $\Gamma(s^L) > 0$ and $\Gamma(\overline{s}) < 0$, the Intermediate Value Theorem guarantees that there exists $s^* \in (s^L, \overline{s})$ such that $\Gamma(s^*) = 0$. ■

We notice that, when $E = 0$, the existence of the fully coordinated default equilibrium does not depend on our assumption that the bank randomly audits projects when he lacks resources to monitor all entrepreneurs that have declared default. Therefore, without capital to monitor the bank is always subject to a collective default, regardless of its monitoring strategy. We show in section 2.3.2, however, that by adding a forgiveness clause in the debt contract it signs with the entrepreneurs and adjusting its monitoring strategy, the bank can eliminate the fully coordinated default outcome.

Partially coordinated defaults depend on the bank adopting a random audit strategy when he lacks resources to monitor all entrepreneurs in default (see section 2.2). Also, there can be either a finite number of equilibria featuring partially coordinated defaults or an infinite number of them depending on whether 0 is a regular value of Γ. If it is a regular value then the number of equilibria with partially coordinated defaults is finite and odd. For the remainder of this paper, we focus on regular equilibria, which are robust to small perturbations of the set of parameters.

2 A general solution to rule out bad equilibria:

In this section we show how the investor can, by adopting what we call a *sequential audit* strategy, prevent the entrepreneurs from coordinating on an undesirable equilibrium. This strategy can be implemented by the investor if he is able to secure any strictly positive level of resources once auditing is to take place. We will first describe the *sequential audit* strategy assuming that an amount of capital of δ can be raised. Then, we will describe three ways by which the investor is in fact able to raise this positive amount of capital.

2.1 The Sequential Audit Solution

Suppose that, at the moment of the signing of the contract, the investor divides the entrepreneurs in $1/\varepsilon$ groups of mass ε, where

$$\varepsilon = \frac{\delta}{\int_0^{\overline{s}} c(s,k)h(s)ds} \tag{1}$$

The groups are then randomly ordered as $(g_1, g_2, ..., g_{1/\varepsilon})$, and this order is common knowledge among investor and entrepreneurs. Note that $\varepsilon \int_0^{\overline{s}} c(s,k)h(s)ds$ is exactly the amount of resources that the investor must have in order to audit all entrepreneurs in one given group, regardless of their reporting strategy.

Once the investor starts auditing, he will do so sequentially, auditing entrepreneurs in group $n+1$ only after he has audited all defaulted projects in group n. Hence, even tough the entrepreneurs are ex-ante identical, the bank treats them asymmetrically when it uses a sequential audit strategy.

With δ in capital, the investor can credibly commit to audit all entrepreneurs in g_1. Therefore the first group never defaults strategically, since doing so would automatically trigger an audit, and seizure of the entire project's return. We now show that if the entrepreneurs in group n report truthfully, the investor collects enough resources to commit to audit all entrepreneurs belonging to group $n+1$ that have declared default.

Note that truthful reporting by a given group increases the investor's auditing resources by

$$\varepsilon \left[(1 - H(s^D))D - \int_0^{s^D} c(s,k)h(s)ds \right].$$

The first term in brackets is the amount raised from the creditworthy entrepreneurs. The second term is the total cost incurred with auditing projects in default. The whole expression is positive by (A1). Therefore, if the investor has enough resources to provide incentives for truthful reporting among entrepreneurs in group n, truthful reporting in group $n+1$ will be assured as well. After all, the investor's financial strength is only improving, and the pool of projects potentially subject to audit is decreasing. As this argument holds for an arbitrary n, no group will default strategically.

Proposition 5 *If the bank has δ of capital to audit and uses a sequential audit strategy, truthtelling is the unique equilibrium of the optimal mechanism. Moreover, truthful reporting is obtained in a process that resembles the process of iterative deletion of strictly dominated messages.*

What are the economic forces behind this simple solution? As we have argued, coordinated defaults exist because of the strategic complementarity between the entrepreneurs' decisions to default. The sequential audit strategy is successful precisely because it breaks down this strategic complementarity. The default by a given group of entrepreneurs does not affect the probability of those in g_1 being audited. An entrepreneur in this group who declares default will be surely audited, regardless of the other entrepreneurs' decisions. Therefore, his incentives to default are not affected by the default of others. Furthermore, once g_n pays up, the incentives for truth-telling of g_{n+1} are guaranteed, and coordinated defaults unravel. More importantly, truthtelling is the only strategy that survives a procedure of deletion of dominant strategies. In fact, the sequential audit strategy guarantees that truthtelling is dominant for entrepreneurs in g_1. Entrepreneurs in g_2, aware that those in g_1 will not lie, will also find it dominant to report truthfully and so on. Hence, with some resources and the sequential audit strategy, the implementation is robust (Bergemann and Morris, 2009).

In the next sections, we will point out a few ways by which the bank can obtain the amount δ of Proposition 5.

2.2 Partially Coordinated Defaults

When *partially coordinated defaults* arise, the bank is able to raise resources form a group of creditworthy entrepreneurs who have chosen to report truthfully. More formally, suppose that all the partially coordinated default equilibria are given by $\{(p_1, s_1^*)..., (p_K, s_K^*)\}$[3] . Let (p, s^{MAX}) be the one with the largest s_k^*.

The investor can apply the sequential audit strategy to prevent partially coordinated defaults, taking

$$\delta = (1 - H(s^{MAX}))D$$

This is the least amount of capital that the investor will raise in any of the partially coordinated defaults. The group size ε will then be chosen according to 1. Hence, the sequential audit solution is capable of eliminating all partially coordinated defaults, without any loss in efficiency (since there is no need to raise/keep costly capital in $t = 0$). This solution has its shortcomings, as it is ineffective in eliminating the fully coordinated default equilibrium. Indeed, if all entrepreneurs default, the bank will not collect the needed amount of resources to perform the sequential audit.

2.3 Solutions for Fully Coordinated Defaults:

2.3.1 Positive Capital

One easy way for the investor to guarantee a positive level of capital once auditing is to take place, is to form a capital cushion at the financing stage. That is, at $t = 0$, the investor publicly announces that he is hoarding an amount of δ in cash. The capital cushion, together with the sequential audit strategy, creates a mechanism that is dominant strategy incentive compatible. This implies that truth-telling is an equilibrium strategy for the entrepreneurs, regardless of their prior beliefs. Furthermore, the inefficiency which arises from the holding of a positive level of costly capital can be made arbitrarily small.

2.3.2 Debt Forgiveness

An alternative form of raising the necessary capital to implement sequential audits involves granting debt forgiveness to a group of entrepreneurs. To show that, we explicitly explore the fact that bad equilibria exist because entrepreneurs form beliefs that others will default strategically and these beliefs are correct in equilibrium.

We assume that, at the signing of the contract, the investor chooses randomly a group Δ of mass δ of entrepreneurs, and subsequently divides the remaining entrepreneurs in groups of size of at most ε. The

[3] This set has a finite number of elements, since we are restricting our analysis to regular equilibria.

debt contract with entrepreneurs in Δ^c is the standard debt contract, whereas the contract signed with entrepreneurs in Δ is altered as follows. After the realization of the projects' returns, but before any payment is made, each entrepreneur in Δ is required to report a flag $f_i \in \{s^D, \overline{s}\}$ to the investor. This flag represents each entrepreneurs' belief about the behavior of the entrepreneurs in Δ^c. If every entrepreneur in Δ^c declares default, then those who reported $f_i = \overline{s}$, receive debt forgiveness of $D - c_0$. If a group of positive mass in Δ^c honors their debt, the entrepreneurs in Δ will be audited and fully expropriated.

Under this contract, when every entrepreneur in Δ^c declares default, entrepreneurs in Δ are indifferent between joining the coordinated default and suffering the non pecuniary penalty of c_0, or paying the investor the same amount. We suppose that when confronted with this situation, they always choose to pay. The investor is thus able to collect $\delta(1 - H(s^c))c_0$, where s^c is such that $f(s^c) = c_0$. Once the investor has raised this amount of capital, he is able to proceed with the sequential audits, provided that ε is chosen appropriately. Under this agreement, truth-telling by every entrepreneur is the only equilibrium and debt forgiveness only occurs off equilibrium.

Since no capital needs to be put aside to implement it, the debt forgiveness solution is less costly than the solution in which the bank hoards capital. However, the strategy adopted by each individual entrepreneur when the bank uses the debt forgiveness solution depends on their correct beliefs about the other entrepreneurs' strategies. In this is respect, it is more demanding than the solution in which the bank hoards capital, as the latter induces truthtelling in dominant strategies for the entrepreneurs.

3 Conclusion

In this paper, we have shown that, when a bank's resources to monitor projects are bounded, financial intermediation in a costly state verification model leads to the existence of multiple equilibria. In some of these equilibria, borrowers default because they expect other borrowers to default as well. As opposed to what has been extensively analyzed in the bank run literature, the source of the fragility we identify comes from the bank's asset structure, which is composed of projects that call for close monitoring, rather than from the bank´s funding structure.

We have argued that, to prevent bad equilibria, a bank needs to break the strategic complementarities among borrowers' default decisions. This can be done through the adoption of a sequential audit strategy and by securing a given amount of resources to be able to elicit untruthful reporting from the first group of borrowers in a sequential audit strategy.

While cast in terms of financial intermediation, we believe the ideas we have put forth in this paper can be applied to other settings in which a large number of agents have to be monitored/audited. The deterrence of crime waves by a police force who faces a large population of criminals is one example. Tax collection by a governmental agency that has to rely on income reports of individual tax payers, and the problem of a CEO who relies on the reports about the profitability of a company's divisions by local managers who can self-deal are yet other examples.