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Project Financing when the Principal Cannot Commit*

M. Martin Boyer†

Résumé / Abstract

Prenons une économie où un entrepreneur a besoin de financement afin d'entreprendre un projet risqué dont le coût est fixe et dont le rendement peut être faible ou élevé. Supposons alors que ce rendement est une information privée de l'entrepreneur. Si le montant que l'entrepreneur doit rembourser au financier dépend du rendement sur le projet risqué, s'il est coûteux pour le financier de vérifier le rendement réel du projet, et si le financier ne peut se commettre en une stratégie de vérification, alors il devient optimal pour l'entrepreneur de ne pas dire la vérité tout le temps. Nous trouvons premièrement que l'entrepreneur sur-finance son projet d'investissement si le financier ne peut se commettre, et deuxièmement que l'entrepreneur a une plus grande richesse ex post si le projet ne porte pas fruit. Ce sur-financement et cette plus grande richesse dans le mauvais état de la nature sont le produit de l'absence d'engagement de la part du principal qui doit utiliser ces signaux coûteux afin de réduire le nombre de faux messages dans l'économie.

Suppose an entrepreneur needs funds from a financier to invest in a risky project whose cost is fixed, and whose return may be high or low. Suppose also that the project's realized return is an information that is private to the entrepreneur. If the amount the entrepreneur pays back to the financier depends on the risky project's outcome, if it is costly for the financier to verify the project's true realized return, and if the financier cannot commit to an auditing strategy, then it is optimal for the entrepreneur to misreport the true state of the world with some probability. In other words, it is in the entrepreneur's interest to lie with a degree of probability. We find that the entrepreneur over-finances his project when the financier cannot commit, and that he has greater wealth ex post if the project is not successful. Over-borrowing and greater wealth in the low-return state result in reducing the number of false reports in the economy.

Mots Clés : Engagement, financement, information asymétrique, aléa moral ex post

Keywords: Commitment, financing, asymmetric information, ex post moral hazard

JEL: D82, C72, G33

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1 Introduction

1.1 Motivation

When an individual has a risky project to invest in, he may go to a banker to borrow the funds that are needed. If he has some private information concerning the project, he may then find it in his best interest to attempt to extract a rent from the financier. For example, the entrepreneur[1] may shirk his responsibilities, thus reducing the probability that the project will have a high return. This problem of shirking responsibilities is known as *ex ante moral hazard* in the literature.

Another type of asymmetric information between the entrepreneur and the financier concerns the return on the project. If the transfer between the entrepreneur and the financier depends on a message sent by the entrepreneur after he has privately witnessed the state of the world (i.e.: he is the only one to know what the return on the investment is), then the entrepreneur may have an incentive to misreport this information to the financier. This incentive can be viewed as a problem of *ex post moral hazard*. We focus exclusively on the ex post moral hazard problem in this paper.

A well known result in the literature (see Townsend, 1979, and Gale and Hellwig, 1987) is that if there is ex post moral hazard on the part of the entrepreneur, and if the financier can commit to a deterministic auditing strategy, the optimal contract between the two players will be what Gale and Hellwig call a *standard debt contract*. A standard debt contract specifies that an entrepreneur who is able to make his scheduled payments (interest on the debt, presumably) is not audited. As soon as he misses a payment, however, he is audited and all his assets are seized. In this type of contract, it is not optimal for an entrepreneur to miss a payment he is able to make. Since he is always audited when he misses a payment, his cheating will be invariably discovered.

On the other side of the market is the financier. For the financier, the provisions of the standard debt contract seem attractive: by auditing every time a payment is missed, she is guaranteed that no payment capable of being made is ever missed. Unfortunately, when the time comes to audit a missed payment, both the financier and the entrepreneur find it optimal to renegotiate[2] that part of the contract. If the financier knows that the entrepreneur has told the truth (because telling the truth is always the best strategy), and that auditing the entrepreneur is costly, then she will want to renegotiate the contract to reduce her audit costs. The entrepreneur also wants to renegotiate since he has nothing to gain by being audited.

If the entrepreneur willingly agrees to give everything to the financier, then he may be rewarded

[1] For the remainder of the paper, the financier shall be a *she*, and the entrepreneur shall be a *he*.

[2] Surprisingly Shleifer and Vishny (1997) do not mention this renegotiation problem in their survey of corporate governance. This renegotiation is not the same as the possibility of bribing a manager, a possibility they do mention. Gale and Hellwig (1989) discuss the possible renegotiation game between the entrepreneur and the financier.

by the financier who might be willing to share the savings generated by not conducting the audit. In other words, when there is an audit, the payoff to the entrepreneur is *zero*, while the payoff to the financier is $W_L - c$, where W_L is the residual wealth of the entrepreneur in case of bankruptcy and c is the cost of auditing. If no audits are conducted, and the entrepreneur willingly gives his residual wealth to the financier, then the payoffs to the agents are εc for the entrepreneur and $W - \varepsilon c$ for the financier, where $\varepsilon < 1$ is whatever percentage of the savings the financier is willing to share with the entrepreneur. In this instance not auditing Pareto-dominates auditing, at least ex post.

If the entrepreneur knows that the financier never wants to audit ex post, he will find it in his best interest to always miss a payment. If the financier knows that the entrepreneur always misses a payment, the financier will not be so inclined to never audit. In the end what happens is that the entrepreneur sometimes misses the payment on purpose, and the financier audits only a fraction of the payments that are missed.[3] In game theory terms, the players are playing mixed strategies.

We shall thus relax the assumption that the financier can commit to an auditing strategy. Without commitment, the financier cannot guarantee that the entrepreneur will always reveal the project's true realized return. This means that the incentive compatibility constraint is substituted by Nash equilibrium constraints for the entrepreneur and the financier. The optimal reporting strategy of the entrepreneur and the optimal auditing strategy of the financier yield a Perfect Bayesian Nash Equilibrium (PBNE) in mixed strategies. This PBNE tells us how the players are behaving when Nature decides the project's realized return. The goal of this paper is therefore to design the optimal contract between an entrepreneur and a financier taking into account the Nash behavior of the players. This would imply that the contract we hereby derive is not first- or even second-best. In fact it is a *third-best contract,* given the impossibility of implementing the second best contract that would be obtained using the revelation principle.[4]

The problem studied is closely related to that of sovereign debt as presented by Gale and Hellwig (1989). The difference in the modelling is that Gale and Hellwig do not allow the financier to seize the assets of the country who misreports its ability to repay its debt. Auditing then becomes merely a way of potentially punishing the entrepreneur. We allow the financier to collect what she would have collected had the entrepreneur told the truth. We do not, however, allow the financier to be able to collect any penalty from the borrowing country. As in Gale and Hellwig, the penalty is strictly paid by the entrepreneur. This means that the penalty can be viewed as a sunk cost.

[3] Picard (1996) and Boyer (2000) provides a discussion of the commitment problem for a principal in an insurance fraud context, while Khalil (1997) does the same in a monopoly regulation context.

[4] Loosely put, the revelation principle basically states that amongst all implementable second-best contracts, there is at least one where truth telling is always obtained; see Myerson (1979).

1.2 Findings

The main findings of this paper are three-fold. First, there exists a unique PBNE in mixed strategies in what is called the *payment game*. Using a two-point distribution of the returns, the PBNE is such that: 1- the entrepreneur always tells the truth if the low return is realized; 2- the entrepreneur plays a mixed strategy between reporting a high return and reporting a low return if the high return is realized; 3- the financier never audits the report of a high return; and 4- the financier audits the report of a low return a fraction of the time. As shown by Gale and Hellwig (1989), this is the only equilibrium that passes the Kohlberg-Mertens selection criterion.

The second result of the paper is that the entrepreneur ends up with greater wealth ex post if the project has a low return than if the project has a high return. This means that the difference between a project's realized return and the payment made to the financier is smaller when the project has a high return than when it has a low return. In the low return state, it is as if the financier were forgiving part of the entrepreneur's debt. The occurrence of this finding was hypothesized by Rajan (1992) and Bester (1994).

Finally, the third finding indicates that the proportion of outside financing is greater when the financier cannot commit to an auditing strategy than when she can commit. This last finding resembles that of Khalil and Parigi (1998) who find that the amount *invested* increases when there is no commitment. We, on the other hand, find that the amount *financed* increases when there is no commitment.

The main reason why more outside financing occurs when there is no commitment is that it is a way for the financier to signal that she has more to lose by not auditing. By lending more, the financier has more to lose if the entrepreneur is not caught cheating. This creates an incentive for the entrepreneur to cheat less often. The same type of reasoning can be used to explain why the entrepreneur is better off ex post in the low return state. Looking at what happens from the financier's point of view, it is clear that under commitment, the financier collects more if the return is high than if it is low. The same is true when there is no commitment, except that the difference between the amounts collected is greater. By increasing the difference between what she collects in the high return state and what she collects in the low return state, the financier sends the signal that she has a lot to lose by letting the entrepreneur get away with announcing the wrong state of the world. The entrepreneur must then scale down his probability of lying to internalize these implicit incentives for the financier to audit.

1.3 The Literature

There is a wide-ranging and extensive literature on agency problems between a financier and an entrepreneur. Shleifer and Vishny (1997) provide a survey of the literature on the general subject of corporate governance. We shall complement this survey by focusing on the problem of an entrepreneur who has private information regarding the return on his investment, and who must report that return to a financier. Given that his final wealth depends on the report he makes, there is an incentive to misreport the actual return. This incentive to misreport is known as ex post moral hazard.

In a world where it cost nothing to verify the agent's report, the principal should always verify, and no misreporting should ever occur. Gale and Hellwig (1985) characterize the optimal contract between an entrepreneur and a financier[5] where they find that the optimal contract is a debt contract where the entrepreneur is never audited as long as he is able to make his (fixed) interest payment, but is always audited if he misses a payment (declares bankruptcy and his assets are seized). In both papers it is possible to demonstrate that the level of investment is reduced because of moral hazard and costly bankruptcy, just as in Grossman and Hart (1986).

In every paper mentioned so far, there is the assumption that the principal is able to commit to the exact strategy that induces truth-telling. Unfortunately, such a commitment may not be credible. If the principal knows that the agent has told the truth, what is the point of conducting an audit? This inability to commit has the consequence that the agent attempts to extract rents with some probability. It also induces the principal to audit with greater probability than under full commitment.

The commitment problem has attracted a fair amount of research.[6] For example, let us mention Gale and Hellwig (1989), Scheepens (1995), Persons (1997), and Khalil and Parigi (1998). These papers are similar to the one we present, but with some important differences. For example Scheepens' entrepreneur is risk-neutral, while ours is risk-averse. He also assumes that the detection of a fraudulent bankruptcy is not perfect. Finally, he restricts his analysis to standard debt contracts, and looks at the optimal behavior of the players in terms of such contracts. Our model goes further, as the optimality of the debt contract per se is reconsidered when the financier cannot commit to

[5] See also Hellwig (1977), Diamond (1984), Gale and Hellwig (1989), and Mookherjee and Png (1989) and Bond and Crocker (1997) in an insurance context.

[6] Beaudry and Poitevin (1995) study a commitment problem, but it is the entrepreneur's commitment not to seek supplemental financing from a second financier that is of interest to them. Gobert and Poitevin (1997) also relax the assumption of an agent's commitment to a contract. Using a multi-period setting where an agent's future income is unknown and where a principal can to some extent smooth out future income with a contract, they show that allowing agents to save some of their earnings may mitigate some of the agent's commitment problems. In an insurance setting, see Picard (1996) and Boyer (2000).

an auditing strategy.

Khalil and Parigi (1998) approach the problem from a different angle. While both players are risk neutral, the entrepreneur's production function is chosen to be increasing and concave so that his payoff is an increasing function of his investment. Also they let the entrepreneur choose the absolute size of the project rather than the proportion he invests in it. Another major difference is that we make an explicit distinction between the investment period and the payoff period. Khalil and Parigi make no such difference. Khalil and Parigi also let the penalty imposed on the entrepreneur who is caught sending the wrong message be paid to the financier, while our penalty is a deadweight cost to society. Finally, whereas Khalil (1997) maximize the financier's profits, we maximize the entrepreneur's expected utility.

Persons (1997) approaches the problem from the point of view of many investors who are implicated in the project's financing. What this does is introduce a strategic interaction between the financiers in determining who must audit. Persons finds that in order to induce an optimal level of auditing, the contract must stipulate that the party who does not conduct the audit must be penalized if the other party conducts the audit and finds the entrepreneur to have misrepresented the state of the world. He also assumes that the penalty paid by the entrepreneur if the latter is found to have misreported the state of the world is contractible. This means that his contract stipulates a very large transfer from the entrepreneur to the financier if he is found to have cheated. This very large transfer motivates the financier to audit more often since auditing becomes a way to make money. He bases this assumption on the work of Betker (1995) who finds that creditors' committees are allowed to recover their expenses. In reality, however, the entire penalty payment does not necessarily go to this committee. For example, an entrepreneur found guilty of fraudulent bankruptcy may go to prison; this penalty does not benefit the financiers. Another example where the penalty is not paid to the creditors is in the case of sovereign debt. A country cannot be forced by the courts to pay an amount to some financier who feels wronged. The greatest penalty that can be inflicted is that no financier will ever want to do business with that country in the future.

One of the ways in which our paper differs from the previous two is from the point of view of the penalty. In that respect we follow Gale and Hellwig (1989) in presuming that it may not be possible to ensure that the monetary penalty for lying is paid. Therefore, we let the penalty be only the difference between the entrepreneur's expected utility when he purchases the contract, and his expected utility if he remains in autarchy. In other words, the penalty is only that he is shutout of the market forever. Thus the penalty is not *paid to* the financier, it is only *paid by* the entrepreneur.

The model applies easily to the problem of sovereign debt as developed by Bulow and Rogoff

(1989) and Gale and Hellwig (1989). Our paper looks at a particular equilibrium outcome of Gale and Hellwig's renegotiation game, and derives the optimal contract given that equilibrium. The equilibrium outcome we shall use is the one called *separating* by Gale and Hellwig. As anticipated by Gale and Hellwig, the equilibrium leads to a Pareto-dominated outcome.

The remainder of the paper goes as follows. The basic assumptions of the model, the setup of the model and the parameters used are presented in the next section. The *payment game* played between the entrepreneur and the financier is also developed in Section 2. In Section 3, we develop the model. We find the optimal contract between the informed entrepreneur and the uninformed financier. Finally Section 4 discusses the implications of such a contract and concludes.

2 Assumptions and Setup

Players are infinitely lived. Their utility is equal to the discounted sum of their expected utilities in each period. The discount rate is the same for every player, $\delta < 1$. Each period is divided into two stages, the financing/investment stage and the return/game/payoff stage. These stages are not discounted. The entrepreneur is risk averse with a twice differentiable von Neumann-Morgenstern utility function over final wealth ($U' > 0$, $U'' < 0$, $U'(0) = \infty$, $U'(\infty) = 0$), and receives exogenous wage Y in each stage of each period. The financier is risk neutral and expects to make zero profit on each contract. The entrepreneur has no memory, while the financier has a perfect memory.[7]

In the first stage the entrepreneur may consume his wage and/or invest in a risky project. The project pays off in the second stage. The project is unique, indivisible and costs $I > 0$. Let α denote the share of the investment contributed by the entrepreneur himself. This means that he needs to finance $D = (1 - \alpha)I$ on the outside. In the second stage, Nature decides on the project's realization. There are only two possible returns on investment (ROI), $\frac{W_L}{I}$ and $\frac{W_H}{I}$, with $W_H > W_L$. W_H occurs with probability π. The actual ROI is private information to the entrepreneur. The financier can learn about the return if she incurs an auditing cost, c.

Given that the entrepreneur finances some amount D in the first stage, he needs to pay it back in the second stage. If the high return is realized, then the entrepreneur needs to pay back $R_H D$. If the low return is realized, then he needs to pay back $R_L D$. Therefore the contract specifies a payback schedule contingent on the announced state of the world. These paybacks are subject to limited liability constraints: $R_i D \leq W_i$, $i \in \{L, H\}$. These limited liability constraints mean that the entrepreneur cannot be forced to pay back more than the total return on the project in each state. This game is then played every period until the entrepreneur is caught sending a false

[7] We make these two assumptions only in order to evacuate reputation concerns in the first case, and to make the autarchic penalty credible in the second case.

message, in which case no contract are ever signed (the entrepreneur is in autarchy). The sequence of the game in any period T is shown in figure 1.

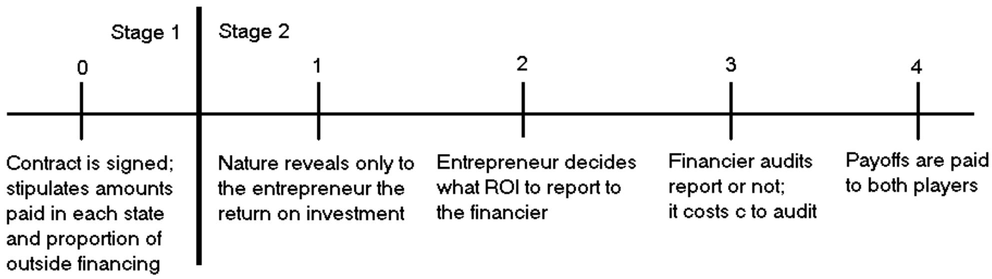

Figure 1: Sequence of play.

In this setup, the entrepreneur is not constrained to tell the truth. In fact, upon learning about the realized ROI, he may misreport it to the financier. The reason why truth-telling may not be the optimal strategy for the entrepreneur is that the financier cannot commit credibly to an auditing strategy. This means that the financier audits only if she finds it in her best interest to do so *ex post*. If the entrepreneur lies and the financier audits, then the lie shall be discovered with probability one. In this event, the payment from the entrepreneur to the financier is equal to what he would have paid had he not lied, but the entrepreneur must also incur some penalty. This penalty, measured in utility terms, is a deadweight cost to the economy in the sense that it is paid by the entrepreneur, but is not collected by the financier. This penalty represents the foregone utility of remaining in autarchy. We shall denote this foregone utility k.[8] A table listing all the possible payoffs to the financier and the entrepreneur which are contingent upon every possible outcome is provided in the appendix as Table 1.

Before presenting the maximization problem per se, let's start by presenting the equilibrium of the payment game whose extensive form is displayed in Figure 2. This game yields a unique PBNE in mixed strategies which is presented as lemma 1.[9]

Lemma 1 *The unique PBNE in mixed strategy*[10] *of this game is such that:*

1-The entrepreneur always reports a low return when the actual return is low.

2-The entrepreneur reports a low return with probability η, and a high return with probability $1-\eta$, when the actual return is high.

[8] Let $\overline{V}$ be the entrepreneur's expected utility in a given period if he signs the contract, and let $\underline{V}$ be his expected utility in autarchy. Then $k = \frac{\delta}{1-\delta}\left(\overline{V} - \underline{V}\right)$.

[9] In this game, the definitions of perfect Bayesian and sequential equilibrium coincide (see Myerson, 1991).

[10] Since we have a two-player game where each player has only two possible actions, there can be at most one mixed-strategy equilibrium (see Gibbons, 1992).

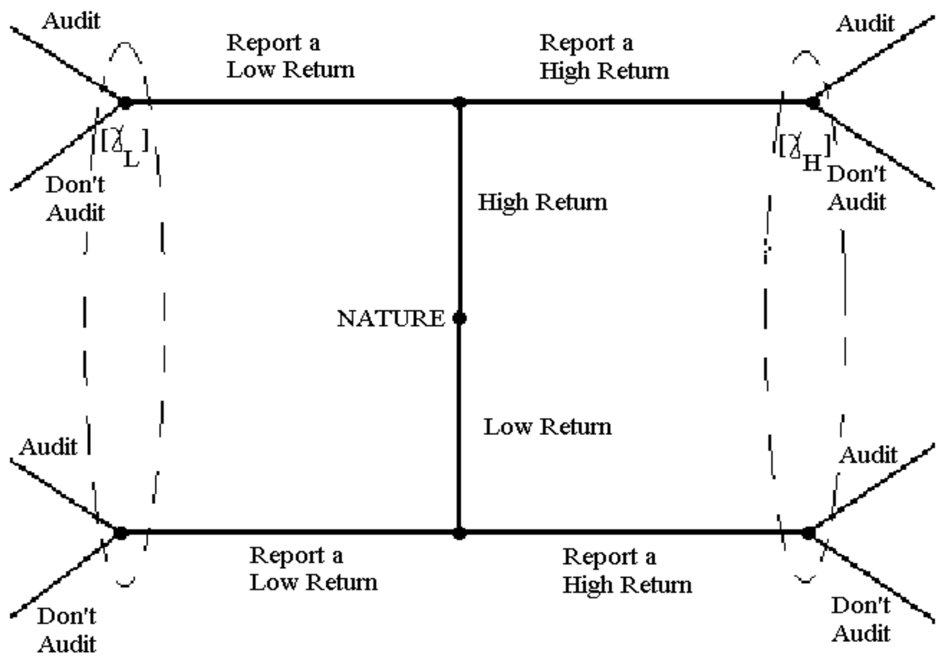

Figure 2: Extensive form of the payment game.

3-The financier never audits an entrepreneur who reports a high return.

4-The financier audits with probability ν an entrepreneur who reports a low return.

η and ν are given by

$$\eta = \left(\frac{c}{(R_H - R_L)\,D - c}\right)\left(\frac{1-\pi}{\pi}\right) \tag{1}$$

and

$$\nu = \frac{U\,(Y - R_L D + W_H) - U\,(Y - R_H D + W_H)}{U\,(Y - R_L D + W_H) - U\,(Y - R_H D + W_H) + k} \tag{2}$$

Proof: *All the proofs are in the appendix.*•

It is clear that the only type of lie that occurs is the entrepreneur's depiction of the true return as being lower than in reality. This seems logical; if the entrepreneur needs to pay more to the financier when the return on the investment is greater, then he will want to tell her that the return is lower than in reality. This means that the entrepreneur never over-reports the return on the project. Also, since the financier knows that the entrepreneur never reports that a project's return is high when in fact it is low, she knows for sure that the entrepreneur is telling the truth if he reports a high return. There is therefore no need to audit in this circumstance. In the other cases, the equilibrium of the game is such that the entrepreneur and the financier play mixed strategies.

This means that in equilibrium, some entrepreneurs are successful at extracting rents from the financier in the sense that some lie and are not audited. As shown by Gale and Hellwig (1989), this equilibrium is the only stable equilibrium of the game.

3 The Model

3.1 Optimal Contract

The equilibrium strategies are constraints that the financier needs to consider when she designs the contract. In other words, the behavior of the two players in the second stage are anticipated rationally by the financier when she designs the contract in the first stage. The problem is then to find a payment schedule (R_L and R_H), and an entrepreneur's proportion of the investment α that maximizes the entrepreneur's expected utility.

$$\begin{aligned} EU &= U(Y-\alpha I)+(1-\pi)U(Y-R_L D+W_L) \\ &\quad +\pi(1-\eta)U(Y-R_H D+W_H) \\ &\quad +\pi\eta\nu\left[U(Y-R_H D+W_H)-k\right] \\ &\quad +\pi\eta(1-\nu)U(Y-R_L D+W_H) \end{aligned} \tag{3}$$

By substituting for the values of η and ν found in (1) and (2), (3) becomes

$$EU = U(Y-\alpha I)+(1-\pi)U(Y-R_L D+W_L)+\pi U(Y-R_H D+W_H) \tag{4}$$

We can restrict the analysis to only one period since all periods are the same, and the impact of all future periods is incorporated into the penalty k. The problem for the financier is therefore repeated every period as long as the entrepreneur is not caught cheating. There is no need for the lender to build a reputation for auditing frequently in this model since the entrepreneur is assumed to have no memory. This means that the past actions of the financier (for example always auditing entrepreneurs who report a bad return) are never known to the entrepreneur. And since the formulation of the problem is the same, there is no loss in generality studying a single period.

Besides the Nash equilibrium constraints, another constraint that is imposed on the financier is that her expected profit must be zero. This means that the loan must be paid back entirely in the next stage minus auditing expenses. This zero-profit constraint is then

$$D=(1-\pi)R_L D+\pi(1-\eta)R_H D+\pi\eta\nu R_H D+\pi\eta(1-\nu)R_L D-c\nu(1-\pi+\pi\eta) \tag{5}$$

The initial-stage loan on the left must be equal to the second-stage expected payback on the right. $(1-\pi)$ is the probability that the ROI is low, in which case the entrepreneur only needs to pay

$R_L D$. $\pi(1-\eta)$ is the probability that the ROI is high and that the entrepreneur is telling the truth, in which case he needs to pay $R_H D$. The probability that he says the ROI is low when in fact it is high is given by η. When the entrepreneur lies, he is caught with probability ν, in which case he needs to pay the financier $R_H D$. If he is not caught (with probability $1-\nu$), then he must pay only $R_L D$, which means that he was able to extract a rent from the financier. Finally, $c\nu\,(1-\pi+\pi\eta)$ is the expected cost of the audit strategy.

By substituting for the value of η given in (1), it is easy to simplify (5) to

$$1-\pi R_H-(1-\pi)R_L=-\pi\left(\frac{c}{(R_H-R_L)\,D-c}\right)\left(\frac{1-\pi}{\pi}\right)(R_H-R_L) \tag{6}$$

By definition $R_H > R_L$ and

$$\eta=\left(\frac{c}{(R_H-R_L)\,D-c}\right)\left(\frac{1-\pi}{\pi}\right)\geq 0 \tag{7}$$

It is then clear that $1-\pi R_H-(1-\pi)R_L<0$. What does the left hand side of equation (6) represent? Presumably the financier will not want to invest if she expects a return that is lower than some minimum. In other words, the expected return on the investment, $\pi R_H+(1-\pi)R_L$, cannot be smaller than the minimum a financier is willing to accept (which is 1). Therefore the left hand side of (6) represents the difference between the financier's minimum acceptable return and the expected actual return on his loan. This difference cannot be positive as it would mean that the expected actual return is lower than the minimum.

Letting $D=(1-\alpha)\,I$ and rearranging equation (6) yields

$$(1-\alpha)=\left(\frac{1-R_H}{1-\pi R_H-(1-\pi)R_L}\right)\left(\frac{\frac{c}{I}}{R_H-R_L}\right) \tag{8}$$

This last equation gives us an equation for the proportion of the project that is financed externally. The simplified problem is then

$$\max_{R_L,R_H,\alpha} EU=U(Y-\alpha I)+(1-\pi)U\left(Y-R_L(1-\alpha)I+W_L\right)+\pi U\left(Y-R_H(1-\alpha)I+W_H\right) \tag{SP}$$

subject[11] to

$$\alpha=1-\left(\frac{1-R_H}{1-\pi R_H-(1-\pi)R_L}\right)\left(\frac{\frac{c}{I}}{R_H-R_L}\right) \tag{ZP}$$

$$W_L-R_L\,(1-\alpha)\,I \;\geq\; 0 \tag{LL$_L$}$$

$$W_H-R_H\,(1-\alpha)\,I \;\geq\; 0 \tag{LL$_H$}$$

[11]The PBNE constraints have been included directly in the zero-profit constraint, in the participation constraint, and in the maximization problem.

$$\overline{V} \geq \underline{V} \tag{PC}$$

ZP represents the zero-profit constraint of the financier. The LL_i constraints are the limited liability constraints. They stipulate that the entrepreneur cannot be forced to pay more than the actual return on the project in any state of the world. In other words, if the amount he needs to pay, $R_i(1-\alpha)$, is greater than the wealth generated by the project, W_i, he may file for bankruptcy to protect his other assets. The last constraint is the participation constraint, which means that the entrepreneur has to be better off investing in this project than not investing. Let's abstract from the participation constraint and the limited liability constraints, and concentrate on an interior solution.

Lemma 2 *After substituting ZP into SP, and letting*

$$\alpha_H = \frac{\partial \alpha}{\partial R_H} = (1-\alpha)\left(\frac{\pi(1-R_H)^2 + (1-\pi)(1-R_L)^2}{(1-R_H)\left[1-\pi R_H-(1-\pi)R_L\right](R_H-R_L)}\right) \tag{9}$$

$$\alpha_L = \frac{\partial \alpha}{\partial R_L} = (1-\alpha)\left(\frac{(1-\pi)(R_H-R_L)^2}{(1-R_H)\left[1-\pi R_H-(1-\pi)R_L\right](R_H-R_L)}\right) - \alpha_H \tag{10}$$

and

$$V' = \begin{array}{c} (1-\pi)R_L U'(Y-R_L(1-\alpha)I+W_L) \\ +\pi R_H U'(Y-R_H(1-\alpha)I+W_H) - U'(Y-\alpha I) \end{array} \tag{11}$$

the two necessary conditions for an optimum are

$$\frac{(1-\pi)U'(Y-R_L(1-\alpha)I+W_L)}{V'} = \frac{\alpha_L}{1-\alpha} \tag{NC_1}$$

and

$$\frac{\pi U'(Y-R_H(1-\alpha)I+W_H)}{V'} = \frac{\alpha_H}{1-\alpha} \tag{NC_2}$$

It is interesting to note that the penalty inflicted on those entrepreneurs who were found to have cheated has no impact on the optimal contract. When we look at the necessary conditions for an optimum (NC_1 and NC_2), nowhere do we see the penalty parameter k. This result contrasts with that of Scheepens (1995) who finds that the size of the penalty has a non-trivial impact on the shape of the optimal contract.

The reason why the penalty has no impact on the optimal contract is a combination of two effects: the penalty is a deadweight loss, and the auditing occurs ex post. Since the financier cannot use auditing as a way to recoup her auditing costs, auditing is purely a way of detecting entrepreneurs who send false messages. It is easy to show that this independence no longer holds when the penalty is paid, in part or in total, to the financier. This is clear since the amount of money the financier can recoup must be included as a revenue under zero-profit conditions. The other effect is that the financier's decision to audit comes last. It is easy to show that the financier's probability of auditing decreases as the penalty increases ($\frac{\partial \nu}{\partial k} < 0$). This means that the financier adjusts her auditing strategy to compensate for the penalty. The adjustment is exactly such that the penalty becomes irrelevant. This is due to the fact that the auditing strategy is chosen so that the entrepreneur is indifferent to the choice of cheating or not cheating. By increasing the penalty the financier must reduce her auditing probability in order for the entrepreneur to remain indifferent in choosing either course of action. In the end, any change in the penalty is offset by a change in the auditing strategy.

The policy implications of this finding are striking. It will not be possible to alter the optimal contract on the basis of the penalty inflicted on those found to have sent a wrongful message. Furthermore, increasing or reducing the deadweight penalty for sending a false message will not affect the probability of the entrepreneur sending a false message. The reason is simple; since the contract is independent of the penalty, and since the penalty affect the entrepreneur's probability of lying only via the optimal contract (η depends on k only through R_L and R_H, see equation 1), it follows that the entrepreneur's decision to lie is independent of the penalty. The other interesting features of the optimal contract are presented in the next two subsections of the paper.

3.2 Implications

The first implication of the optimal contract is that the entrepreneur's final wealth is greater in the state of the world where the return on the project is lower. This is presented as proposition 1.

Proposition 1 *The entrepreneur's final wealth is greater in the low return state than in the high return state.*

It may seem strange to see that the entrepreneur is better off in a low ROI state than in a high ROI state. This raises the possible problem that the entrepreneur may not want to invest all the necessary time and effort to make sure that the project has a high return. However, the investment of some kind of effort is not modelled here; we are only concerned about the problems of revealing the true state of the world.

The entrepreneur is in essence penalized for having his project turn out to be a success, since he is better off in the low ROI state. The reason is that the entrepreneur is forced to not understate the true return on the project. This is exactly what is happening. By increasing the difference between the payment in the high ROI state, $R_H(1-\alpha)I$, and the payment in the low ROI state,

$R_L(1-\alpha)I$, the entrepreneur has to lower his probability of sending a false message concerning the true return. Put differently, as the difference between R_H and R_L increases, the probability of lying, η, decreases. Since the financier has more to gain by auditing, the entrepreneur must reduce his probability of sending a false message in order for the financier to remain indifferent about auditing or not auditing.

If there were no ex post moral hazard, it can be readily demonstrated and quite intuitively grasped that the entrepreneur would choose a contract in which his second-period final wealth is equal in the two states of the world. With ex post moral hazard however, we see that the entrepreneur's final wealth is greater if the project has a low return. Putting it a different way, ex post moral hazard reduces the financier's final wealth if the project has a low return. This implicitly increases the willingness of the financier to make sure that the entrepreneur's report of a low return is truthful. Thus by increasing the difference between what she collects in the high return state and what she collects in the low return state, the financier sends the signal that she has a lot to lose by letting the entrepreneur get away with announcing a false state of the world. The entrepreneur then must scale down his probability of lying to internalize these implicit incentives for the financier to audit.

The next question is then to find out what fraction of the project will be financed by the entrepreneur. If $\alpha = 0$ ($\alpha = 1$), then the entire project is outside (inside) financed.

Proposition 2 *The entrepreneur finances more than he needs. In other words,* $\alpha < 0$.

A negative α means that the amount levied through outside financing is greater than the cost of the project (i.e.: $D > I$). It is interesting to note that the entrepreneur's limited liability is but a sufficient constraint for α to be negative. In fact, it is very easy to construct a numerical example where there is no limited liability, and where α is negative. An example of a negative α is when the entrepreneur consumes various perks. When entrepreneurs levy outside funds at a given moment in time, the financiers know that they run the risk of having the entrepreneur use part of that loan to increase his present consumption. What the present contract does is explicitly quantify the amount of perks that entrepreneurs can consume today. Therefore perks can be viewed as the difference between the cost of the project and the amount of outside financing. The question that comes to mind is why a financier would do such a thing?

The main reason for over-financing is that it implicitly forces her to audit more often, and thus induces the entrepreneur to tell the truth with greater probability. It is clear that the financier has more to lose by not auditing if she lends more. The amount at stake is given by $(R_H - R_L)(1-\alpha)I$. This means that ceteris paribus a smaller α (i.e., a greater share invested by the financier in the project) increases the amount at risk. Since there is more to be lost, the entrepreneur will have to reduce his probability of sending a false message. In other words, we have that $\frac{\partial \eta}{\partial \alpha} > 0$.

A possible explanation for this result is that over-financing represents some kind of bribe paid ex ante to the entrepreneur. Shleifer and Vishny (1997) suggest that it would be possible to solve the ex ante inefficiency encountered in Jensen and Meckling (1976) if we were to let the entrepreneur accept a bribe. This bribe would allow the optimal level of investment to be obtained. However, the bribes that Shleifer and Vishny talk about are bribes that would induce the entrepreneur to invest in the socially optimal project. This is more a case of adverse selection between projects. In our setup, there is only one type of project, with more than one outcome. This means that a bribe does not necessarily work since some entrepreneurs still lie about the true outcome of a risky project.

Another possible explanation for this over-financing is that the financier is also acting as an insurer in smoothing marginal utilities across states. We know that the entrepreneur will not invest in the project in the first period if it does not give him greater expected wealth in the second period. It then makes sense that he would want to transfer some of that excess second-period wealth to the initial period.

Another interesting feature of the contract is that it allows negative interest rates. This finding is presented in the following corollary.

Corollary 1 *If $W_L < I$, then $R_L < 1$.*

A negative interest rate just means that the entrepreneur needs to reimburse less than the face value of the loan itself. This result is not unusual. It is implicit in debt contracts in which an entrepreneur sees all his assets seized when he cannot make a scheduled payment that the interest rate in those states is negative. What is more interesting with the present contract is that the entrepreneur does not need to give away all his assets in the low return state. In fact, since the entrepreneur's ex post wealth is greater in the low return state, it cannot be that all the project's realized returns are paid to the financier. In other words, $R_L < \frac{W_L}{(1-\alpha)I}$, whatever the value of W_L. Moreover, nothing in this contract prevents the financier from giving money to the entrepreneur if the return on the project is low. To see how that can happen, suppose that the project is a total bust. With $W_L = 0$,we must have $R_L < 0$ since $R_L < \frac{W_L}{(1-\alpha)I}$. This means that the financier would pay the entrepreneur some amount if the ROI is low.

A direct consequence of this corollary is that the entrepreneur is always able to fulfill the provisions of the contract when the ROI is low. In other words, the limited liability constraint in the low ROI state is never binding. Obviously the limited liability constraint is more stringent when the entrepreneur's wealth is lower. Here the entrepreneur's wealth is lower in the state where the ROI is high. Therefore the only time an entrepreneur may declare bankruptcy[12] is if the ROI is high. This raises the interesting point that if the entrepreneur is bankrupt, the financier will never audit him.

This result stems from the reporting and auditing behavior of the players. We know from the PBNE that with some probability the entrepreneur will tell the truth if the ROI is low. We also know that if the entrepreneur declares that his project has a high ROI then the financier never audits him. Combined with the fact that bankruptcy can only occur in the high ROI state, it follows that an entrepreneur who declares bankruptcy is never audited. This finding is completely the opposite of the one that is predicted through standard debt contracts à la Gale and Hellwig (1985) whereby an entrepreneur who declares bankruptcy is audited.

This contract resembles the implicit contract between rich countries and poor countries in the sense that it gives a rationale for debt forgiveness if the borrowing country's project fails. From Corollary 1, we see that it may sometimes be optimal to give extra money to countries whose return on an investment project was very poor. It also gives a rationale for the international boycott of any future lending to a country who is found to have misreported the success of an investment project. Finally, the contract is such that the borrowing country borrows more than it needs to undertake the project in order to increase current consumption.

Since the financier cannot commit to auditing due to the cost of doing so, the contract is such that part of the debt is forgiven in the event that the return on the investment is low. When the return on the investment is high, however, the borrowing country ends up paying a lot in interest payments, which corresponds to the high risk such a country faces.

Unfortunately, the contract we obtain still allows some inefficiency to remain in the economy. A major inefficiency that exists is that some investments that have a positive net present value (NPV) are not undertaken because of the cost of conducting the audits. We show this as a corollary.

Corollary 2 *Suppose there exists a project whose NPV is given by $\varepsilon = \pi W_H + (1-\pi)W_L - I > 0$. As $\varepsilon \to 0^+$, then the project will not be undertaken.*

This corollary shows that the possibility for the entrepreneur to extract a rent from the financier prevents projects that would be beneficial for society from being undertaken. Having positive NPV projects be put on ice is a common outcome when there are agency problems in the economy, even when the financier can commit to every provision of the debt contract. The reason is that the money necessary to conduct audits has to come from somewhere. It will typically come from the

[12] In the sense that all the project's returns are given to the bank: $W_i = R_i(1-\alpha)I$.

entrepreneur paying a higher interest rate when his project has a high return. Therefore the same project could have a positive NPV using the interest rates when there is no possibility of moral hazard, and a negative NPV when interest rates are adjusted to compensate for the audits.

3.3 Commitment

In this section of the paper we compare the results under no commitment to those obtained under full commitment. This means that the revelation principle is used to derive the optimal contract. The problem is then

$$\max_{R_L,R_H,\alpha,\nu} EU = U(Y-\alpha I) + (1-\pi)U(Y - R_L(1-\alpha)I + W_L) + \pi U(Y - R_H(1-\alpha)I + W_H) \tag{12}$$

subject to

$$(1-\pi)\, R_L\,(1-\alpha)\, I + \pi R_H\,(1-\alpha)\, I - c\nu\,(1-\pi) - (1-\alpha)\, I = 0 \tag{13}$$

$$\frac{U\,(Y - R_L(1-\alpha)I + W_H) - U\,(Y - R_H(1-\alpha)I + W_H)}{U\,(Y - R_L(1-\alpha)I + W_H) - U\,(Y - R_H(1-\alpha)I + W_H) + k} - \nu = 0 \tag{14}$$

$$EU^* \geq 2U(Y) \tag{15}$$

The next proposition can now be stated.

Proposition 3 *If the financier can commit to an auditing strategy, then the optimal contract is such that the entrepreneur's final wealth is greater in the high return state.*

This result is the complete opposite of the one we obtained in the previous section of the paper. It is, however, in line with traditional results in the literature. It is interesting to note that by merely removing the commitment assumption, the shape of the optimal contract is reversed. In one case the entrepreneur is better off if the project has a high return, while in the other he is better off if the project has a low return. The reason why the shape of the contract is reversed is that under commitment, the financier does not need to embed provisions in the contract that will make her more inclined to audit; the commitment assumption does that. Since she does not need to make it sequentially rational to audit, the financier can then concentrate on reducing the incentive for the entrepreneur to misreport by reducing the possible gains from it. With commitment, the optimal contract is such that the entrepreneur's final wealth is more equal than without commitment, which makes the gains from cheating smaller.

One may wonder if there is a loss of well-being associated with the financier's inability to commit to an auditing strategy. It is clear from the revelation principle that the allocation under commitment is Pareto optimal. The question is whether the allocation under no commitment is

Pareto-equal to the allocation under commitment. The answer is no; there is a loss of welfare associated with the financier not being able to commit. This is stated formally as Proposition 4.

Proposition 4 *The allocation under no commitment is Pareto dominated.*

This proposition tells us that there would be a welfare gain from being able to commit. This finding is intuitive. Since without commitment the entrepreneur is indifferent to the choice of cheating or not cheating (the financier's auditing strategy is such that the entrepreneur is indeed indifferent), there is a loss of welfare associated with the fact that more auditing is conducted under no commitment than under commitment. This means that more resources are devoted to auditing when there is no commitment, even if the entrepreneur is indifferent about cheating or not cheating. There is a loss of welfare in this.

Given that the allocation under no commitment is Pareto-dominated by the allocation under full commitment, and given that the entrepreneur's final wealth is greater in the low (high) ROI state when the financier cannot (can) commit to an auditing strategy, how does this translate into the amount borrowed? Enter Proposition 5.

Proposition 5 *Outside financing is greater if the financier cannot commit to an auditing strategy than if she can commit.*

When the financier cannot commit *explicitly* to an auditing strategy, she needs to modify the optimal contract to imbed an *implicit* commitment to audit more often. This implicit commitment is achieved by sending a message such that it would be too costly for the financier not to audit. This signal is sent in two ways. First, the entrepreneur's final wealth is greater in the low return state than in the high return state. This means that the financier has more to lose by not auditing. It is clear from the entrepreneur's probability of cheating (η) that the greater the difference between his payoff in the high return state and his payoff in the low return state, the smaller his probability of announcing the false state of the world (i.e., $\frac{\partial \eta}{\partial (R_H - R_L)} < 0$). The second way the signal is sent is through the proportion of the project financed externally. By engaging more wealth into the project the financier has more to lose when the entrepreneur declares that the ROI is low. Again from the entrepreneur's probability of cheating (η), we see that as the amount internally financed increases (α increases), the probability of announcing the false state of the world decreases ($\frac{\partial \eta}{\partial \alpha} > 0$). Therefore, the entrepreneur will cheat less when α is smaller.

4 Discussion and Conclusion

The main results of the paper revolve around the counter-intuitive ways that a financier induces the entrepreneur to tell the truth with greater probability. When the financier cannot commit explicitly to an auditing strategy, he must instead use an implicit commitment. One way to do this is by increasing the amount that the financier has at risk by not auditing; she needs to signal that audits will be more frequent because she has more to lose by not auditing. In the model, the implicit signal is sent in two ways.

First, the financier increases the difference between the money owed to her by the entrepreneur in the high- and low-return states. We see that the amount of money the financier collects is greater if the return on investment is high. This explains why the entrepreneur is better off when his project has a low ROI. By being so much better off when the ROI is high, the financier is implicitly saying that she will make sure whenever the entrepreneur reveals a low ROI that he has told the truth. Compared with the case of a standard debt contract where $R_L = \frac{W_L}{I}$, and $R_H = R$ such that $1 = \pi R + (1-\pi)\frac{W_L}{I}$, our contract is much less equitable: $R_L < \frac{W_L}{I}$, and $R_H > R$. Although this contract seems less equitable than a standard debt contract, the entrepreneur ends up having a lower probability of cheating than if he were faced with a standard debt contract. This conclusion is straightforward from the equation that determines η, the entrepreneur's probability of reporting a false ROI. Taking the partial derivative with respect to R_L and R_H yields $\frac{\partial \eta}{\partial R_L} > 0$ and $\frac{\partial \eta}{\partial R_H} < 0$. Therefore, an increase in R_H and a reduction in R_L reduces the probability of the entrepreneur misreporting the true return on his risky project.

The second way that the financier sends an implicit signal about her willingness to audit is through the amount of money she invests. By over-financing the entrepreneur's project, the financier is implicitly saying that she has more to lose by not auditing. Therefore we should expect her to audit more often when she invests more money in the entrepreneur's project. Knowing that the financier will audit more often will induce the entrepreneur to cheat less often. This result is straightforward from η. Clearly, the smaller α is, the smaller the probability of committing fraud.

This contract may explain why banks and other lenders accept a certain amount of perquisites consumption by the managers of corporation. By letting the entrepreneur consume perquisites in the first stage, the financier signals that she has relatively more to lose by not auditing in the second stage, which induces the entrepreneur to misreport the state of the world with lower probability. The ex post moral hazard problem has a major drawback, however, since some projects which might be beneficial to society are not undertaken. We therefore have some under-investment in the economy as a whole, even if individual projects are over-financed.

It would be possible to view the model developed herein as a sovereign debt model. The only penalty that a lender can impose on a sovereign nation is a refusal to lend further money. The penalty is therefore not paid to anyone, it is just a reduction in the utility of the entrepreneur. The contract also gives a rationale for forgiving the debt of poorer countries as an implicit contract between the lending country (financier) and the borrowing country (entrepreneur). Since the financier cannot commit, the implicit contract between the financier and the entrepreneur is such that part of the debt is forgiven in case the return on the investment is low. When the return on the investment is high, however, the borrowing country ends up paying considerable amounts in interest payments, which corresponds to the high risk that country faces.

The goal of this paper was to derive the optimal contract between an entrepreneur who has private information about the realized return on a risky project and an uninformed financier. We concentrated on the problem of the entrepreneur's possibility of misreporting the return in order to extract a rent from the financier. There was only one possible project whose setup cost was fixed, which involved no effort on the part of the entrepreneur to make sure that the higher return was realized. In other words, we concentrated purely on an ex post moral hazard problem à la Townsend (1979) and Gale and Hellwig (1985). The originality of the paper lies in the fact that the assumption of the financier's commitment to an auditing strategy is relaxed. This means that the optimality of the debt contract must be reconsidered.

In summary, we find that the entrepreneur is better off in the low return-on-investment state than in the high return-on-investment state in the sense that his ex post wealth is greater. We also find that an entrepreneur who wants to invest in a risky project will finance more on the outside than he would have had the financier been able to commit to an auditing strategy. Outside Over-financing is a way for the financier to signal to the entrepreneur that she has more to lose, and thus that the entrepreneur should commit fraud less often. The converse is also true: since the entrepreneur has more to gain, the financier should audit more often. Increasing outside financing is therefore a way of solving part of the asymmetry problem by reducing one player's incentive to cheat and by increasing the other player's incentive to audit. The optimal contract is confined to a particular equilibrium of the problem posed by Gale and Hellwig (1989), which they call *separating*. Finally, we find a loss of welfare associated with the financier's inability to commit.

5 Appendix: Tables and Proofs

Table 1

Undiscounted monetary payoffs to the entrepreneur and the financier which are contingent on their actions and the state of the world.

State of the world	Action of Entrepreneur	Action of Financier	Payoff to Entrepreneur	Payoff to Financier
First stage	Invest I	Invest $(1-\alpha)I$	$U(Y-\alpha I)$	$-(1-\alpha)I$
Low ROI	Report W_L	Audit	$U(Y-R_L(1-\alpha)I+W_L)$	$R_L(1-\alpha)I-c$
Low ROI	Report W_L	Don't audit	$U(Y-R_L(1-\alpha)I+W_L)$	$R_L(1-\alpha)I$
Low ROI	*Report* W_H	*Audit*	$U(Y-R_L(1-\alpha)I+W_L)-k$	$R_L(1-\alpha)I-c$
Low ROI	*Report* W_H	*Don't audit*	$U(Y-R_H(1-\alpha)I+W_L)$	$R_H(1-\alpha)I$
High ROI	Report W_L	Audit	$U(Y-R_H(1-\alpha)I+W_H)-k$	$R_H(1-\alpha)I-c$
High ROI	Report W_L	Don't audit	$U(Y-R_L(1-\alpha)I+W_H)$	$R_L(1-\alpha)I$
High ROI	*Report* W_H	*Audit*	$U(Y-R_H(1-\alpha)I+W_H)$	$R_H(1-\alpha)I-c$
High ROI	Report W_H	Don't audit	$U(Y-R_H(1-\alpha)I+W_H)$	$R_H(1-\alpha)I$

The contingent states in italics never occur in equilibrium: they represent actions that are off the equilibrium path.

Proof of lemma 1. Looking at the right side of Figure 2, it is obvious that $\gamma_H = 1$. Suppose Nature chooses the return to be low (W_L). Reporting a low return (W'_L) always dominates reporting a high return (W'_H), whatever the financier does. When the financier hears message W'_H, she knows with certainty that it is truthful, which means that $\gamma_H = 1$. Thus the only meaningful strategy for the financier when a W'_H message is sent is to never audit. We have now found three of the six elements of the sextuplet.

Lets now move to the left side of figure 2. By Bayes' rule γ_L, the financier's posterior belief that the true return is low given that the entrepreneur sent message W'_L, is equal to

$$\gamma_L = \frac{1-\pi}{(1-\pi)+\pi\eta} \tag{16}$$

Only one strategy of the entrepreneur will induce the financier to be indifferent about auditing or not auditing a message. That strategy must be such that γ_L solves

$$(-c+R_H(1-\alpha)I)\gamma_L + (-c+R_L(1-\alpha)I)(1-\gamma_L) = R_H(1-\alpha)I \tag{17}$$

and

$$\gamma_L = \frac{(R_H-R_L)(1-\alpha)I-c}{(R_H-R_L)(1-\alpha)I} \tag{18}$$

Substituting (18) in (16) yields

$$\eta = \left(\frac{c}{(R_H - R_L)(1-\alpha)I - c}\right)\left(\frac{1-\pi}{\pi}\right) \tag{19}$$

All that is left to calculate is the auditing strategy of the financier when the agent reports W_L'. Her strategy must be such that the entrepreneur is indifferent about telling the truth or sending a false message, given that the return is high. ν, the probability of auditing a W_L' message, equals

$$\nu = \frac{U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right)}{U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right) + k} \tag{20}$$

Since all six elements of our PBNE have been found, the proof is done.•

Proof of lemma 2. The first-order conditions of this problem are

$$\begin{aligned}\frac{\partial EU}{\partial R_L} &= (1-\pi)U'\left(Y - R_L(1-\alpha)I + W_L\right)R_L\alpha_L I \\ &\quad -(1-\pi)U'\left(Y - R_L(1-\alpha)I + W_L\right)(1-\alpha)I \\ &\quad +\pi U'\left(Y - R_H(1-\alpha)I + W_H\right)R_H\alpha_L I - U'(Y-\alpha I)\alpha_L I\end{aligned} \tag{FOC$_L$}$$

$$\begin{aligned}\frac{\partial EU}{\partial R_H} &= \pi U'\left(Y - R_H(1-\alpha)I + W_H\right)R_H\alpha_H I \\ &\quad -\pi U'\left(Y - R_H(1-\alpha)I + W_H\right)(1-\alpha)I \\ &\quad +(1-\pi)U'\left(Y - R_L(1-\alpha)I + W_L\right)R_L\alpha_H I - U'(Y-\alpha I)\alpha_H I\end{aligned} \tag{FOC$_H$}$$

rearranging the terms yields the desired result.•

Proof of proposition 1. Taking the ratio of the necessary conditions yields

$$\frac{NC1}{NC2} = \frac{(1-\pi)U'\left(Y - R_L(1-\alpha)I + W_L\right)}{\pi U'\left(Y - R_H(1-\alpha)I + W_H\right)} = \frac{\frac{\alpha_L}{1-\alpha}}{\frac{\alpha_H}{1-\alpha}} \tag{21}$$

We want to show that the entrepreneur's wealth is greater in the low ROI state. If this is true, then the entrepreneur's marginal utility will be greater in the high ROI state

$$U'\left(Y - R_L(1-\alpha)I + W_L\right) < U'\left(Y - R_H(1-\alpha)I + W_H\right) \tag{22}$$

We know that

$$\frac{U'\left(Y - R_L(1-\alpha)I + W_L\right)}{U'\left(Y - R_H(1-\alpha)I + W_H\right)} = \left(\frac{\pi}{1-\pi}\right)\left(\frac{\alpha_L}{\alpha_H}\right) \tag{23}$$

Thus (22) holds if and only if $\pi\alpha_L < (1-\pi)\alpha_H$. Recall from (9) that

$$\alpha_H = (1-\alpha)\left(\frac{(1-\pi)\left(R_H - R_L\right)^2}{(1-R_H)(R_H-R_L)\left[1-(1-\pi)R_L - \pi R_H\right]}\right) - \alpha_L \tag{24}$$

We then arrive at $\pi\alpha_L < (1-\pi)\alpha_H$ if and only if

$$\pi\alpha_L < (1-\pi)\left[(1-\alpha)\left(\frac{(1-\pi)(R_H-R_L)^2}{(1-R_H)(R_H-R_L)[1-(1-\pi)R_L-\pi R_H]}\right)-\alpha_L\right] \tag{25}$$

and

$$\alpha_L < (1-\alpha)\left(\frac{(1-\pi)(R_H-R_L)^2}{(1-R_H)(R_H-R_L)[1-(1-\pi)R_L-\pi R_H]}\right) \tag{26}$$

Substituting for α_L given in (10) and simplifying, $\pi\alpha_L < (1-\pi)\alpha_H$ if and only if

$$\pi(1-\pi)(R_H-R_L)^2-(1-\pi)(1-R_L)^2-\pi(1-R_H)^2 < 0 \tag{27}$$

Expanding the squares yields

$$\pi(1-\pi)\left(R_H^2-2R_HR_L+R_L^2\right)-(1-\pi)\left(1-2R_L+R_L^2\right)-\pi\left(1-2R_H+R_H^2\right) < 0 \tag{28}$$

Combining terms

$$-\pi^2R_H^2-(1-\pi)^2R_L^2-1-2\pi(1-\pi)R_HR_L+2(1-\pi)R_L+2\pi R_H < 0 \tag{29}$$

Finally

$$-\left[1-\pi R_H-(1-\pi)R_L\right]^2 < 0 \tag{30}$$

which is obviously true.•

<u>Proof of proposition 2</u>. Let's rewrite NC_1 and NC_2 as

$$(1-\pi)U'(Y-R_L(1-\alpha)I+W_L) = \frac{\alpha_L}{1-\alpha}V' \tag{31}$$
$$\pi U'(Y-R_H(1-\alpha)I+W_H) = \frac{\alpha_H}{1-\alpha}V' \tag{32}$$

Expanding V' we have

$$(1-\pi)U'(Y-R_L(1-\alpha)I+W_L) = \frac{\alpha_L}{1-\alpha}\left[\begin{array}{c}(1-\pi)R_LU'(Y-R_L(1-\alpha)I+W_L)\\ +\pi R_HU'(Y-R_H(1-\alpha)I+W_H)\\ -U'(Y-\alpha I)\end{array}\right] \tag{33}$$

and

$$\pi U'(Y-R_H(1-\alpha)I+W_H) = \frac{\alpha_H}{1-\alpha}\left[\begin{array}{c}(1-\pi)R_LU'(Y-R_L(1-\alpha)I+W_L)\\ +\pi R_HU'(Y-R_H(1-\alpha)I+W_H)\\ -U'(Y-\alpha I)\end{array}\right] \tag{34}$$

Combining terms yields

$$(1-\pi)U'(Y-R_L(1-\alpha)I+W_L) = \left(\frac{\frac{\alpha_L}{1-\alpha}}{1-\frac{\alpha_L}{1-\alpha}R_L}\right)\left[\begin{array}{c}\pi R_HU'(Y-R_H(1-\alpha)I+W_H)\\ -U'(Y-\alpha I)\end{array}\right] \tag{35}$$

$$\pi U'\left(Y - R_H(1-\alpha)I + W_H\right) = \left(\frac{\frac{\alpha_H}{1-\alpha}}{1 - \frac{\alpha_H}{1-\alpha}R_H}\right)\left[\begin{array}{c} (1-\pi)R_L U'\left(Y - R_L(1-\alpha)I + W_L\right) \\ -U'(Y-\alpha I) \end{array}\right] \tag{36}$$

We can rearrange these equations as

$$\frac{U'\left(Y - R_L(1-\alpha)I + W_L\right)}{U'(Y-\alpha I)} = -\left(\frac{1}{1-\pi}\right)\frac{\frac{\alpha_L}{1-\alpha}}{1 - \frac{\alpha_H}{1-\alpha}R_H - \frac{\alpha_L}{1-\alpha}R_L} \tag{37}$$

$$\frac{U'\left(Y - R_H(1-\alpha)I + W_H\right)}{U'(Y-\alpha I)} = -\left(\frac{1}{\pi}\right)\frac{\frac{\alpha_H}{1-\alpha}}{1 - \frac{\alpha_H}{1-\alpha}R_H - \frac{\alpha_L}{1-\alpha}R_L} \tag{38}$$

Using (10) and (9), and the fact that

$$1 - \frac{\alpha_H}{1-\alpha}R_H - \frac{\alpha_L}{1-\alpha}R_L = \frac{(1-\pi)(R_H - R_L)}{(1-\pi R_H - (1-\pi)R_L)(1-R_H)} < 0 \tag{39}$$

(37) and (38) can be rewritten as

$$\frac{U'\left(Y - R_L(1-\alpha)I + W_L\right)}{U'(Y-\alpha I)} = \frac{(1-\pi)(R_H - R_L)^2 - \pi(1-R_H)^2 - (1-\pi)(1-R_L)^2}{(1-\pi)^2(R_H-R_L)^2} \tag{40}$$

and

$$\frac{U'\left(Y - R_H(1-\alpha)I + W_H\right)}{U'(Y-\alpha I)} = \frac{\pi(1-R_H)^2 + (1-\pi)(1-R_L)^2}{\pi(1-\pi)(R_H-R_L)^2} \tag{41}$$

Only (41) is needed for the remainder of the proof. It is easily shown that

$$\frac{\pi(1-R_H)^2 + (1-\pi)(1-R_L)^2}{\pi(1-\pi)(R_H-R_L)^2} > 1 \tag{42}$$

It follows that

$$\frac{U'\left(Y - R_H(1-\alpha)I + W_H\right)}{U'(Y-\alpha I)} > 1 \tag{43}$$

Therefore the entrepreneur's wealth in the high ROI state must be smaller than his first-stage wealth. Therefore the entrepreneur's proportion of the project must be smaller than

$$\alpha < \frac{R_H I - W_H}{(1+R_H)I} \tag{44}$$

On the other hand, the limited liability constraint in the high ROI state stipulates that $(1-\alpha)R_H I \leq W_H$, which can also be written as

$$\alpha > \frac{R_H I - W_H}{R_H I} \tag{45}$$

Combining (44) and (45), the limited liability constraint and the necessary condition hold when

$$\frac{R_H I - W_H}{(1+R_H)I} > \alpha > \frac{R_H I - W_H}{R_H I} \tag{46}$$

It is a straightforward observation that (46) holds only if $R_H I - W_H < 0$. Since $(1+R_H)I > 0$, α must be negative.•

Proof of corollary 1. From the limited liability constraint in the low ROI state, we see that $W_L \geq R_L(1-\alpha)I$. If we suppose that $W_L < I$, then either $R_L < 1$, or $\alpha > 0$. But from proposition 2 we know that $\alpha < 0$. Thus it has to be that if $W_L < I$, then $R_L < 1$.•

Proof of corollary 2. From (6) we know that

$$1 - \pi R_H - (1-\pi)R_L = -\pi \left(\frac{c}{(R_H - R_L)(1-\alpha) I - c} \right) \left(\frac{1-\pi}{\pi} \right) (R_H - R_L) \tag{47}$$

Multiplying both sides by $I = \pi W_H + (1-\pi)W_L - \varepsilon > 0$, and using (1) yield

$$[1 - \pi R_H - (1-\pi)R_L] [\pi W_H + (1-\pi)W_L - \varepsilon] = -\pi\eta(R_H - R_L) [\pi W_H + (1-\pi)W_L - \varepsilon] \tag{48}$$

This can be rewritten as

$$[1 - \pi R_H - (1-\pi)R_L] [\pi W_H + (1-\pi)W_L - \varepsilon] = -\pi\eta(R_H - R_L)I \tag{49}$$

$$\pi W_H + (1-\pi)W_L - \varepsilon - [\pi R_H - (1-\pi)R_L] [\pi W_H + (1-\pi)W_L - \varepsilon] = -\pi\eta(R_H - R_L)I \tag{50}$$

Obviously the right hand side of this equation is negative, which means that

$$\varepsilon > \pi W_H + (1-\pi)W_L - [\pi R_H - (1-\pi)R_L] I \tag{51}$$

and

$$\varepsilon > \pi[W_H - R_H I] + (1-\pi)[W_L - R_L I] \tag{52}$$

As ε approaches zero, we find that

$$0 > \pi[W_H - R_H I] + (1-\pi)[W_L - R_L I] \tag{53}$$

which is not possible since the limited liability constraints mandate us to have

$$W_H - R_H I \;\; > \;\; 0 \tag{54}$$

$$W_L - R_L I \;\; > \;\; 0 \tag{55}$$

Therefore a number of projects that have a positive net present value will not be undertaken.•

Proof of proposition 3. Concentrating on an interior solution, the six first-order conditions of the problem with commitment are

$$\begin{aligned} \frac{\partial V}{\partial R_L} &= 0 = -(1-\pi) U'(Y - R_L(1-\alpha)I + W_L)(1-\alpha) I + \lambda_1 (1-\pi)(1-\alpha) I \\ &\quad -\lambda_2 \frac{(1-\alpha) I U'(Y - R_L(1-\alpha)I + W_H) k}{[U(Y - R_L(1-\alpha)I + W_H) - U(Y - R_H(1-\alpha)I + W_H) - k]^2} \end{aligned} \tag{56}$$

$$\frac{\partial V}{\partial R_H} = 0 = -\pi U'\left(Y - R_H(1-\alpha)I + W_H\right)(1-\alpha)I + \lambda_1 \pi (1-\alpha) I \tag{57}$$
$$+\lambda_2 \frac{(1-\alpha) I U'\left(Y - R_H(1-\alpha)I + W_H\right) k}{\left[U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right) + k\right]^2}$$

$$\frac{\partial V}{\partial \nu} = 0 = -\lambda_1 (1-\pi) c - \lambda_2 \tag{58}$$

$$\frac{\partial V}{\partial \alpha} = 0 = -U'(Y - \alpha I)I + \pi U'\left(Y - R_H(1-\alpha)I + W_H\right) R_H I \tag{59}$$
$$+ (1-\pi) U'\left(Y - R_L(1-\alpha)I + W_L\right) R_L I + \lambda_1 \left[1 - \pi R_H - (1-\pi) R_L\right] I$$
$$+\lambda_2 I k \frac{R_L U'\left(Y - R_L(1-\alpha)I + W_H\right) - R_H U'\left(Y - R_H(1-\alpha)I + W_H\right)}{\left[U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right) + k\right]^2}$$

$$\frac{\partial V}{\partial \lambda_1} = 0 = (1-\pi) R_L (1-\alpha) I + \pi R_H (1-\alpha) I - (1-\alpha) I - c\nu (1-\pi) \tag{60}$$

$$\frac{\partial V}{\partial \lambda_2} = 0 = -\left[\nu - \frac{U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right)}{U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right) + k}\right] \tag{61}$$

From $\frac{\partial V}{\partial R_L} = 0$ and $\frac{\partial V}{\partial R_H} = 0$ we obtain

$$\frac{\lambda_2 k}{\Omega} = -\frac{(1-\pi) U'\left(Y - R_L(1-\alpha)I + W_L\right) - \lambda_1 (1-\pi)}{U'\left(Y - R_L(1-\alpha)I + W_H\right)} \tag{62}$$

$$\frac{\lambda_2 k}{\Omega} = \frac{\pi U'\left(Y - R_H(1-\alpha)I + W_H\right) - \lambda_1 \pi}{U'\left(Y - R_H(1-\alpha)I + W_H\right)} \tag{63}$$

where

$$\Omega = \left[U\left(Y - R_L(1-\alpha)I + W_H\right) - U\left(Y - R_H(1-\alpha)I + W_H\right) + k\right]^2 > 0 \tag{64}$$

This gives us an expression for λ_1 and λ_2

$$\lambda_1 = U'\left(Y - R_H(1-\alpha)I + W_H\right) \frac{\begin{array}{c}\pi U'\left(Y - R_L(1-\alpha)I + W_H\right) \\ + (1-\pi) U'\left(Y - R_L(1-\alpha)I + W_L\right)\end{array}}{\begin{array}{c}\pi U'\left(Y - R_L(1-\alpha)I + W_H\right) \\ + (1-\pi) U'\left(Y - R_H(1-\alpha)I + W_H\right)\end{array}} \tag{65}$$

and

$$\lambda_2 = \pi (1-\pi) \frac{1}{k} \Omega \frac{U'\left(Y - R_H(1-\alpha)I + W_H\right) - U'\left(Y - R_L(1-\alpha)I + W_L\right)}{\pi U'\left(Y - R_L(1-\alpha)I + W_H\right) + (1-\pi) U'\left(Y - R_H(1-\alpha)I + W_H\right)} \tag{66}$$

From $\frac{\partial V}{\partial \nu} = 0$, we know that $\lambda_2 = -(1-\pi) c \lambda_1$. Thus

$$U'\left(Y - R_H(1-\alpha)I + W_H\right) = -\pi \frac{1}{ck} \Omega \frac{\begin{array}{c}U'\left(Y - R_H(1-\alpha)I + W_H\right) \\ -U'\left(Y - R_L(1-\alpha)I + W_L\right)\end{array}}{\begin{array}{c}\pi U'\left(Y - R_L(1-\alpha)I + W_H\right) \\ + (1-\pi) U'\left(Y - R_L(1-\alpha)I + W_L\right)\end{array}} \tag{67}$$

Since $U'(.) > 0$, this equation holds if and only if

$$U'(Y - R_H(1-\alpha)I + W_H) < U'(Y - R_L(1-\alpha)I + W_L) \tag{68}$$

which means that the agent's final wealth is greater in the high ROI state.•

Proof of proposition 4. It is interesting to note that the maximizing function is the same under commitment as under no commitment. Using the envelope theorem it is then sufficient to show that the zero-profit constraint is more binding in the no-commitment case than in the commitment case. The way we shall proceed is to show for any equilibrium value of the repayment, (R_L, R_H), that the proportion invested in the commitment case is greater. Let the variables used for the commitment case be denoted by $\widehat{}$, and for the no-commitment case by $\widetilde{}$. We want to show for any (R_L, R_H), that $\widehat{\alpha} > \widetilde{\alpha}$. We know that

$$\widehat{\alpha} = 1 + \frac{(1-\pi)\,\widehat{\nu}\frac{c}{I}}{1 - \pi\widehat{R_H} - (1-\pi)\,\widehat{R_L}} \tag{69}$$

and

$$\widetilde{\alpha} = 1 - \left(\frac{1 - \widetilde{R_H}}{1 - \pi\widetilde{R_H} - (1-\pi)\,\widetilde{R_L}}\right)\left(\frac{\frac{c}{I}}{\widetilde{R_H} - \widetilde{R_L}}\right) \tag{70}$$

We then get that $\widehat{\alpha} > \widetilde{\alpha}$ if and only if

$$\widehat{\nu} < -\left(\frac{1}{1-\pi}\right)\left(\frac{1-\widetilde{R_H}}{\widetilde{R_H} - \widetilde{R_L}}\right)\left(\frac{1 - \pi\widehat{R_H} - (1-\pi)\,\widehat{R_L}}{1 - \pi\widetilde{R_H} - (1-\pi)\,\widetilde{R_L}}\right) \tag{71}$$

Evaluating $\left(\widetilde{R_L}, \widetilde{R_H}\right)$ and $\left(\widehat{R_L}, \widehat{R_H}\right)$at some (R_L, R_H), we get

$$\widehat{\nu} < -\left(\frac{1}{1-\pi}\right)\left(\frac{1-R_H}{R_H - R_L}\right) \tag{72}$$

which is always true since $\left(\frac{-1}{1-\pi}\right)\left(\frac{1-R_H}{R_H-R_L}\right) > 1$. Therefore for any (R_L, R_H), $\widehat{\alpha} > \widetilde{\alpha}$. And since the maximizing function is the same, it has to be that the entrepreneur is better off under commitment.•

Proof of proposition 5. What we want to show here is that in equilibrium, $\widehat{\alpha^*} \geq \widetilde{\alpha^*}$. The way we shall proceed is to show that this inequality holds at the extremities of the distribution of a parameter. Using (71) and substituting for the value of $\widehat{\nu}$ obtained by solving $\frac{\partial V}{\partial \lambda_2} = 0$ yields

$$\widehat{\nu} = \frac{\begin{bmatrix} U\left(Y - \widehat{R_L}(1-\widehat{\alpha})I + W_H\right) \\ -U\left(Y - \widehat{R_H}(1-\widehat{\alpha})I + W_H\right) \end{bmatrix}}{\begin{bmatrix} U\left(Y - \widehat{R_L}(1-\widehat{\alpha})I + W_H\right) \\ -U\left(Y - \widehat{R_H}(1-\widehat{\alpha})I + W_H\right) + \widehat{k} \end{bmatrix}} < -\left(\frac{1}{1-\pi}\right)\frac{\left(\frac{1-\widetilde{R_H}}{\widetilde{R_H}-\widetilde{R_L}}\right)}{\left(\frac{1-\pi\widetilde{R_H}-(1-\pi)\widetilde{R_L}}{1-\pi\widehat{R_H}-(1-\pi)\widehat{R_L}}\right)} \tag{73}$$

Bear in mind that the non-negative penalty is given by

$$k = \left(\frac{\delta}{1-\delta}\right)\left(\overline{V} - \underline{V}\right) \tag{74}$$

As $k \to \infty$ (which happens when $\delta \to 1$), $\widehat{\nu} \to 0$. It is clear that (73) always holds since the right hand side is always positive. As $\delta \to 0$, $k \to 0$, which means that $\widehat{\nu} \to 1$. In that case the optimal contract is the same with commitment as without commitment; that is $\left(\widetilde{R_L^*}, \widetilde{R_H^*}\right) = \left(\widehat{R_L^*}, \widehat{R_H^*}\right)$. Thus (73) holds since $\left(\frac{-1}{1-\pi}\right)\left(\frac{1-\widetilde{R_H}}{\widetilde{R_H}-\widetilde{R_L}}\right) > 1$. The last step is to show that

$$-\left(\frac{1}{1-\pi}\right)\left(\frac{1-\widetilde{R_H}}{\widetilde{R_H}-\widetilde{R_L}}\right)\left(\frac{1-\pi\widehat{R_H}-(1-\pi)\widehat{R_L}}{1-\pi\widetilde{R_H}-(1-\pi)\widetilde{R_L}}\right) \tag{75}$$

is continuous and monotonous in k. We know from the necessary conditions for an optimum when there is no commitment that the penalty does not affect the shape of the optimal contract; that is $\left(\widetilde{R_L^*}, \widetilde{R_H^*}\right)$ is independent of k. This means that we can concentrate on deriving the effect of k solely on $1-\pi\widehat{R_H}-(1-\pi)\widehat{R_L}$. It is clear that this is continuous and monotone decreasing in k (the greater the penalty, the closer to the first-best allocation we are going to get). As k increases, $\widehat{R_H}$ increases and $\widehat{R_L}$ decreases, so that eventually, as $k \to \infty$, $\widehat{R_H}$ and $\widehat{R_L}$ are chosen such that

$$U\left(Y - R_L(1-\alpha)I + W_L\right) = U\left(Y - R_H(1-\alpha)I + W_H\right) = U\left(Y - \alpha I\right) \tag{76}$$

which means that the first best is achieved and that the marginal utilities in every state and every stage of the game are equalized.•

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