A Theory of Outside Equity: Financing Multiple Projects*

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Abstract

In the financial economics literature debt contracts provide optimal solutions for addressing managerial moral hazard problems. We analyze a model with multiple projects where the manager obtains private information about their quality after the contract with investors is agreed. The likelihood of success of each project depends on both its quality and the level of effort exerted on it by the manager. We find distributions of the quality shock such that the optimal financial contract requires the investor to hold an equity claim. Our model addresses issues that are relevant for financial intermediation and corporate governance.

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1. Introduction

In the financial contracting literature debt contracts provide optimal solutions for addressing managerial moral hazard problems. For example, Innes (1990) demonstrates that when outside investors are unable to observe the manager's effort and the manager is protected by limited liability the optimal contract requires that the manager is only compensated when the output of the project is above a certain threshold value, which implies that external investors hold a debt claim. Laux (2001) extends Innes (1990) to the case of multiple projects and shows that as long as the returns across projects are not perfectly correlated, the optimal scheme compensates the manager only when all projects succeed, which once more implies that external investors hold a debt claim. Indeed, in both models, when the payoffs of investors are also restricted to be monotonic in the project's output the optimal financial claim is the standard debt contract. In this paper, we extend Laux (2001) and allow the manager, as an insider, to have better information about the projects under her management than outside investors. In particular, we introduce an interim quality shock that is realized after the financial contract is signed and observed only by the manager. We find that under certain distributions of the quality shock the optimal financial contract requires the investors to hold an equity claim.[1]

In our model, as in Laux (2001), a manager is managing two projects. After the investment in the two projects is sunk, each project is hit by a binary quality shock. A negative shock means that the manager's effort cannot affect the probability of success and we have a type l project. In contrast, a positive shock means that the project's probability of success can be increased by the manager's effort and we have a type h project. The realization of the quality shock is observed only by the manager. Thus, the contract that the investors offer to the manager can be conditioned only on the outcomes of the two projects. Moreover, we show that no mechanism that tries to elicit the manager's private

[1] Notice that in our model at the time when the contract is signed both parties are equally informed. This is in contrast to the hidden information literature where nature chooses the type of the agent prior to the signing of the contract. In that literature it is well konwn that debt, because of its low-information-intensity, is the optimal financial contract (see, for example, Myers and Majluf, 1984).

information about the quality shock can improve on the results. When the probability that a project is type h is equal to one, our model is reduced to Laux (2001). Indeed, we show that when that probability is close enough to one, the optimal scheme compensates the manager only when both projects succeed, which leaves the investors holding a debt claim, as in Laux (2001). Intuitively, as Laux (2001) and Tirole (2006) have argued, such 'cross-pledging' reduces incentive costs by punishing the manager when only one project succeeds.[2]

Our innovation lies on the observation that this cross-pledging scheme can ruin the manager's incentives when one project is type h and the other is type l. To see this, consider the case in which the probability of success of a type l project is very close to zero. Under the cross-pledging scheme, even if the manager exerts effort on the type h project, the probability that both projects succeed and therefore she is compensated, is still very small. Thus, she has no incentives to exert effort on the type h project. In this case, to provide the manager with incentives to exert effort on the type h project, she should also receive a payoff when only one project succeeds. However, this payoff should not be too large, otherwise, it would ruin her incentives to exert effort on the two projects when both are type h. Thus, we find that when the probability of success of a type l project is sufficiently low and the objective of the investor is to offer incentives to the manager to always exert effort on a type h project, the optimal scheme offers the manager a compensation that it is linear in the project's return, which requires outside investors to hold an equity claim.

Ex ante, providing maximal incentives to the manager is not always optimal. More specifically, we find that when the probability that a project is type h is either too high or too low (in which case the probability that one project is type h and the other is type l is very low) cross-pledging dominates outside equity. The intuition here is that it is too

[2] There are some other papers that have identified benefits from cross-pledging in non-finance applications. Smitz (2013) considers the benefits of bunling projects together rather than having them managed separately and shows that when the pricipal is financially constrained the bundling, and its associated cross-pledging benefits, might be too costly. Kräkel and Schöttner (2016) consider sequential projects and associated contracts and show the benefits of conditioning later contracts on early project outcomes.

costly to provide incentives to the manager for states of nature that are highly unlikely. In such cases it is better to offer a cross-pledging contract that provides the manager with incentives to exert effort only when both projects are type h.

Relative to debt which implements cross-pledging, outside equity maintains the manager's incentives to exert effort when one of the projects is type l and cannot benefit from managerial effort. Thus, our paper re-confirms the commonly held view that issuing outside equity enhances the firm's resilience to negative shocks on its assets, but our innovation is that the benefit of such enhancement is related neither to bankruptcy (e.g. Allen, 1981) nor to financial stress (e.g. Myers, 1977), but to agency costs.

Our model sheds light on certain observations related to financial intermediation. Existing studies such as Diamond (1984) and Tirole (2006) demonstrate that to obtain the benefit of diversification or 'cross-pledging' from financing multiple projects, on the liability side of their balance sheets intermediaries should issue low-risk debt claims. In our model the intermediary provides a valuable service that enhances the probability of success of a certain type of project. Under the reasonable supposition that a single monitor can only be involved with a small number of projects the intermediary will need to employ multiple monitors. This gives rise to an *internal control problem* which is exacerbated as the number of projects increases. We obtain the following two results. Under the assumption that the internal control problem is not serious, sufficient diversification offers banks dominating advantages over equity funds. Specifically, we will show that if the monitor alone can monitor all projects, then under the bank contractual arrangement the monitor's per-project rent tends to vanish. The logic is similar to that in Diamond (1984), although the friction is different. Then, we show that the balance between the two types of financial intermediaries is restored when we take into account the internal control problem.Thus, our model offers one possible explanation for the observation that some types of financial intermediaries, such as commercial banks, are mainly funded by issuing debt contracts (e.g. deposits) while others, such as private equity funds,[3] are mainly funded by

[3] The volume of capital managed by private equity funds has risen from \$5 billion in 1980 to \$100 billion

offering investors – i.e. limited partners – equity claims (see Metrick and Yasuda, 2010). Our model, recognizes the endogeneity of these contractual arrangements, and offers the following predictions about the operations of these two classes of financial intermediaries. Relative to commercial banks, private equity funds are more likely to finance projects with (a) relatively high return and low cost to monitoring, and (b) high-risk and high-return payoffs. Gompers (1995) and Sahlman (1990) provide evidence from the venture capital market that supports the above predictions.[4]

Our paper is organized as follows. In the remaining of this section we review the related literature. In section 2, we present the model and derive the main result of the paper under the supposition that the contract agreed between the entrepreneur and the investor can be only conditioned on the outcomes of the two projects. In section 3, we discuss the relevance of our model for financial intermediation. In the last section we offer some final comments. All proofs are included in Appendix A. In Appendix B we apply the revelation principle and show that the mechanism derived in the main paper cannot be improved by eliciting the entrepreneur's private information.

Related Literature In their classic paper, Jensen and Meckling (1976) argue that firms choose their capital structure in order to minimize agency costs related with outside equity and debt. According to the agency theory of capital structure, firms issue equity because high debt levels induce excessive risk taking. In our model agency costs associated with debt are absent. Nevertheless, we show that there are cases where outside equity provides better incentives to managers.

Outside equity is part of the optimal design of capital structure when contracts are incomplete because of uncertainty about future actions. In Dewatripont and Tirole (1994)

in 1994 to about \$1 trillion in 2012. The first couple of figures were taken from Fenn, Liang and Prowse (1995) while the last figure is reported in Metrick and Yasuda (2012). To put these figures in perspective, the total loans and leases granted to businesses and households by U.S. commercial banks form 1/10/2012 till 30/9/2012 according to FDIC was approximately \$7 trillion.

[4]The coexistence of different types of financial intermediaries is also addressed by Ueda (2004) and Winton and Yerramilli (2008). In both of these papers potential lenders differ in their ability either to monitor or evaluate projects while our results do not rely on such heterogeneity.

outside equity holders are allocated control rights in those states where the firm performs well while the holders of debt take control in those states where the firm underperforms. In Berkovitch and Israel (1996) and Fluck (1998) managerial efficiency is achieved by a mix of outside equity and debt and by the contingent allocation of the right to replace the manager. In our model contracting is complete and thus the allocation of decision rights is not an issue.

A mix of debt and equity can be optimal when enforcement of contracts is imperfect. In Allen (1981) the borrower can strategically default thus avoiding meeting her debt obligations with the lender. An equity contract supported by collateral avoids fixed obligations which in low states absorb most of the project's payoff thus offering incentives to the borrower to default. A similar structure of contracts is optimal in Ellingsen and Kristiansen (2011) where borrowers can divert capital away form the projects that was intended to finance. In contrast, in our model contracts are perfectly enforceable.

Outside equity also plays a role as a residual claim when there is an optimal limit to debt financing. For example, when managers have a choice over the size of projects the optimal capital structure balances the trade-off between underinvestment caused by debt overhang (Myers, 1977) and overinvestment caused by excess cash flow (Jensen, 1986). Moreover, according to the trade-off theory (e.g., Abel, 2018) bankruptcy costs set a limit to the level of debt that is issued because of the preferential tax treatment of interest payments relative to dividends.

The optimality of linear contracts has also been considered by Holmström and Milgrom (1987) and Carroll (2015). In Holmström and Milgrom (1987) the manager can observe interim payoff (past performance), which limits how the principal can use this payoff in the compensation contract if the principal wants to induce continuous high effort (which in our case is akin to inducing high effort on all projects). In the present paper, we investigate the optimality of linear contracts when we explicitly allow the investor to choose on whether or not to induce high effort whenever a project is type h. Carroll (2015) demonstrates the optimality of linear contracts when the principal is uncertain about the actions available to the agent whereas this uncertainty is absent in our model. Furthermore, our paper features a switch between linear contracts (i.e. equity contracts) and concave-shaped contracts (i.e. debt contracts) as the parameter values change, a switch that is not present in those papers.

In our paper, while cross pledging entails the two projects are combined, the linear contract can be implemented by financing the two projects in separation if their outcomes can be individually observed. Linear contracts provide the agent separate incentives for each project. This is valuable precisely when the agent has valuable information about the difference in quality of the two projects. A similar mechanism is present in the information destruction effect of pooling in DeMarzo (2005).

Lastly, our results are also relevant for managerial compensation in multitask settings. The literature on managerial compensation is vast and has recognized a variety of reasons that high-powered incentives might distort the decisions of managers (for related surveys, see Frydman and Jenter (2010) and Edmans and Gabaix (2016)). For example, Bénabou and Tirole (2016) show that reliance on high-powered incentives shifts effort away from tasks that are less easily contractible such as, for example, risk management. Therefore, in their work high-power incentives encourage the undertaking of too many risks. In the financial sector high-powered incentives offered to managers can lead to excess risk-taking (Bolton *et al.,* 2015) and short-termist behavior (Bolton *et al.,* 2006). In our paper, we propose a different channel through which high-powered incentives can lead to inefficient decisions. We show that 'cross-pledging' contracts can discourage managers from exerting effort on highly productive projects.

2. The Model

We consider a three-date model, $t = 0$, 1 and 2. At date 0 an entrepreneur[5] seeks funding from a deep pocket investor to finance two projects. Each project can either succeed or fail. At date 2, if a project succeeds it will return R, while if it fails it will return $R_0 < R$.

[5]Sometimes we refer to the 'entrepreneur' as the 'manager' of the two projects.

The probability of success of a project depends on (a) a binary shock realized at date 1, and (b) the entrepreneur's level of effort. At date 0, it is common knowledge that the shock is identically and independently distributed across the two projects. With probability θ a project is type h, while with probability $1-\theta$ is type l. After observing the type of each project, the entrepreneur chooses on how many projects to exert effort. Exerting effort does not affect the probability of success of a type l project which is equal to q. In contrast, for a type h project, exerting effort increases its probability of success from q to p.[6] Exerting effort on a project incurs to the entrepreneur a cost c. The investor cannot observe neither the realized project types nor the effort level exerted by the entrepreneur. Both agents are risk neutral and protected by limited liability. Observe that the social value of exerting effort on a type h project is $(p-q)(R-R_0)-c$. We assume that this social value is positive, that is,

$$R - R_0 > c_\Delta, \tag{2.1}$$

where $c_\Delta \equiv c/(p-q)$, otherwise, there is no reason for the investors to provide incentives to the entrepreneur to exert effort. Notice that in the one project case c_Δ is equal to the minimum reward that should be offered to the etrepreneur in the case of success in order to offer her incentives to exert effort on a type h project. The corresponding expected wage is equal to pc_Δ.[7]

We assume the investor has all the bargaining power in the contractual relationship with the entrepreneur. Hence, the optimal contract is to maximize the pledgeable income to the investor. An alternative interpretation of our model is that the investor is the principal and hires the a manager to run the two projects. As is typical in the principal-agent literature, the optimal contract is to maximize the payoff of the principal, namely, the investor. Due to this alternative interpretation of our model, we simply refer to the

[6] We only assume that the probability of success of a type l project is equal to the probability of success of a type h project when the manager does not exert any effort to keep the exposition of the model simple. These two probabilities can be different as long as both of them are sufficiently lower than the probability of success of a type h project when the manager does exert effort.

[7] To induce the manager to exert effort, the *ex post* payoff, ω, must satisfy $p\omega - c \geq q\omega$, that is $\omega \geq c_\Delta$.

agent as the manager.

In order to simplify the exposition of the results, in this main text, we assume that the contract agreed between the manager and the investor is only conditioned on the outcomes of the two projects. In Appendix B, we apply the revelation principle and show that the mechanism cannot be improved by eliciting the manager's private information. Moreover, without any loss of generality, we treat the two projects symmetrically. Therefore, the projects' outcomes can be represented by the number of successful projects $i \in \{0, 1, 2\}$ and a contract can be represented by the payoff to the investor in each of these three states, $\{r_i\}_{i=0,1,2}$, or the compensation to the manager, $\{w_i\}_{i=0,1,2}$. Let V_i denote the total payoffs of the two projects in state i. Then, $V_i = iR + (2-i) R_0$ and $w_i + r_i = V_i$. Limited liability implies that for any $i \in \{0, 1, 2\}$

$$0 \leq w_i \leq V_i. \tag{2.2}$$

Obviously, the manager should receive no reward if both projects fail, that is, $w_0 = 0$.

When designing the compensation scheme the investor has to consider whether it is optimal to offer incentives to the manager to exert effort (a) only when both projects are type h, or (b) whenever a project is type h regardless the other project's type. The investor maximizes her return by comparing the payoffs from the two cases. Let $m(k, n)$ denote the net expected payoff to the manager when n projects are type h and she exerts effort on $k \leq n$ projects. Then,

$$\begin{aligned}
m(2,2) &= p^2 w_2 + 2p(1-p)w_1 + (1-p)^2 w_0 - 2c; \\
m(1,2) &= pqw_2 + (p(1-q) + q(1-p)) w_1 + (1-p)(1-q) w_0 - c; \\
m(0,2) &= q^2 w_2 + 2q(1-q)w_1 + (1-q)^2 w_0; \\
m(1,1) &= m(1,2); \\
m(0,1) &= m(0,2).
\end{aligned}$$

For example $m(1,2)$ is equal to the manager's net payoff when both projects are type h and the manager chooses to exert effort on only one of them, which thus succeeds with probability p, while the other succeeds with probability q. Then, the probability that both projects succeed is equal to pq in which case the manager's compensation is equal to w_2. With probability $p(1-q)$ the project on which the manager has exerted effort succeeds while the other project fails and with probability $q(1-p)$ the project on which the manager has not exerted effort succeeds while the other project fails. In each of these two cases the manager's compensation is equal to w_1. Lastly, with probability $(1-p)(1-q)$ neither project succeeds and the manager obtains wage w_0.

2.1. Case 1: The manager is offered incentives to exert effort only when both projects are type h

In this case the following incentive compatibility constraints must be satisfied:

$$m(2,2) \geqslant m(1,2) \tag{2.3}$$

$$m(2,2) \geqslant m(0,2) \tag{2.4}$$

$$m(0,1) \geqslant m(1,1) \tag{2.5}$$

The incentive compatibility constraint (2.3) requires that when both projects are type h the manager prefers to exert effort on both of them rather than on only one of them. Constraint (2.4) requires that when both projects are type h the manager prefers to exert effort on both of them rather than on none of them. Lastly, constraint (2.5) requires that when only one project is type h the manager prefers not to exert effort on it.

With probability θ^2, both projects are type h, the manager exerts effort on both projects and each project succeeds with probability p. In all the other states of nature a project is either type l or type h but the manager exerts no effort on it, and hence, it succeeds with probability q. Therefore, ex ante, both projects succeed with probability $\theta^2 p^2 + \left(1-\theta^2\right) q^2$, and only one project succeeds with probability $\theta^2 2p(1-p) + \left(1-\theta^2\right) 2q(1-q)$, and with the complementary probability neither project succeeds. Therefore, the investor solves:

$$\min_{\{w_1,w_2\}} \left[\theta^2 p^2 + \left(1-\theta^2\right) q^2\right] w_2 + 2\left[\theta^2 p(1-p) + \left(1-\theta^2\right) q(1-q)\right] w_1, \tag{2.6}$$

subject to (2.2), (2.3), (2.4), (2.5).

The following proposition describes the optimal contract:

Proposition 1 *Suppose that the investor would like the manager to exert effort only when both projects are type h. Then the manager's compensation scheme is given by:*

$$(w_0, w_1, w_2) = \left(0, 0, \frac{2}{p+q} c_\Delta\right).$$

The return to the investor is equal to

$$(r_0, r_1, r_2) = \left(2R_0, R + R_0, 2R - \frac{2}{p+q} c_\Delta\right).$$

In the optimal contract, the investor's payoff is concave in the firm's revenue V. In this sense, she holds a debt claim. Here, as in Laux (2001), the optimal contract is driven by cross-pledging; that is, the manager does not receive any compensation unless both projects succeed. In fact, the model of Laux (2001) is obtained by setting $\theta = 1$. Thus, the optimal scheme provides maximal incentives to the manager to exert effort on both projects when both are type h while discourages the exertion of effort when only one is type h.

2.2. Case 2: The manager is offered incentives to exert effort on every type h project

In this case the following incentive compatibility constraint substitutes for (2.5):

$$m(1,1) \geqslant m(0,1). \tag{2.7}$$

Constraint (2.7) requires that when only one project is type h the manager prefers to exert effort on it.

With probability θ a project is type h and the manager exerts effort on it and thus the project succeeds with probability p. Therefore, in this case, the *ex ante* probability that a project succeeds is give by $p_s \equiv \theta p + (1-\theta) q$. Hence, the investor's expected payoff is equal to:

$$p_s^2 (2R - w_2) + 2p_s (1-p_s)(R + R_0 - w_1) + (1-p_s)^2 (2R_0 - w_0). \qquad (2.8)$$

Maximization of the investor's return equivalent to the following minimization problem:

$$\min_{\{w_1, w_2\}} p_s^2 w_2 + 2p_s (1-p_s) w_1 + (1-p_s)^2 w_0,$$

subject to (2.2), (2.3), (2.4) and (2.7).[8]

Proposition 2 *Suppose that the investor would like the manager to exert effort on every type h project and let $\theta < 1$. Then the optimal scheme is given by:*

i) If $q < (p-q)\theta$, then for $i \in \{0,1,2\}$, $w_i = ic_\Delta = \frac{c_\Delta}{R-R_0}(V_i - 2R_0)$ and hence the return to the investor is equal to $r_i = V_i - ic_\Delta = \left(1 - \frac{c_\Delta}{R-R_0}\right)(V_i - 2R_0) + 2R_0$.

ii) If $q > (p-q)\theta$, then $(w_0, w_1, w_2) = \left(0, 0, \frac{1}{q}c_\Delta\right)$ and the return to the investor is equal to $(r_0, r_1, r_2) = \left(2R_0, R + R_0, 2R - \frac{1}{q}c_\Delta\right)$.

In case (ii) of Proposition 2, the manager is paid only when both projects succeed and the optimal contact is driven by cross-pledging, as pointed out by Laux (2001) and Tirole (2006). As the manager holds a convex claim, a concave claim is held by the investor. If $2R - \frac{1}{q}c_\Delta > R + R_0 \Leftrightarrow R - \frac{1}{q}c_\Delta > R_0$, it can be implemented with a standard debt contract with face value $2R - \frac{1}{q}c_\Delta$. If the inequality is not satisfied then the solution corresponds to the 'live or die' type of contract that was originally derived by Innes (1990). As Innes

[8] There is also a participation constraint but limited liabilitry and non-negativity constraints imply that it does not bind in equilibrium.

(1990) demonstrated if we also require that the compensation to investors is non-decreasing with the return V of the firm then, in the latter case, the optimal solution takes the form of standard debt. As incentives are weaker relative to the case of the 'live or die' type of contract, the range of parameters that debt dominates is reduced.

In case (i), the optimal contract can be implemented by letting the investor hold a claim that is a combination of risk free debt of face value $2R_0$ and fraction $1-\frac{c_\Delta}{R-R_0}$ of equity and, thus,the manager holds the remainder fraction, $\frac{c_\Delta}{R-R_0}$, of equity, where by Assumption (2.1), $1-\frac{c_\Delta}{R-R_0}>0$. In this case, the manager holds a linear claim (and so does the investor) and cross-pledging is no longer optimal. According to the proposition, this is the case when the probability of success of a type l project, q, is small enough. Cross pledging ruins the manager's incentive to exert effort on a type h project when the other project is type l. To see this point, consider the case where $q\approx 0$. If the contract compensates the manager only when both projects succeed she does not have any incentives to exert effort on the type h project given that the increment in the probability that she will receive compensation, $(p-q)\,q$, is very small (violating (2.7)). This implies that if q is small enough, then the manager must also be compensated when only one project succeeds, that is, $w_1>0$. However, there is a limit to how high the compensation can be in that case. If that compensation w_1 is more than half of the compensation w_2 that she would receive if both projects succeed then her incentives to exert effort on both projects when they are type h would be destroyed (violating (2.3)). Thus, the compensation has to be set proportional to the number of successful projects (constraints (2.3) and (2.7) are both binding) and we have a linear contract.

Because of this linearity, the optimal contract case (i) can also be implemented by having each project financed separately with the investor holding a debt claim with face value $R-c_\Delta$. However, observe that relative to this separate finance arrangement there is an information cost saving advantage with the combined finance arrangement where the investor holds a claim that combines a risk free debt and fraction $1-\frac{c_\Delta}{R-R_0}$ of equity. The arrangement of separate finance demands that the returns of both projects are observed by the investor, whereas the arrangement of combined finance demands the observability of only the sum total of the two returns. If we assume that only the aggregate outcome is observable, but not the return of each project, which is a reasonable assumption on multi-divisional firms, then the combined arrangement is the only feasible way to implement the optimal contract shown in case (i). This is different from DeMarzo (2006) where projects (in that case assets) can be completely separated through signaling.

2.3. The Optimal Contract

Putting Propositions 1 and 2 together, we find that when $q > (p-q)\,\theta$, or equivalently $\theta < q/\,(p-q)$, the optimal financial contract is debt irrespective of whether the manager is offered incentives to exert effort only when both projects are type h or he is offered incentives to always exert effort when a project is type h. However, when $\theta > q/\,(p-q)$, the optimal scheme requires the investor to hold a concave claim in the former case but a linear claim in the latter case. Lastly, if no incentives are provided, then the investor's payoff is $2\left[qR + (1-q)\,R_0\right]$. By comparing the investor's payoff between these three cases, we arrive at the following theorem:[9]

Theorem 1 *i) If* $\theta < \frac{q}{p-q}$ *or* $\theta = 1$, *the optimal contract either gives the investor a concave (debt) claim or provides the manager with no incentives to exert effort;*

ii) if $1 > \theta > \frac{q}{p-q}$, *then*

(a) if $\frac{R-R_0}{c_\Delta} > \frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1$, *the optimal contract gives the investor a linear claim, which is a combination of risk-free debt and equity, and induces the manager to exert effort to any project that is type* h*;*

(b) if $\frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1 > \frac{R-R_0}{c_\Delta} > \frac{\theta^2p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)}$, *the optimal contract gives the investor a concave (debt) claim and induces the manager to exert effort only when both projects are type* h*; and*

[9] Where we use the result that if $\theta > \frac{q}{p-q}$, then $\frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1 > \frac{\theta p+(1-\theta)q}{\theta(p-q)} > \frac{\theta^2p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)}$, which is proved in Appendix along with the proof of the theorem.

(c) if $\frac{\theta^2 p^2+\left(1-\theta^2\right)q^2}{\theta^2\left(p^2-q^2\right)} > \frac{R-R_0}{c_\Delta}$*, the optimal contract provides the manager with no incentives to exert effort.*

We have explained above why when $\theta < q/\left(p-q\right)$ the optimal contract always gives investors a debt-like concave claim.[10] The result for the case where $\theta > q/\left(p-q\right)$ is also intuitive. $\left(p-q\right)\left(R-R_0\right)$ measures the benefit of monitoring and c measures the cost. Hence, the ratio $\left(R-R_0\right)/c_\Delta$ measures the benefit of monitoring per unit cost and thereby the effectiveness of monitoring. The theorem then states that the optimal level of effort – case 1 versus case 2 – increases with the effectiveness of monitoring, that is, the ratio $\left(R-R_0\right)/c_\Delta$. At one extreme, when this ratio is sufficiently high (ii.a) the optimal contract induces maximum effort from the manager, which requires the investor to hold an equity claim (in addition to a risk free debt). At the other extreme, when this ratio is sufficiently low (ii.c) it is not worth to induce any effort at all. In between, we have (ii.b), where the optimal contract induces the manager to exert effort only when both projects are type h and for this purpose the investor holds a debt-like concave claim.

The optimality of having the investor hold a debt-like claim is due to cross pledging, which, as Laux (2001) has shown, reduces the costs of providing incentive. However, we know from Proposition 2 that cross pledging ruins the manager's incentives to work hard on a type h project if the other project is type l. It is the preservation of the manager's incentives to work hard on the type h project in this contingency that makes the outside equity optimal. Put differently, outside equity is optimal because it makes the manager's incentive robust to the quality shock.

The contingency of one project being type h and the other type l, under which outside equity has an advantage, occurs ex ante with probability $2\theta\left(1-\theta\right)$. Therefore, if this probability is too low outside equity is unlikely to be beneficial. Thus, according to the theorem when $\theta(1-\theta)$ is very small, the condition for case (ii.a) is unlikely to be satisfied. Indeed, if $\theta = 1$, our model is identical to Laux (2001). Then, the condition for case (ii.a)

[10] By debt-like we refer to both 'live or die' and standard debt contracts. See the discussion after Proposition 1.

can never be met and the optimal contract is always driven by cross-pledging, as Laux (2001) has found.

A comparative static analysis of Theorem 1 leads to some testable predictions concerning the use of outside equity. According to the theorem, the investor holds an equity claim if

$$\theta > \frac{q}{p-q} \tag{2.9}$$

$$\frac{R-R_0}{c}(p-q) > \frac{pq}{\theta(1-\theta)(p^2-q^2)}+1. \tag{2.10}$$

We say that the investor is more likely to hold an equity claim after a *ceteris paribus* change in parameter x if such a change makes these two inequalities looser, that is, it makes either their left hand sides greater or their right hand sides smaller. Then, we have the following corollary:

Corollary 1 *Then, for $\theta < 1$, the investor is more likely to hold an equity claim if R is higher, c is lower (the cost of providing effort incentives decreases), $p-q$ is higher while $p+q$ stays the same (the marginal increase in the expected payoff of h projects increases), p is higher and q is lower.*

3. Implications of the Model for Financial Intermediation

Our model can account for certain features of the contractual arrangements of financial intermediaries. According to the types of contracts on the liability side of their balance sheets financial intermediaries can be classified into two groups. One group consists of commercial banks which raise funds mainly by offering fix obligations (debt contracts) to investors (depositors). The other group, which has grown rapidly in recent years, includes *private equity funds* which, unlike banks, raise funds by offering profit-sharing payoffs to their investors who are known as limited partners (see Metrick and Yasuda, 2010). After they fund projects financial intermediaries have to decide on which projects it is worth spending resources on services that will improve their prospects (often such services are referred to as 'monitoring services').

Our model can be useful in understanding the relative strengths and weaknesses of these two groups of financial intermediaries. To see this, consider the following reinterpretation of our model. The entrepreneur-manager is actually a financial intermediary, which seeks funding from investors to finance two projects. In particular, the probability of success of a project depends on the input of a certain service that costs the intermediary c to provide; and this service makes a substantial difference only under certain contingency, namely, contingency h. This service, following the literature on financial intermediation, is referred to as 'monitoring', whereby the intermediary is referred to as the *monitor*. It captures any input in management, marketing, or identifying potential consumers. With this interpretation, the contract to investors $\{r_i\}_{i=0,1,2}$ is the liability side contract by which the intermediary is financed. Our results imply that in equilibrium, only two types of liability contracts are offered. One gives the investors a concave claim, that is,

$$r_1 > \frac{r_0 + r_2}{2},$$

which is like debt. The other gives them a linear claim, that is,

$$r_1 = \frac{r_0 + r_2}{2},$$

which can be implemented by a combination of risk-free debt and a pure equity. In the former case, the intermediary represents a commercial bank, in the latter, a private equity fund.

The following comparative statics directly follow from Corollary 1:

1. Equity contracts are more likely to be offered when the difference $p - q$ is high and c is low, that is the return of exerting effort is high and the cost is low.

2. Equity contracts are more likely to be offered when R is high and q is low, that is,

for financing high-risk/high-return projects.

There is some evidence consistent with the above predictions. For example, Dunne, Roberts and Samuelson (1988) find that low payoff to monitoring and low profitability are the characteristics of mature firms while Sahlman (1990) and Ueda (2004) find that the profitability of young firms in high-risk innovative sectors is very strong conditional on survival (namely success). Consistent with the common held view, our model predicts that banks are more likely to fund mature firms while private equity funds young firms in the innovation sector.

3.1. Diversification and Internal Control

Thus far, we have assumed that there are only two projects. In this subsection we consider the robustness of our results to sufficient diversification, which, since the seminal work of Diamond (1984), is regarded as a driving force for the viability of financial intermediaries. There is an important diffrence between the contracting environments in Diamond (1984) and in this paper. In Diamond (1984) the intermediary is unable to costlessly observe project returns. In our model the friction is not costly state verification, but moral hazard due to the inability of investors to observe whether the intermediary provides the services that enhance the probability of success of a certain type of project. Despite this difference, we will show that under the bank contractual arrangement, as in Diamond (1984), sufficient diversification drives the per project agency rent of the intermediary to zero. Hence, sufficient diversification, by minimising the cost of incentives, offers banks an advantage over equity funds. However, this results holds true only if a single agent can *alone* monitor a large number of projects. If this is not the case, and a single agent can only monitor a small number of projects, then the intermediary has to delegate the monitoring of most of the projects to other agents. This gives rise to an *internal control problem* associated with moral hazard due to this additional layer of monitoring. We will show that the internal control problem is more severe under the the bank contractual arrangenet than under the equity-fund one. Thus, the balance between the two types of financial intermediaries is restored when we take into account the internal control problem.

Suppose that there are N projects, where N is a large number. The liability contract of the intermediary is $\{r_i\}_{i \in \mathbf{N}}$, where $\mathbf{N} := \{1, 2, ..., N\}$. Then in the contingency where i projects have succeeded, the payment to the monitor is equal to $w_i = (N - i) R_0 + iR - r_i$. In this new setting, the contractual arrangement for equity funds is the same as before. The investors hold a risk-free debt claim of face value NR_0 and a share of $1 - \frac{c_\Delta}{R - R_0}$ of the equity interest and the monitor holds the rest $\frac{c_\Delta}{R - R_0}$ fraction of the equity interest. That is, per project, the monitor is paid nothing if the project fails and c_Δ if it succeeds. With this payment structure, she monitors a project whenever it is type h. Ex ante, her rent per project is $p_s c_\Delta - \theta c = \underline{q} c_\Delta > 0$, which clearly does not depend on the value of N.

The contractual arrangement for banks in this setting is characterized by a threshold number $n^* < N$ such that the monitor is offered incentives to monitor all type h projects in all contingencies where the number of type h projects, k, is greater than n^*.[11] Finding the optimal contract for banks is extremely complicated. Below, we will follow Diamond (1984), and demonstrate our main result for a contractual arrangements that is close to the optimal one. We will show that under that arrangement the monitor's rent per-project converges to 0 and the per-project payoff to investors converges to the first-best value $p_s R + (1 - p_s) R_0 - \theta c$.[12] These two features must also be present in the optimal arrangement for banks.

The particular arrangement we consider is as follows. The investors hold a debt claim with face value $F := N [p_s R + (1 - p_s) R_0 - \theta c] (1 - \delta)$, where δ is a small positive number. That is, $r_i = \min ((N - i) R_0 + iR, F)$. We denote this contractual arrangement by C_δ. Under this arrangement, the ex ante per-project rent to the monitor is no larger than $\delta [p_s R + (1 - p_s) R_0 - \theta c]$, which converges to zero as δ approaches zero. Ex post, the

[11] In the main part of the paper where we considered the case $N = 2$, n^* is either equal to 2 (Proposition 1) or 1 (Proposition 2).

[12] In the first-best arrangement, that is, the optimal arrangement when the monitoring action is contractible, the monitor will monitor whenever a project is type h and her compensation is equal to c. Ex ante the project succeeds with probability p_s and the monitor is paid pc.

monitor is paid if and only if the number of successful project $i \geq \lambda_\delta N$, where

$$\lambda_\delta := (1-\delta)\, p_s - \frac{(1-\delta)\,\theta c + \delta R_0}{R - R_0},$$

in which case, the debt to investors is paid in full. We can now prove our main result. Observe that $\lambda_0 > q$ is equivalent to $R - R_0 > c_\Delta$, namely the service is valuable, which is assumed in (2.1). Also observe that

$$\frac{\lambda_0 - q}{p - q - \frac{c}{R - R_0}} = \theta.$$

Therefore, given a $\delta > 0$ small enough, $\lambda_\delta > q$ and there exists $\varepsilon > 0$ such that

$$\frac{\lambda_\delta - q}{p - q - (1+\varepsilon)\,\frac{c}{R - R_0}} = \theta.$$

Proposition 3 *Given any $\delta \gtrsim 0$ (greater but arbitrarily close to 0) and any $\epsilon \in (0, \min(\varepsilon, 1))$, there exists a number $\widehat{N}$ such that if $N > \widehat{N}$, under the contractual arrangement $C\{\delta\}$, the monitor monitors all type h projects when the number of such projects k satisfies*

$$k \geq \frac{\lambda_\delta - q}{p - q - (1+\epsilon)\,\frac{c}{R - R_0}} N; \tag{3.1}$$

and she monitors none of the type h project if

$$k \leq \frac{\lambda_\delta - q}{p - q - (1-\epsilon)\,\frac{c}{R - R_0}} N. \tag{3.2}$$

Moreover, as N goes to infinity, the probability that k satisfies the former inequality approaches 1.

While the proof of the proposition might be technical, the intuition is straightforward. If the number k of type h projects satisfies inequality (3.1), then conditional on the monitor monitoring all type h projects, it is almost certain that the number of successful projects is above $\lambda_\delta N$, so that the debt to investors is fully paid, and the monitor obtains a positive rent.[13] The full payment of the debt, moreover, means that the monitor is the residual claimer, which indeed provides her with incentives to monitor each and every type h project. If the number k of type h project satisfies inequality (3.2), then even if all type h projects were to be monitored, almost certain the number of successful projects is at best just above $\lambda_\delta N$, in which case the payment is not worth the cost of monitoring, and the monitor is better off by monitoring none of the projects. Lastly, observe that inequality (3.1) is equivalent to $k/(N\theta) \geq \mu$ for some $\mu < 1$ (due to $\epsilon < \varepsilon$). Therefore, as N goes to infinity, the probability that the inequality holds converges to 1 and all type h projects are *almost always* monitored and, hence, the first-best allocation is approximated.

Under sufficient diversification the bank contractual arrangement almost implements the first-best allocation by giving the monitor an almost zero rent per project. However, that is based on the assumption that the monitor alone can single-handedly monitor all N projects. If this is not possible then the monitor will have to delegate the monitoring of some projects to some other agents. Given that monitoring is not observable, delegation creates another layer of moral hazard which we refer to as the *internal control problem*; we also refer to the per-delegate cost incurred to overcome this moral hazard problem as the *internal control cost,* and we denote the latter by c_N when the number of delegates is equal to N.

The severity of the internal control problem varies between banks and equity funds. It is negligible under equity funds where the investors' payoff remains the same if each delegate is paid c_Δ when the project assigned to him succeeds and nothing when it fails. Under this contract, he will monitor a project when it is type h and, thus, there is no need to spend resources monitoring him. In contrast, the contractual arrangement for banks suffers severerly from the internal control problem. The reason is rooted in the very feature that allows banks to reduce incentive costs. Under the bank contract, a delegate is paid only when a sufficiently large quantity of projects succeeds. Therefore,

[13] Inequality (3.1) is equivalent to $(N-k)\,R_0 + kR - F - kc \geq \epsilon kc$.

each delegate imposes positive externalities upon other delegates, given that the success of his project increases the expected payoff of all other delegates. It is exactly because of these externalities that the banks reduce the cost of providing incentives relative to equity funds. If not nonitored, each delegate will not have incentives to monitor his assigned project. Therefore, banks have to spend resources monitoring each one of the delegates. We can also see that if the internal control cost c_N is high enough then it makes sense to provide each delegate with incentives to monitor the assigned project rather than using costly resources to monitor him. In this case, the minimum incentive payment he should receive conditional on the success of his project is c_Δ. That is, under the supposition that offering incentives is worthwhile,[14] the equity fund is the only contractual arrangement that provides the monitoring service and dominates the bank contractual arrangement. In summary, banks dominate when there is scope for sufficient diversification *and* the internal control cost is low, while equity funds dominate when either the scope for diversification is limited or the internal control cost is high.

4. Conclusion

We have demonstrated a novel role for outside equity. In most of the financial economics literature the role of equity has been as a residual claim. This is not surprising given that the main objective has been to explain why debt is so prevalent given that is a more complex instrument with higher associated transactions costs than equity. There have been some sporadic attempts to rationalize outside equity for the direct benefits that it provides and this paper falls into that category.

In our model, after projects have been funded, their manager receives inside information about their prospects in which case she will have to decide whether or not it is worth spending extra resources to improve their likelihood of success. As in the classical managerial moral hazard model the likelihood of success of each project depends on the level of

[14]That is, if $(p_s - q)(R - R_0) > p_s c_\Delta$.

effort that the manager will exert on it which is unobservable by investors. The difference is that in our model only some projects can benefit from the manager's input and projects that do benefit are only revealed to the entrepreneur and only after the funding contract with investors is agreed. There are two main results. We have shown that it is not always optimal to design schemes that provide maximal incentives to the manager. More importantly, we have found that even when it is optimal to provide maximal incentives, in some cases the best way to do so is by having the investors holding an equity claim.

Our model has some interesting implications for the theory of financial intermediation. In particular, we have argued that it can explain some of the differences between private equity funds and commercial banks with respect to their practices and types of contracts that they offer to their clients.

Our results also contribute to the managerial compensation literature. Existing studies have demonstrated that high powered incentives encourage both risk-taking and short-termist behaviors (see Frydman and Jenter (2010) and Edmans and Gabaix (2016) for surveys). We suggest an alternative channel through which high-powered incentives might lead to inefficient decisions. When managers who are responsible for multiple projects obtain privately information about their quality then high-powered incentives, offered by 'cross pledging' contracts, might discourage them from exerting effort even on highly productive projects.

We have assumed that project types are independently distributed. Our results suggest that when project types are strongly positively correlated projects are more likely to be funded by debt while when types are negatively correlated projects are more likely to be funded by equity.

5. Appendix A: Proofs

5.1. Proof of Proposition 1

Together the incentive constraints (2.4) and (2.5) imply (2.3). This is because $m(2,2) \geqslant m(0,2) = m(0,1) \geq m(1,1) = m(1,2)$; where the first inequality is implied by constraint (2.4) and the second inequality by constraint (2.5). Therefore (2.3) is not binding. We can write constraint (2.4) as

$$\frac{p+q}{2} w_2 + (1-(p+q))\, w_1 \geq c_\Delta; \tag{5.1}$$

and constraint (2.5) as

$$q w_2 + (1-2q)\, w_1 \leq c_\Delta. \tag{5.2}$$

The investor's problem can be written as

$$\min_{\{w_1,w_2\}} \left[\theta^2 p^2 + \left(1-\theta^2\right) q^2\right] w_2 + \left[\theta^2 2p(1-p) + \left(1-\theta^2\right) 2q(1-q)\right] w_1 \tag{5.3}$$

subject to (5.1) and (5.2) as well as $w_1, w_2 \geq 0$. A decline in w_2, which reduces the objective function, tightens constraint (5.1) but relaxes constraint (5.2). Therefore, at the optimum, constraint (5.1) is binding and we have:

$$\frac{p+q}{2} w_2 + (1-(p+q))\, w_1 = c_\Delta,$$

from which we find

$$w_2 = \frac{2}{p+q}\left(c_\Delta - (1-(p+q))\, w_1\right).$$

Substitute that into the objective function and simplify it as a function of w_1 only. The derivative with respect to $w_1$has the same sign as

$$-\frac{2q}{p+q} + 1 < 0.$$

It follows that at the optimum, $w_1 = 0$ and $w_2 = \frac{2}{p+q}c_\Delta$. We can check this wage contract satisfies constraint (5.2). Hence, it is the solution to problem (5.3). □

5.2. Proof of Proposition 2

Together the incentive constraints (2.3) and (2.7) imply (2.4). This is because $m(2,2) \geqslant m(1,2) = m(1,1) \geq m(0,1) = m(0,2)$; where the first inequality is implied by constraint (2.3) and the second inequality by constraint (2.7). Obviously, in any optimal incentive scheme, the manager should not be rewarded with any payment in case of both projects having failed, that is, $w_0 = 0$. Then we can write (2.3) as

$$pw_2 + (1-2p)w_1 \geqslant c_\Delta$$

and (2.7) as:

$$qw_2 + (1-2q)w_1 \geqslant c_\Delta$$

At least one of the two constraints must be binding at the optimum; otherwise w_2 can be reduced, which decreases the manager's compensation and benefits the investor. We first show that (2.7) must be binding. Suppose that only (2.3) is binding, namely

$$pw_2 + (1-2p)w_1 = c_\Delta. \tag{5.4}$$

Then (2.7) is satisfied if and only if $qw_2 + (1-2q)w_1 \geq pw_2 + (1-2p)w_1$, namely $2w_1 \geq w_2$. Solving (5.4) for w_2 and substituting the solution in the manager's expected compensation function, the problem of minimizing the compensation is reduced to

$$\min_{w_1} \left(2\theta - \theta^2\right) \left[(p-q)\left(q\frac{c_\Delta - (1-2p)w_1}{p} + (1-2q)w_1\right) - c\right] + \left[q^2\frac{c_\Delta - (1-2p)w_1}{p} + 2q(1-q)w_1\right],$$

subject to $2w_1 \geq w_2$

The derivative of the objective function with respect to w_1 is equal to

$$\left(2\theta-\theta^2\right)\left[(p-q)q\left(-\frac{1-2p}{p}+\frac{1-2q}{q}\right)\right]+q^2\left[-\frac{1-2p}{p}+\frac{2(1-q)}{q}\right]>0,$$

because $\frac{1-2p}{p}<\frac{1-2q}{q}<\frac{2(1-q)}{q}$. Therefore, the investors would like to increase w_1, and as a result decrease w_2, as much as possible. Hence at the optimum, $2w_1 \geq w_2$ will be binding, that is, (2.7) will also be binding.

As (2.7) is binding, we have

$$qw_2+(1-2q)w_1=c_\Delta. \tag{5.5}$$

Then, (2.3) is satisfied if and only if $2w_1 \leq w_2$. Solving (5.5) for w_2 and substituting the solution in the manager's expected compensation function, the problem of minimizing the compensation is reduced to

$$\min_{w_1}\theta^2\left[(p-q)\left(p\frac{c_\Delta-(1-2q)w_1}{q}+(1-2p)w_1\right)-c\right]+\left[q^2\frac{c_\Delta-(1-2q)w_1}{q}+2q(1-q)w_1\right],$$

subject to $2w_1 \leq w_2$.

The derivative of the objective function has the same sign as $-\theta+\frac{q}{p-q}$. Therefore, we have two cases.

i) If $\theta>\frac{q}{p-q}$ then the derivative is negative and the investor would like to set w_1 as high as possible. As a result, the constraint $2w_1 \leq w_2$, namely (2.3), is binding, which implies that $w_1=\frac{w_2}{2}$. The last expression together with (5.5) implies that the optimal contract is given by $\{w_1,w_2\}=\{c_\Delta,2c_\Delta\}$.

ii) If $\theta<\frac{q}{p-q}$ then then the derivative is positive and the investor would like to set w_1 as low as possible, that is $w_1=0$, which together with (5.5) implies that the optimal contract is given by $\{w_1,w_2\}=\left\{0,\frac{1}{q}c_\Delta\right\}$. □

5.3. Proof of Theorem 1

We first prove the following lemma:

Lemma 1 *If* $\theta > \frac{q}{p-q}$*, then* $\frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1 > \frac{\theta p+(1-\theta)q}{\theta(p-q)} > \frac{\theta^2 p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)}$.

Proof The first inequality is equivalent to

$$\begin{aligned}
\frac{pq+\theta(1-\theta)\left(p^2-q^2\right)}{\theta(1-\theta)\left(p^2-q^2\right)} &> \frac{\theta p+(1-\theta)q}{\theta\left(p-q\right)} \Leftrightarrow \\
pq+\theta(1-\theta)\left(p^2-q^2\right) &> (1-\theta)\left[\theta p^2+pq+(1-\theta)\,q^2\right] \Leftrightarrow \\
\theta pq &> (1-\theta)\,q^2 \Leftrightarrow \\
\theta p &> (1-\theta)\,q \Leftrightarrow \\
\theta &> \frac{q}{p+q},
\end{aligned}$$

which certainly holds true if $\theta > \frac{q}{p-q}$.

The second inequality is:

$$\begin{aligned}
\frac{\theta p+(1-\theta)q}{\theta\left(p-q\right)} &> \frac{\theta^2p^2+\left(1-\theta^2\right)q^2}{\theta^2\left(p^2-q^2\right)} \Leftrightarrow \\
\theta\left[\theta p^2+pq+(1-\theta)\,q^2\right] &> \theta^2p^2+\left(1-\theta^2\right)q^2 \Leftrightarrow \\
\theta pq &> (1-\theta)\,q^2,
\end{aligned}$$

which, as shown above, holds true if $\theta > \frac{q}{p-q}$.□

Now, we can prove the theorem:

Part (i) is obvious. For part (ii), first, substitute the manager's optimal compensation scheme found in Proposition 1 (i) in the pledgeable income for Case1, to get

$$\begin{aligned}
V_E &= p_s^2\left(2R-2c_\Delta\right)+2p_s\left(1-p_s\right)\left(R+R_0-c_\Delta\right)+2\left(1-p_s\right)^2R_0 \\
&= 2\left[p_s\left(R-c_\Delta\right)+\left(1-p_s\right)R_0\right].
\end{aligned}$$

This is intuitive, because ex ante each project succeeds with probability p_s, in which case the manager is rewarded with c_Δ, and fails with probability $1-p_s$, in which case she is not rewarded.

Second, substitute the manager's optimal compensation scheme found in Proposition 2, in the pledgeable income for Case 2, to get

$$\begin{aligned}
V_D &= \left[\theta^2 p^2 + \left(1-\theta^2\right) q^2\right]\left(2R - \frac{2c_\Delta}{p+q}\right) + \left[2p(1-p)\theta^2 + 2q(1-q)\left(1-\theta^2\right)\right](R+R_0) \\
&\quad + \left[\theta^2 (1-p)^2 + \left(1-\theta^2\right)(1-q)^2\right] \times 2R_0 \\
&= 2\left\{\left[\theta^2 p + \left(1-\theta^2\right) q\right] R + \left[\theta^2 (1-p) + \left(1-\theta^2\right)(1-q)\right] R_0\right\} \\
&\quad -2\left[\theta^2 p^2 + \left(1-\theta^2\right) q^2\right] \frac{c_\Delta}{p+q}.
\end{aligned}$$

This is also intuitive. The term in "{}" is the expected revenue from each project, as it succeeds with probability $\theta^2 p + \left(1-\theta^2\right) q$. Subtracting from this revenue the expected payment to the manager yields the payoff to the investors.

Lastly, if no incentives are provided, the pledgeable income is equal to $V_{No} := 2\left[qR + (1-q) R_0\right]$.

By comparing the above three expressions we arrive at the following results: first,

$$\begin{aligned}
V_E &> V_D \Leftrightarrow \\
p_s (R - c_\Delta) + (1-p_s) R_0 &> \begin{array}{r} \left[p\theta^2 + \left(1-\theta^2\right) q\right] R + \left[\theta^2 (1-p) + \left(1-\theta^2\right)(1-q)\right] R_0 \\ - \left[\theta^2 p^2 + \left(1-\theta^2\right) q^2\right] \frac{c_\Delta}{p+q} \end{array} \Leftrightarrow \\
\left(p_s - \left[p\theta^2 + \left(1-\theta^2\right) q\right]\right)(R - R_0) &> \left[p_s - \frac{\theta^2 p^2 + \left(1-\theta^2\right) q^2}{p+q}\right] c_\Delta \Leftrightarrow \\
\left(\theta - \theta^2\right)(p-q)(R-R_0) &> \frac{\left(\theta-\theta^2\right)\left(p^2-q^2\right) + pq}{p+q} c_\Delta \Leftrightarrow \\
\frac{R-R_0}{c_\Delta} &> \frac{pq}{\theta(1-\theta)\left(p^2-q^2\right)} + 1;
\end{aligned}$$

second,

$$
\begin{aligned}
V_E &> V_{No} \Leftrightarrow \\
p_s\,(R - c_\Delta) + (1 - p_s)\,R_0 &> qR + (1 - q)\,R_0 \Leftrightarrow \\
\theta\,(p - q)\,(R - R_0) &> (\theta p + (1 - \theta) q)\,c_\Delta \Leftrightarrow \\
\frac{R - R_0}{c_\Delta} &> \frac{\theta p + (1 - \theta) q}{\theta\,(p - q)};
\end{aligned}
$$

and third,

$$
\begin{aligned}
V_D &> V_{No} \Leftrightarrow \\
\begin{array}{r} \left[p\theta^2 + \left(1 - \theta^2\right) q\right] R + \left[\theta^2\,(1 - p) + \left(1 - \theta^2\right)(1 - q)\right] R_0 \\ - \left[\theta^2 p^2 + \left(1 - \theta^2\right) q^2\right] \frac{c_\Delta}{p+q} \end{array} &> qR + (1 - q)\,R_0 \Leftrightarrow \\
\theta^2\,(p - q)\,(R - R_0) &> \left(\frac{\theta^2 p^2 + \left(1 - \theta^2\right) q^2}{p + q}\right) c_\Delta \Leftrightarrow \\
\frac{R - R_0}{c_\Delta} &> \frac{\theta^2 p^2 + \left(1 - \theta^2\right) q^2}{\theta^2\,(p^2 - q^2)}.
\end{aligned}
$$

By Lemma 1, $\frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1 > \frac{\theta p+(1-\theta)q}{\theta(p-q)} > \frac{\theta^2 p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)}$. Therefore, if $\frac{R-R_0}{c_\Delta} > \frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1$, then $V_E > V_D$ and $V_E > V_{No}$ and, hence, at the optimum the investor holds an equity claim and the manager exerts effort whenever a project is type h. If $\frac{pq}{\theta(1-\theta)(p^2-q^2)} + 1 > \frac{R-R_0}{c_\Delta} > \frac{\theta^2 p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)}$, then $V_D > V_E$ and $V_D > V_{No}$ and, hence, at the optimum, the investor holds a debt claim and the manager exerts effort only when both projects are type h. Lastly, if $\frac{\theta^2 p^2+\left(1-\theta^2\right)q^2}{\theta^2(p^2-q^2)} > \frac{R-R_0}{c_\Delta}$, then $V_{No} > V_E$ and $V_{No} > V_D$ and, hence, at the optimum no incentives are provided. □

5.4. Proof of Corollary 1

The comparative static analysis with respect to R and c is straightforward. Regarding $\Delta \equiv p - q$, let $s := p + q$. Then $p = \frac{s+\Delta}{2}$ and $q = \frac{s-\Delta}{2}$. The left hand side of (2.9) is independent of Δ, but the right hand side is equal to $\frac{s-\Delta}{2\Delta}$ and decreases with Δ, and therefore inequality (2.9) is looser with an increase in $\Delta = p - q$. As for inequality (2.10), its left hand side is equal to $\frac{R-R_0}{c}\Delta$ and increases with Δ, while its right hand side is equal to $\frac{s^2-\Delta^2}{4\theta(1-\theta)\Delta s} + 1$ and, thus, decreases with Δ. Hence, the inequality is looser with an increase in $\Delta = p - q$. Lastly, if q is smaller, the left hand side of (2.9) is unchanged, but the right hand side decreases, hence the inequality becoming looser; and the left hand side of (2.10) increases and the right hand side decreases, hence inequality (2.10) becomes looser too. □

Proof of Proposition 3

The following definitions will be used in the proof. Let k denote the number of type h projects which defines the state of the world when the monitor's incentives are concerned. We will be applying the Central Limit Theorem many times and we let $\Phi(\cdot)$ be the c.d.f. of the standard normal distribution. Given two large numbers N and k, by the Central Limit Theorem, the event that out of $N-k$ type l projects (each of which succeeds with probability q) no less than $(N-k)q - \sigma_N\sqrt{(N-k)q(1-q)}$ of them succeed occurs with probability $\Phi(\sigma_N)$. This is also equal to the probability of the event that out of k monitored type h projects, no less than $kp - \sigma_N\sqrt{kp(1-p)}$ of them succeed. Therefore, with a probability greater than $[\Phi(\sigma_N)]^2$, the number of successful projects is no smaller than $S_u(N,k) := (N-k)q - \sigma_N\sqrt{(N-k)q(1-q)} + kp - \sigma_N\sqrt{kp(1-p)}$. Similarly, with probability $\Phi(\sigma_N)$, out of $N-k$ type l projects, the number of successful ones is no larger than $(N-k)q + \sigma_N\sqrt{(N-k)q(1-q)}$. This is also equal to the probability of the event that out of k monitored type h projects the number of successful ones is no larger than $kp+\sigma_N\sqrt{kp(1-p)}$. Therefore, with a probability greater than $[\Phi(\sigma_N)]^2$, the number of successful projects is no larger than $S_d(N,k) := (N-k)q + \sigma_N\sqrt{(N-k)q(1-q)} + kp+\sigma_N\sqrt{kp(1-p)}$. Below we let $\sigma_N = \log N$, which is in order smaller than $\sqrt{N}$, that is, $\sigma_N = o(\sqrt{N})$. Then, $S_u(N,k) = (N-k)q+kp-o(N)$ and $S_d(N,k) = (N-k)q+kp+o(N)$.

Next, we prove the Proposition. We first establish that if the number of type h projects, k, is high enough so as to satisfy inequality (3.1) and if N is large enough the monitor has incentives to monitor all h type projects . Let $k' = \frac{\lambda_\delta - q}{p-q-\left(1+\frac{\epsilon}{2}\right)\frac{c}{R-R_0}} N$, which is equivalent to

$$(N-k')q + k'p = \lambda_\delta N + \left(1+\frac{\epsilon}{2}\right)\frac{k'c}{R-R_0}.$$

Then $k' < k$ and for N large enough, $S_u(N,k') = \lambda_\delta N + \left(1+\frac{\epsilon}{2}\right)\frac{k'c}{R-R_0} - o(N) > \lambda_\delta N$. If the monitor chooses to monitor k' out of k type h projects, then with probability greater than $[\Phi(\log N)]^2$, no less than $S_u(N,k')$ projects succeed, in which case, as $S_u(N,k') > \lambda_\delta N$, the debt to the investor is paid in full and the monitor's net gain from monitoring is no smaller than $S_u(N,k')R + (N - S_u(N,k'))\, R_0 - F - k'c = [S_u(N,k') - \lambda_\delta N]\,(R-R_0) - k'c = \frac{\epsilon}{2}ck' - o(N) = \frac{\epsilon}{2}c\frac{\lambda_\delta - q}{p-q-\left(1+\frac{\epsilon}{2}\right)\frac{c}{R-R_0}}N - o(N) > 0$. Thus if she monitors k' projects, her profit is no less than $[\Phi(\log N)]^2 \frac{\epsilon}{2}c\frac{\lambda_\delta - q}{p-q-\left(1+\frac{\epsilon}{2}\right)\frac{c}{R-R_0}}N + (1-[\Phi(\log N)]^2)(-Nc) - o(N) := V(k')$. With $N \to \infty$, $V(k') \to \infty$ as $\Phi(\log N) \to 1$ and $(1-[\Phi(\log N)]^2)N \to 0$. On the other hand, if she monitors $k'' = o(N)$ of type h projects, then with probability greater than $[\Phi(\sigma_N)]^2$, no more than $S_d(N,k'') = (N-k'')q + k'' + o(N) = Nq + o(N)$ projects succeed. As $Nq < \lambda_\delta N$, with probability greater than $[\Phi(\sigma_N)]^2$, the debt to investors cannot be paid in full and thus the monitor obtains nothing. It follows that by not monitoring a sufficiently large number of projects, the monitor's payoff is negligible. Therefore, this option is dominated by the option of monitoring k' projects. Now we prove that she will monitor all of the k type h projects. We know that if she monitors a sufficiently large number – say k' – of projects, almost certain the debt is fully paid and the monitor obtains a positive profit. In this case, the monitor is the residual claimer. Her marginal net gain from one more type h project monitored is , with almost certainty, equal to $(p-q)(R-R_0) - c > 0$. Thus, she will monitor all of the type h projects if their number k satisfies inequality (3.1).

Now, we prove that if k is small enough so as to satisfy inequality (3.2), which is equivalent to

$$(N-k)\,q + kp \leq \lambda_\delta N + (1-\epsilon)\frac{kc}{R-R_0}, \tag{5.6}$$

then the monitor will monitor none of the h type projects. First we prove it for the case in which k satisfies

$$(N-k)\,q+kp\leq(1-\epsilon')\,\lambda_{\delta}N, \tag{5.7}$$

for some $\epsilon'>0$ small enough such that $(1-\epsilon')\,\lambda_{\delta}-q>0$. In this case, even if she monitors all h type projects, it is almost certain (with probability greater than $[\Phi(\sigma_N)]^2$), that no more than $S_d(N,k)$ projects succeed, in which case, as $S_d(N,k)R+(N-S_u(N,k))\,R_0-F=-\epsilon'\lambda_{\delta}N+o(N)<0$, the monitor defaults on the debt payment and obtains nothing. Hence, almost all of the gain from the increase in the probability of success of a monitored project goes to the investors. As a result, monitoring any type h project makes her worse off relative to not monitoring it. Now consider the case in which k violates inequality (5.7), that is,

$$k>\frac{(1-\epsilon')\,\lambda_{\delta}-q}{p-q}N.$$

We have seen that it makes no sense for the monitor to monitor such a quantity of projects that it is almost certain that will default, in which case she would be better off by not monitoring at all. On the other hand, if conditional on having monitored a large enough quantity of type h projects, it would almost be certain that the debt will be fully paid, then the monitor becomes the residual claimer (as we have seen) and she has incentives to monitor the rest of h type projects, if there are any. Therefore, the monitor monitors either none or all of the type h projects. With the former option, it is almost certain that she obtains 0 payoff (as she does not expend any monitoring costs). With the latter, with a probability greater than $[\Phi(\sigma_N)]^2$, no more than $S_d(N,k)$ projects succeed, in which case by inequality (5.6) her profit is no larger than $S_d(N,k)R+(N-S_u(N,k))\,R_0-F-kc\leq(1-\epsilon)\,kc-kc=-\epsilon kc<-\epsilon c\frac{(1-\epsilon')\lambda_{\delta}-q}{p-q}N$. Therefore, overall her profit is no larger than $[\Phi(\sigma_N)]^2\left(--\epsilon c\frac{(1-\epsilon')\lambda_{\delta}-q}{p-q}N\right)+(1-[\Phi(\sigma_N)]^2)\,NR$, which is in the order of $-\epsilon c\frac{(1-\epsilon')\lambda_{\delta}-q}{p-q}N$ for a large N. Therefore, the option of monitoring all k projects is dominated by that of monitoring none.

Now we show that the ex ante probability that the number of type h projects k satisfies (3.1) goes to 1 if N goes to infinity. By the Central Limit Theorem, $\frac{k-N\theta}{\sqrt{N\theta(1-\theta)}}$ approaches the standard normal distribution. Therefore, the probability of k satisfying inequality (3.1) approaches $\Phi\left(\frac{\mu N}{\sqrt{N\theta(1-\theta)}}\right)$, where $\mu := \theta - \frac{\lambda_\delta - q}{p-q-(1+\epsilon)\frac{c}{R-R_0}}$. Because $\epsilon < \varepsilon$ and $\mu = 0$ if $\epsilon = \varepsilon$, we have $\mu > 0$. Therefore, $\Phi\left(\frac{\mu N}{\sqrt{N\theta(1-\theta)}}\right) \to 1$ as N goes to infinity. $\square$

6. Appendix B: The Direct Mechanism

In the main paper, we have assumed that the compensation contract offered to the manager depends only on the outcomes of the two projects. In this Appendix, we show that eliciting the manager's information about project types cannot improve on the mechanism derived above. The intuition behind this result is as follows. Holding fixed the type of incentives that the investor would like the manager to take (i.e. exerting effort when both projects are type h or whenever one is type h), the total surplus is fixed. This is because the original contract already implements the desired incentives. The investor cannot gain by learning the types of the two projects as the manager's payoff cannot be reduced without destroying the corresponding incentives induced by the scheme.

According to the revelation principle (Myerson, 1982) we only need to focus on the direct mechanism and its truth-telling equilibrium. We need to introduce some new notations. Let $t_j \in \{h, l\}$ denote the true type of project $j \in \{1, 2\}$, $\hat{t}_j \in \{h, l\}$ the entrepreneur's corresponding report, and $o_j \in \{s, f\}$ the outcome (success, fail) of project j. Further, we let $w^{o_1 o_2}_{\hat{t}_1 \hat{t}_2}$ denote the payment to the manager when she reports $\hat{t}_1$ and $\hat{t}_2$ with corresponding project outcomes being o_1 and o_2. Limited liability implies that $w^{ff}_{\hat{t}_1 \hat{t}_2} = 0$. Lastly, let $m_{\hat{t}_1 \hat{t}_2}(e_1, e_2; t_1 t_2)$ denote the manager's expected payoff when she reports $\hat{t}_1$ and $\hat{t}_2$, the true project types are t_1 and t_2, and she exerts effort $e_j \in \{1, 0\}$ on project j; for example

$$
\begin{aligned}
m_{\hat{t}_1 \hat{t}_2}(1, 1; hh) &= p^2 w^{ss}_{\hat{t}_1 \hat{t}_2} + p(1-p)\left(w^{sf}_{\hat{t}_1 \hat{t}_2} + w^{fs}_{\hat{t}_1 \hat{t}_2}\right) - 2c \\
m_{\hat{t}_1 \hat{t}_2}(1, 0; hh) &= pq w^{ss}_{\hat{t}_1 \hat{t}_2} + p(1-q) w^{sf}_{\hat{t}_1 \hat{t}_2} + (1-p) q w^{fs}_{\hat{t}_1 \hat{t}_2} - c.
\end{aligned}
$$

Obviously the mechanism we have considered in the previous section, where the payment was independent of the report and symmetric between the two projects, is a special case of this general mechanism; thus

$$\begin{aligned} w^{ss}_{\hat{t}_1\hat{t}_2} &= w_2 \\ w^{sf}_{\hat{t}_1\hat{t}_2} &= w^{fs}_{\hat{t}_1\hat{t}_2} = w_1 \end{aligned}$$

for any $\hat{t}_1$ and $\hat{t}_2$. Comparing the entrepreneur's expected payoffs between the two mechanisms we have:

$$\begin{aligned} m\left(2,2\right) &= m_{\hat{t}_1\hat{t}_2}\left(1,1;hh\right) \\ m\left(1,2\right) &= m_{\hat{t}_1\hat{t}_2}\left(1,0;hh\right) = m_{\hat{t}_1\hat{t}_2}\left(0,1;hh\right) \\ m\left(0,2\right) &= m_{\hat{t}_1\hat{t}_2}\left(0,0;hh\right) \\ m(1,1) &= m_{\hat{t}_1\hat{t}_2}\left(1,0;hl\right) = m_{\hat{t}_1\hat{t}_2}\left(0,1;lh\right) \\ m(0,1) &= m_{\hat{t}_1\hat{t}_2}\left(0,0;hl\right) = m_{\hat{t}_1\hat{t}_2}\left(0,0;lh\right) \end{aligned}$$

for any $\hat{t}_1$ and $\hat{t}_2$.

Next we demonstrate that we cannot improve on the mechanism derived in Section 2 by eliciting the entrepreneur's private information about project types. The proof corresponds to Case 1 where the manager is incentivized to exert effort only in state hh. For brevity, we omit the proof for Case 2 which follows exactly the same steps. The truth-telling equilibrium is the solution of the following problem:

$$V_2 := \min_{\left\{w^{o_1o_2}_{\hat{t}_1\hat{t}_2}\right\}} \theta^2\left[m_{hh}\left(1,1;hh\right)+2c\right]+\theta\left(1-\theta\right)\left[m_{hl}\left(0,0;hl\right)+m_{lh}\left(0,0;lh\right)\right]+\left(1-\theta\right)^2 m_{ll}\left(0,0;ll\right)$$

subject to:

$$
\begin{aligned}
m_{hh}(1,1;hh) &\geq m_{hh}(0,1;hh) && (6.1)\\
m_{hh}(1,1;hh) &\geq m_{hh}(1,0;hh) && (6.2)\\
m_{hh}(1,1;hh) &\geq m_{hh}(0,0;hh) && (6.3)\\
m_{hl}(0,0;hl) &\geq m_{hh}(1,0;hl) && (6.4)\\
m_{lh}(0,0;lh) &\geq m_{hh}(0,1;lh) && (6.5)\\
m_{hl}(0,0;hl) &\geq m_{hh}(0,0;hl) && (6.6)\\
m_{lh}(0,0;lh) &\geq m_{hh}(0,0;lh) && (6.7)\\
m_{ll}(0,0;ll) &\geq m_{hh}(0,0;ll) && (6.8)
\end{aligned}
$$

and other ICs. The fourth and fifth constraints ensure that when there is only one type h project the manager prefers not exerting effort on that project than exerting effort and reporting hh. Define as

$$V_2' := \min_{\left\{w_{\hat{t}_1\hat{t}_2}^{o_1 o_2}\right\}} \theta^2\left[m_{hh}(1,1;hh)+2c\right]+\theta(1-\theta)\left[m_{hh}(0,0;hl)+m_{hh}(0,0;lh)\right]+(1-\theta)^2 m_{hh}(0,0;ll).$$

Notice that the last three constraints imply that $V_2 \geq V_2'$. At the optimum, the inequality holds. Therefore, the three constraints bind. As a result constraints (6.4) and (6.5) are now equivalent to

$$
\begin{aligned}
m_{hh}(0,0;hl) &\geq m_{hh}(1,0;hl) && (6.9)\\
m_{hh}(0,0;lh) &\geq m_{hh}(0,1;lh). && (6.10)
\end{aligned}
$$

The truth-telling equilibrium is given by V_2' subject to (6.1) to (6.3), (6.9), (6.10), and the other constraints. Let V_2'' denote the optimal solution when we ignore those other constraints. Clearly, $V_2^{'} \geq V_2^{''}$. Notice that $V_2^{''}$ includes only terms of the form $w_{hh}^{o_1 o_2}$. Let

$$\begin{aligned} w_2 &: = w_{hh}^{ss} \\ w_1 &: = \frac{w_{hh}^{sf} + w_{hh}^{fs}}{2}, \end{aligned}$$

and based on (w_1, w_2) define $m(k, n)$ as before. Then, the objective function can be written as:

$$\theta^2 [m(2,2) + 2c] + 2\theta(1-\theta) m(0,1) + (1-\theta)^2 m(0,0).$$

Constraints (6.9) and (6.10) imply

$$m(0,1) \geq m(1,1),$$

which is (2.5); and constraints (6.1) to (6.2) imply

$$m(2,2) \geq m(1,2),$$

which is constraint (2.3); and constraint (6.3) is equivalent to

$$m(2,2) \geq m(0,2),$$

which is constraint (2.4). Hence, $V_2^{''} \geq V_2^{'''}$, where

$$V_2^{'''} := \min_{w_1, w_2 \geq 0} \theta^2 [m(2,2) + 2c] + 2\theta(1-\theta) m(0,1) + (1-\theta)^2 m(0,0),$$

subject to (2.3), (2.4) and (2.5). Observe that $V_2^{'''}$ is the problem that we have solved in Section 2. Therefore, eliciting the manager's private information does not improve on the solution.

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