Innovations and Venture Capital

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Abstract

This paper develops a theory why innovation often takes place in new firms that depend overproportionally on external finance usually supplied by specialist intermediaries called venture capitalists. It is argued that innovative projects are characterized by two features: uncertainty that is resolved through a learning by doing process and private benefits for the entrepreneur from running the project. If the effort choice of the entrepreneur is observable to the investor but not contractable the entrepreneur has an incentive not to supply effort to jam the learning process and to prevent the investor from terminating the project. If the investor cannot observe the effort choice his decision must be independent from the actual effort choice and the agency problem can be solved. While banks and internal capital markets suffer from this soft budget constraint problem venture capital funds are immune to it. Because they only have a limited amount of capital new, uninformed investors have to be found to continue the project. This hardens the budget constraint.

Keywords: Contract Theory, Corporate Finance, Venture Capital

JEL-Classification: G24, G31, D82

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"We had to push our device over one major technical hurdle (...). I estimated it would take \$8 million. When I was told we had \$2 million and no more, I thought we were finished. (...) In the end, we did it for \$2 million (...). Looking back, if we had the \$8 million I might never have gotten our engineers to drop their pet projects to ensure the success of our principal product." [1]

1 Introduction

During the last decades many important innovations have taken place in start-up firms financed by venture capital[2]. The importance of external finance and venture capital is also supported by empirical studies. Rajan and Zingales (1998), for example, report that firms in innovative sectors depend overproportionally on external finance and Kortum and Lerner (1998) calculate that every Dollar of R&D financed by venture capital yields 5-10 times the number of patents of regular corporate R&D spending. This is puzzling given that venture capital funds are unlikely to match banks and internal capital markets in terms of capital available. With a limited amount of capital only few firms can be financed. This is expensive because there are economies of scale in monitoring a large portfolio of firms[3]. Therefore several venture capitalists share an investment[4]. But this is costly, too, because each of the venture capitalist has to spend money on screening the projects.

In this paper we will argue that an uninformed investor has a positive effect on the incentives of the entrepreneur because he provides a hard budget constraint by threatening credibly to shut down the project.[5] But the disadvantage of an uniformed investor is the lack of somebody monitoring the firm. The problem can be solved by delegating the monitoring to an intermediary with a limited amount of capital. This arrangement provides close oversight over the firm while delegating the decision whether to continue the project or not to uninformed outsiders in the form of institutional investors, who finance venture capital funds, or newly entering venture capitalists. The literature on venture capital[6] so far has

[1] Clayton, Gambill and Harned(1999) p.51

[2] Some of the most prominent ones are Apple, Intel and Microsoft.

[3] See Diamond (1984).

[4] See Lerner (1994) for an account of this practice called syndication.

[5] See Maskin(1999) for an overview over the literature on hard and soft budget constraints.

[6] See Sahlmann(1990), Gompers (1995), Lerner (1995), Gompers and Lerner (1998).

mainly focused on the importance of monitoring and incentive schemes. This literature, however, cannot answer the question why banks or internal capital markets should not be able to replicate the incentive schemes and do the monitoring as well as a venture capitalist. We argue that banks and internal capital markets have too much capital to provide a hard budget constraint while small venture capital funds can do so.

In the following we briefly outline the basic intuition for our results. The first new finding of this paper is that a well informed investor can have a soft budget constraint problem. We assume that there are good and bad projects and that the type is revealed to all participants only through a learning by doing process. I.e. if the investor puts up capital and the entrepreneur exerts effort there is a good or a bad signal. In the first case monetary returns are disbursed in the latter it is efficient to liquidate because the project is very likely to be of low quality. If one of the inputs is missing there will always be a bad signal, which does not convey any information. Moreover, the investor is only interested in monetary returns while the entrepreneur enjoys a benefit from running the firm. Now suppose after investment there has been a bad signal that could be due to lack of effort or a low quality of the project. If an investor could commit to terminating the project after a bad signal no matter what the effort of the entrepreneur was the entrepreneur will work hard to avoid this. However, if the investor can observe the effort choice he will not be able to hold up the commitment in the case when the entrepreneur has not exerted effort. The reason is that the investor now knows that the bad signal was due to the lack of effort. In this case the bad signal does not convey any bad news and it is profitable for him to invest again. If the private benefit from running the firm is worth more to the entrepreneur than her share in possible profits she will exploit this soft budget constraint.

The second result of this paper is that the investor can credibly commit to liquidate the firm after a bad signal if he avoids observing the effort choice. In this case his continuation decision only depends on his beliefs about the effort choice and not on the action itself. Therefore, the only consequence of shirking is that the entrepreneur foregoes the chance of getting her share of profits in case of success. Thus it is optimal to work hard no matter what the investors beliefs are. The uninformed investor in turn knows that in equilibrium failure was due to a bad project and will shut down the firm.

The dilemma is that a well informed investor, who is necessary for monitoring, cannot secure a hard budget constraint for the entrepreneur. Our third result suggests an institutional solution to the problem in the form of delegating the monitoring decision to an investor with a limited amount of capital (i.e. a venture capitalist). He will run out of capital at some point and new, uninformed investors, who ensure a hard budget constraint, have to be found to keep the project going. This problem will occur with projects that are in need of close supervision by the investors and are characterized by big private benefits to the entrepreneur and a high probability of failure. All this is typical for innovative projects.

Bergemann and Hege (1998) emphasize the importance of the learning process, albeit in an asymmetric information environment. The soft budget constraint problem goes back at least to Kornai (1979). Schmidt (1995), Cremèr (1995) and Faure-Grimaud (1999) discuss settings different from ours, in which less information helps to harden the budget constraint. Most closely related to this paper is Dewatripont and Maskin (1995), who show that investors may profit from being able to commit not to refinance projects. They, however, assume "small banks" that can credibly commit not to refinance projects, of which they know that they are profitable. They do not explain why small banks should not be able to raise new capital in the face of a profitable investment possibility.

The rest of the paper is organized as follows. Section 2 introduces a simple model of investment and learning, which abstracts from the monitoring problem. In Section 3 we give necessary and sufficient conditions for the soft budget constraint problem to occur for the well informed investor. Section 4 extends the model to include the monitoring problem. Section 5 concludes. Most proofs are relegated to the appendix.

2 The Basic Model

There is a riskneutral entrepreneur, who has an idea for a project, but lacks the capital to pursue it. The project requires two types of inputs: capital investment of one (normalized) unit of capital and effort that can only be supplied by the entrepreneur and is for now assumed to be costless to her. This assumption is for simplicity only, and will be relaxed in Section 4. Both inputs are either supplied or not, thus there is a binary choice for the entrepreneur as well as for the investor. Moreover, there are good and bad projects. Depending on the supply of inputs, good and bad projects have different distributions of monetary payoffs. The random monetary payoff $\tilde{R}$ can take on two realizations 0 or R. The monetary benefit need not be disbursed immediately. It only matters that no money is disbursed before there is success so that the entrepreneur cannot accumulate wealth and that monetary returns are verifiable at some point. Therefore R could be some milestone after which the project enters a new phase. The probabilities for a realization of R depend on the supply of inputs and the quality of the project. The probability for success is 0, unless both inputs are supplied and the project is good. In this case there is a probability of success of γ. This implies especially that the distributions for good and bad projects are identical, as long as one of the two inputs is missing. This assumption is stronger than needed. It suffices that effort increases the probability of success.

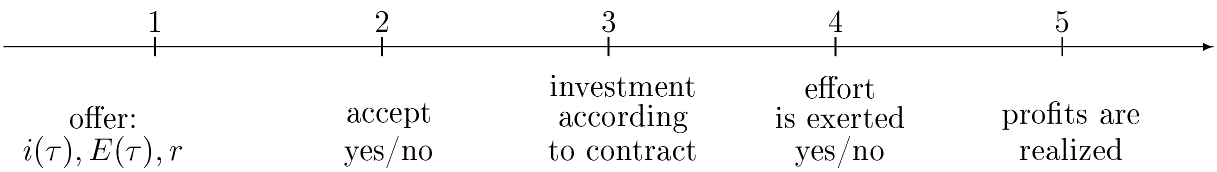
In addition to the possible monetary payoff there is a deterministic private benefit of b for the entrepreneur if the investor puts up the one unit of capital. In case of success there is an additional private benefit of B. Finally there is a common prior regarding the probability of the project being good, which is denoted by λ_0. The project can be undertaken repeatedly as long as there has not been a realization of R (success). In each period the investor and entrepreneur (re)negotiate a financing, decide whether to invest and exert effort or not. Periods are denoted by t. More precisely, each period begins with a (renegotiation) offer by the entrepreneur, which is subsequently either accepted or rejected. If it is rejected any existing contract remains valid. If no contract exists a null contract (no investment in all future periods) is assumed to be the default option. Then there is first the investment decision by the investor and then the effort choice of the entrepreneur. Finally, the profit is realized and is shared according to the contract. Before describing the timing in more detail we specify the contracting environment to derive the set of all admissible contracts.

First of all investment is observable by both parties and verifiable by the courts. A contract offered at time t specifies investment depending on time τ (relative to t) $i(\tau) \in \{0, 1\}$.[7] Here and in the following we omit the fact that every contract also conditions trivially on whether there has been success or not. In addition a contract specifies a series of sharing rules, where $E(\tau)$ is the payment to the entrepreneur if there is success in period τ. I then denotes the respective payment to the investor, i.e.: $R - E$. Finally, the contracting parties decide on

[7] Allowing for contracts specifying random investments does not change the results while complicating the exposition considerably.

the, so called, investment regime $r \in \{0,1\}$: $r = 0$ means that the investor cannot observe the effort choice of the entrepreneur, while $r = 1$ means that he can. The restriction that the regime choice in a contract is once and for all and cannot be conditioned on τ, seems very realistic, given that changing the investment regime is a complicated task. Besides, the qualitative results do not depend on it. Finally, it is assumed that communication is too costly and that contracts therefore cannot condition on messages.

The following figure depicts the exact timing of one period of the game:



There is a discount rate of $\delta < 1$ per period and the following assumption is made with respect to the size of the private benefit in case of success:

$$B = \frac{\delta b}{1-\delta} \tag{1}$$

This amounts to assuming that the entrepreneur stays with her company in case of success or that she writes a contract that compensates her for the foregone private benefits if she is fired. It is obvious that additional incentive problems arise if success means a loss of benefits to the entrepreneur but we are not going to investigate these problems further.

We can now turn to the updating process of the probability that the project is good. Let λ^t be the updated probability that the project is good at the beginning of period t.[8] Moreover, let $i^t = 1$ if the investor invests in period t and 0 otherwise. Finally, let $a^t = \gamma$ if the entrepreneur exerts effort in period t and 0 otherwise. The updating process given the project has not yet been successful at the end of period $t-1$ is given by:

$$\lambda^t(\lambda^{t-1}, a^{t-1}, i^{t-1}) = \frac{\lambda^{t-1}(1 - a^{t-1} i^{t-1})}{1 - \lambda^{t-1} a^{t-1} i^{t-1}} \tag{2}$$

If either $a^{t-1} = 0$ or $i^{t-1} = 0$ then $\lambda^t = \lambda^{t-1}$. Because the good as well as the bad project yield under these circumstances a profit of 0 nothing can be learned from the realization of the profit. In the following, we will call this event no signal in period $t-1$. If there has been

[8] Superscripts denote periods, whereas subscripts will later be used to denote states.

investment and effort ($i^{t-1} = 1$ and $a^{t-1} = \gamma$) there is either a profit of 0 and the updated probability is given by

$$\lambda^t = \frac{\lambda^{t-1}(1-\gamma)}{1-\lambda^{t-1}\gamma} \tag{3}$$

This is called a bad signal. Alternatively, there is a profit of R, in which case the game is over. This shall be called a good signal (or success). The value of λ^t at the beginning of a period will be called state of the system or just state in period t. Because the updating process occurs in discrete jumps and not continuously, the λ^t's can take on only certain values. These possible values depend on the parameters γ and λ_0. For the following it will be useful to define a sequence $\{\lambda_k\}_{k=0}^{\infty}$ containing all possible values of λ^t's, for given values of γ and λ_0. [9]

Definition 1 *Let λ_k denote the updated probability that the project is good given that there have been k periods in which the investor has chosen $i = 1$ and the entrepreneur has chosen $a = 1$, i.e.*

$$\lambda_k = \frac{\lambda_0(1-\gamma)^k}{1-\lambda_0+\lambda_0(1-\gamma)^k} \tag{4}$$

Whenever there is a bad signal in a period, the state proceeds to the next element in the above defined sequence. If there is no signal the state remains the same.

Let the prior λ_0 be high enough to make investment profitable and efficient at the outset. To make things interesting we assume that γ is big enough so that the updated probability after one bad signal (λ_1) is so low that investment is neither profitable for the investor, who ignores the private benefits to the entrepreneur, nor efficient from a social point of view.

Assumption 1

$$\lambda_0 \geq \frac{1-b}{\gamma(R+B)} \quad \textit{and} \quad \lambda_1 = \frac{\lambda_0(1-\gamma)}{1-\lambda_0\gamma} < \frac{1-b}{\gamma(R+B)}$$

This implies that the first best is reached if capital and effort are supplied in period one, but never thereafter.

[9] Of course, the state variable is only well defined if the investor and the entrepreneur can both observe the effort choice. If not the investor will hold a different belief that may be a convex combination of some elements of $\{\lambda_k\}_{k=0}^{\infty}$. In this case the belief of the entrepreneur shall be called state.

3 Informed versus Uninformed Investors

In this section we characterize the (perfect bayesian) equilibria of the above described game. It turns out that in every equilibrium the first best is reached. Besides, over the whole parameter range there are equilibria in which the investor chooses to remain uninformed while equilibria in which the investor becomes informed only exist for a limited parameter range. The following proposition contains the first result:

Proposition 1 *Suppose in period t the game is in state λ_0. If the entrepreneur proposes a contract in which the investor remains uninformed and invests in exchange for a share $I = \frac{1}{\gamma\lambda_0}$ then in any continuation equilibrium the first best is implemented.*

Proof. See Appendix.

The intuition for the proof is the following. Suppose there was a continuation equilibrium, in which the entrepreneur works with a probability smaller than one. Then she could deviate from her equilibrium strategy by working with probability one in period t and then, unless there has been success, return to her equilibrium strategy in the following periods. Now we have to distinguish three states of the world. In the first one the entrepreneur would have worked anyway given her equilibrium strategy. In this case there is no payoff difference between the equilibrium strategy and the deviation. In the second one the entrepreneur would not have worked according to her equilibrium strategy but does so without success given the deviation. In this case the investor cannot distinguish between the equilibrium strategy and the deviation and will play the same strategy in the continuation game. By definition of the deviation the entrepreneur returns to her equilibrium strategy and the expected payoffs in the continuation game are identical. Finally, we have to consider the state of the world in which the entrepreneur would not have worked on the equilibrium path but has deviated by exerting effort and has been successful. Her payoff is then $R+B-I_t$ and she has improved on her equilibrium strategy by deviating. The reason is that the payoff available to both players $R + B$ is bigger than the expected value of the returns in any continuation game and the share of the investor (I_t) is smaller than in any following round, because the investor must always break even in equilibrium and because his beliefs about the project deteriorate he will get a bigger share in later rounds. In fact this proposition is quite powerful and the following corollary follows immediately.

Corollary 1 *In any equilibrium the first best will be reached.*

Proof. In the first period the entrepreneur can always propose the above suggested one period contract, which will be accepted by the investor. It implements the first best and gives the whole surplus to the entrepreneur. If there are other equilibria they must also give her the same payoff because otherwise she would deviate to proposing this contract. Therefore any sequence of contracts that is used in equilibrium must implement the first best. ||

Given that effort is assumed to be costless the only reason why the entrepreneur could not want to work is that she tries to influence the investors belief in case of no success. As long as the investor holds the belief that the entrepreneur has exerted effort it is rational to terminate the project after one period without success and there is no incentive to shirk. We have shown that he will always hold this belief in equilibrium if he is uninformed of the effort choice of the entrepreneur.

It remains to be shown that there are parameter values for which no contract in which the effort choice is observable to the investor implements the first best. This implies that for projects with these parameter values only contracts that make effort unobservable are chosen in equilibrium. The reason why an informed investor cannot induce the entrepreneur to work hard is that the entrepreneur knows that after no success the investor will not revise his belief downwards if he has observed that the entrepreneur has shirked. Hence, he will be willing to refinance the project for another period. The entrepreneur trades off the gain from another period of sure private benefits against the foregone possibility of success. If the private benefit is high and the probability of success low she prefers the former and will not work hard.

Proposition 2 demonstrates for which parameter values simple one period full information contracts can implement the first best. We then check that the parameter range cannot be extended by using more complicated long term contracts, in which the investor is informed.

Proposition 2 *One period, full information contracts can implement the first best, if and only if*

$$(1-\delta)\left[\gamma\lambda_0 R - 1\right] \geq (1-\gamma\lambda_0)\delta b. \tag{5}$$

In this case there exist equilibria, in which full information contracts are used.

Proof. Sufficiency is proved by backward induction. If the belief λ^t drops below λ_0 the investor will reject any offer the entrepreneur could make. Consider any subgame with state λ_0 and assume the entrepreneur has suggested a one period contract, in which there is investment in exchange for a share $I = \frac{1}{\gamma\lambda_0}$ and suppose the investor has accepted this offer. If the entrepreneur exerts effort she gets

$$b + \gamma\lambda_0 \left(R - \frac{1}{\gamma\lambda_0} + B\right)$$

If she chooses $a = 0$ she gets

$$b + \delta \left[b + \gamma\lambda_0 \left(R - \frac{1}{\gamma\lambda_0} + B\right)\right]$$

Thus, she prefers to exert effort if

$$(1-\delta)\left[\gamma\lambda_0 R - 1\right] \geq (1-\gamma\lambda_0)\delta b, \tag{6}$$

This is the condition given in Equation 5. Given the effort choice by the entrepreneur it is optimal for the investor to accept the offer. Because this offer is the lowest one the investor will accept it is the optimal offer for the entrepreneur.

To prove necessity consider the following deviation: the entrepreneur does not work after the above suggested contract has been offered to her in some period. From Proposition 1 we know that she will get $b + \gamma\lambda_0(R + B) - 1$ in any continuation equilibrium. Therefore, she will prefer to deviate if:

$$b + \delta[b + \gamma\lambda_0(R + B) - 1] > b + \gamma\lambda_0(R + B) - 1$$

which again is equivalent to Equation 5. This also holds for contracts that offer less than the whole surplus to the entrepreneur. Contracts that offer her more are not possible in equilibrium because the investor would not break even and therefore would turn down any such offer even if the entrepreneur worked in the ensuing continuation equilibrium. ||

The entrepreneur shirks because she knows that she will get the whole surplus in the next period if necessary by using a contract that keeps the investor uninformed. And she prefers one more b to the loss from getting the whole surplus one period later. One could wonder whether this result depends on the restriction to one period full information contracts. In this case the players are in the same position as in the beginning and it is clear that the entrepreneur can secure the whole surplus. There could, however, be a long term contract that improves the investors fall back option (i.e. going on with the long term contract) in way so that the entrepreneur can no longer insist on getting the whole surplus in a renegotiation after not having worked. In this case she would loose more than just the costs of delay and may be willing to work. That this is not the case is shown in the next proposition. This task is complicated by the fact that before a possible renegotiation the players in this game obtain information about λ, on which they cannot contract at the beginning. Hence, we cannot without loss of generality restrict our attention to contracts that are not renegotiated on the equilibrium path. Instead, we have to check explicitly whether long term full information contracts that are renegotiated on the equilibrium path can achieve the first best.

Proposition 3 *No contract, in which the investor can observe the effort choice of the entrepreneur, implements efficient investment and effort on the equilibrium path if Inequality 5 is violated. In this case full information contracts will not be chosen in equilibrium.*

Proof. See Appendix.

The intuition of the proof is the following. To implement the first best one would have to construct a long term contract that pushes the continuation payoff of the entrepreneur after not exerting effort below the whole surplus. This, however, is impossible because we know from Inequality 5 that the entrepreneur must get even more than the whole surplus to have an incentive to work. Hence, in any period after t the entrepreneur either gets more than the whole surplus or she does not exert effort after there has been investment. In the latter case there will be scope for renegotiation, in which the entrepreneur has all the bargaining power and the investor has a fall back position (continue with the existing contract) that leaves him with a negative payoff. In this renegotiation the first best will be implemented and the investor will be pushed to his fall back position. Therefore, in the renegotiation the entrepreneur gets even more than the whole surplus and has no incentive to work hard in the period before the renegotiation. This implies that for parameters that violate Inequality 5 the entrepreneur cannot propose a full information contract under which she is going to exert effort. Because she is the residual claimant she will want to avoid that and she will employ a contract in which the investor cannot observe her effort choice.

For these results to be interesting we should be able to say something meaningful about the projects that violate Inequality 5. Obviously, if the project is good for sure, i.e. $\lambda_0 = 1$ the problem disappears and no information contracts have no advantage over full information contracts. This happens because the entrepreneur trades off the delay of the expected monetary return against an additional period with a private benefit b in case the project is terminated without success. However with $\lambda_0 = 1$ the project will always be continued until there is success. Therefore the entrepreneur has no incentive to slow down the learning process. Intuitively the same should hold if there is only a little uncertainty. To demonstrate this rigorously we consider a sequence of projects that all have the same net present value C and fulfill Assumption 1 but have less and less uncertainty about the quality. We show that for any net present value C Inequality 5 holds if λ_0 is close enough to one, i.e. if the probability of a bad project is low enough.

We do this by letting λ_0 go to one while adjusting γ and R in a way that Assumption 1 is not violated and that the expected net present value of the monetary benefits is held constant at C. This means γ changes with λ_0 according to

$$\gamma = 1 - \frac{\lambda_1(1-\lambda_0)}{\lambda_0(1-\lambda_1)} \tag{7}$$

and R is adjusted according to

$$R = \frac{1+C}{\gamma\lambda_0} \tag{8}$$

We get the following result:

Proposition 4 *No information contracts can be strictly superior to full information contracts only if there is a sufficient amount of uncertainty and learning.*

Proof. Starting from some value that fulfills Assumption 1 let λ_0 go to one and γ evolve according to (7) while adjusting R according to (8). In the limit Condition 5 then reads:

$$\gamma\lambda_0 R - 1 = C \geq 0 \tag{9}$$

which is always fulfilled. Note that fixing λ_1 indeed is enough to to guarantee that Assumption 1 is satisfied. Because $\gamma\lambda_0 R - 1$ is constant and greater than zero there will always be investment in the first period. The project will be terminated after one trial as long as

$$\gamma\lambda_1 R - 1 < 0$$

The initial values of γ (called $\hat{\gamma}$) and R (called $\hat{R}$) were chosen in accordance with Assumption (1):

$$\hat{\gamma}\lambda_1\hat{R} - 1 < 0$$

Performing the above described comparative statics on γ, λ and R reduces the left hand side. Thus the project will indeed be terminated after one failed trial. ||

This is consistent with the fact that projects financed by venture capitalists are highly risky, especially in the sense that a large number of them are terminated and result in a total loss.[10]

A second result can be derived with respect to the effect of the size of the private benefits b:

Proposition 5 *No information contracts are strictly superior to full information contracts if and only if private benefits are sufficiently large.*

Proof. If b is zero Condition 5 will be violated but it will be fulfilled if b is large enough.||

An increase in b has two effects. It increases the benefits from running the firm but it also increases via Assumption 1 the value in case of success and therefore the cost of delay. To see why it has an unambiguous effect anyway note that there are only two possible outcomes. One is success at some point. In this case the entrepreneur gets a private benefit equivalent to a stream of b from period one to infinity. Delaying the project by not exerting effort does not change the payoff in these states of the world because she does not care if she gets b in one period because the investor refinances after shirking or because there has already been success. If the project is terminated without success, however, she gets an additional b in case of not working, because the firm is shut down at some point. This gain increases with b. Finally the probability of termination is not influenced by the effort decision because there always will be exactly one trial before λ drops too low and the probability of termination is $1-\gamma\lambda_0$. Given that independence, which is lost in case of liquidation, is a major motivation for most entrepreneurs it seems reasonable that b is indeed high for projects that are financed by venture capital.

[10] see Sahlmann (1990)

4 Effort Costs and Monitoring

The above analysis is unsatisfactory because so far we have concluded that the investor should remain uninformed. This clearly is an argument against financing innovative projects by banks or internal capital markets however it is neither clear why the same should not hold true in case of venture capitalists nor does it explain why new firms are not just left alone apart from checking whether a certain verifiable milestone has been reached before new capital is injected. To correct this we need to change the assumption that effort costs are zero so that monitoring may be valuable. Therefore, we introduce an effort cost c and a monitoring technology that if it is applied reduces the effort cost to zero. The idea is that c reflects the enjoyment the entrepreneur has from perks like pursuing his own research agenda in the laboratories of his firm instead of focusing on developing the actual product. This behaviour is assumed to be inefficient, i.e.

$$c < \gamma\lambda_0(R + B) \tag{10}$$

The monitoring technology implies that supervision can prevent the entrepreneur from engaging in activities that bring enjoyment to her but it cannot force her to focus on the project. Even under close supervision she can do nothing, which is not more pleasant to her than actually working but does harm the project. To make things interesting we have to assume that monitoring not only reduces the effort cost but also informs the investor of the effort choice of the entrepreneur. If c is too big an uninformed investor can no longer implement the first best. The reason is that he does provide a hard budget constraint but cannot monitor. This means the wealth constrained entrepreneur has to get a rent to have incentives to exert effort. If the whole surplus is too small she will not work hard without monitoring. The following proposition makes that rigorous[11]:

Proposition 6 *If $c > \gamma\lambda(R + B) - 1$ a contract that leaves the investor uninformed cannot implement the first best.*

Proof. The result follows immediately from the participation constraint of the investor, who only invests if

$$\gamma\lambda_0 I_0 \geq 1$$

[11]Note that that the entrepreneur is assumed to be necessary for the project and cannot be fired.

and the incentive constraint of the entrepreneur, who only works if

$$\gamma\lambda_0(R + B - I_0) \geq c$$

||

Now we see that neither banks or internal capital markets, who are plagued by the soft budget constraint problem, can implement the first best nor is it a solution to just leave the firm alone. As already indicated in the introduction the institutional solution lies in delegating the monitoring task to an intermediary that has just enough capital for one period[12] If the project fails and does not deliver a verifiable milestone new, uninformed investors will be unwilling to inject money. This hardens the budget constraint, while the monitoring is done by the venture capitalist.

5 Discussion and Concluding Remarks

One could wonder if the venture capitalist had an incentive to communicate credibly the true state λ in case the entrepreneur shirked. This would undermine the commitment not to refinance the firm. Under a typical venture capital contract the venture capitalist does not contribute a lot of capital (usually around 1%) but gets a considerable share of profits (around 20-30 %) as so called "carried interest"[13]. Such a contract while giving him excellent incentives to monitor vigorously also induces a propensity to gamble for resurrection. I.e. even if λ is too low for the project to be profitable for the investors the venture capitalist has an incentive to carry on. If the project ultimately fails only the investors loose. If there is success the venture capitalist gets his share. This property of the contract would normally be regarded as a disadvantage. Here it may well be intended to prevent the venture

[12] This is stronger than needed. It is enough that the venture capital fund has so little capital that it is sufficiently likely that there is not enough capital left to completely finance another trial. In reality venture capital funds have for reasons mentioned earlier a portfolio of firms and it is uncertain how much capital exactly is needed for each firm to reach the next milestone. This means that venture capital funds sometimes may have capital left to refinance some of their projects. However, they do not have enough capital to guarantee this for all projects in all states of the world. In this context it is especially important that venture capital funds are not allowed to finance projects out of returns of successful projects. These must be distributed to the investors.

[13] Sahlmann (1990)

capitalist from being able to credibly communicate his knowledge regarding the quality of the project.[14]

The model assumes that the investor as well as the entrepreneur are risk neutral. While this is a standard assumption on the side of the investor, who should be well diversified, it seems to be very problematic concerning the entrepreneur. It turns out, however, that introducing risk aversion on the side of the entrepreneur rather strengthens the case for no information contracts. Risk aversion will raise the question of optimal risk sharing. One would like to insure the entrepreneur against the risk involved in the project. While this can be done with the no information contract it is much more difficult with a full information contract because payments conditional on success are important to give the right incentives.

In the model the entrepreneur has all bargaining power initially as well as in all the renegotiations. Giving the investor bargaining power in all negotiations, however, does not affect the results. The incentive to shirk derives from getting an additional period with a private benefit, while its costs are that the entrepreneur gets her share of the surplus later. We have shown that even if she gets the whole surplus she may have an incentive to delay the project. These incentives will grow stronger if she does not get the whole surplus. A fact that seriously limits the ability of the investor to profit from his bargaining power under full information contracts. A similar problem does not occur under a no information regime. Thus there is an even bigger incentive for the investor than for the entrepreneur to propose a no information contract if he can do so.

Our analysis suggests that a hard budget constraint is essential when financing innovative projects. This can be achieved by uninformed investor that demand verifiable results. Quite generally, small firms under severe pressure from impatient outside investors with a limited amount of capital may be better suited to pursue innovative projects than large corporations or firms in long term relationships with banks.

[14] Of course, one could design a revelation mechanism that induces truth telling. This mechanism, however, would have to leave a rent to the venture capitalist, which could, depending on the venture capitalists contract, outweigh the gains from another period of investment.

6 Appendix

Proof of Proposition 1

Suppose the game is in period t and both players hold the belief λ_0. Denote the history of the game up to the begin of period t by h_t. Suppose at the beginning of t the entrepreneur has proposed a one period, no information contract that commits her to investment with probability one in exchange for $I = \frac{1}{\gamma\lambda_0}$ and the investor has accepted. We will show that there is no equilibrium in the ensuing subgame, in which the entrepreneur chooses to work with probability $q_t < 1$. We will do this by showing that she can always improve her payoff with the following deviation: work in t with probability one and if there is no success imitate the equilibrium strategy from $t+1$ onwards. The pair of strategies that form the proposed continuation equilibrium from $t+1$ on will be denoted by $\sigma = \{\sigma^E_{t+1}, \sigma^I_{t+1}\}$. Let $H(t+1+i, j)$ with $j \leq i$ be the set of histories h_{ij} that lead to state j in period $t+1+i$ starting from history h_t in period t. Then the expected present value of the payoff from the continuation equilibrium given that the project is indeed of good quality (Q^g) can be written as:

$$\Pi^g_{t+1} = \sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^g, \sigma_{t+1}\}\; p(h_{ij}, \sigma_{t+1})\; [b + q(h_{ij}, \sigma_{t+1})\; \gamma\; (R + B - I(h_{ij}, \sigma_{t+1}))] \quad (11)$$

Unless there has been success in an earlier period the game in period $t+1+i$ is in a state $j \leq i$. This state must have been reached by a history $h_{ij} \in H(t+1+i, j)$ Given this history and given the strategies σ_{t+1} there are probabilities for investment $(p(h_{ij}))$, effort $(q(h_{ij}))$ and success (γ) in period $t+1+i$. Moreover, the share the entrepreneur gets in case of success is given by $E(h_{ij}, \sigma_{t+1}) = R - I(h_{ij}, \sigma_{t+1})$. Thus we can calculate the expected gain if success occurs after history h_{ij}. This gain is then weighted with the probability for h_{ij} and discounted to get a contribution to the total continuation payoff. First we sum these contributions over all histories that lead to state j in period $t+1+i$, then over all periods from $t+1$ onwards and finally over states to get the present value of the expected continuation payoff. Likewise, the expected present value of the payoffs conditional on the project being bad $(Q^b)$is:

$$\Pi^b_{t+1} = \sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^b, \sigma_{t+1}\}\; p(h_{ij}, \sigma_{t+1})\; b \quad (12)$$

Let $H'(t+i, k+j)$ be the set of histories that is constructed by replacing every element h_{ij} of $H(t+i, k+j)$ with an element h'_{ij} that is identical to h_{ij} apart from the fact that the entrepreneur has exerted effort in period t, even in the cases in which she would not have done so on the equilibrium path. Because the investor cannot distinguish any h'_{ij} from the respective h_{ij}, his strategy in the continuation game conditional on no success in period t must still be σ^I_{t+1}. The strategy of the entrepreneur is by definition of the deviation σ^E_{t+1}. Hence, it is easy to see from (11) and (12) that the continuation payoffs from period $t+1$ onwards, conditional on the project quality are the same if the entrepreneur has unsuccessfully exerted effort in period t as if she had not exerted effort. Moreover, if the project is bad exerting effort in period t does not affect the payoff. Therefore it suffices to show that the entrepreneur is strictly better off by supplying effort if the project is good and if she is successful in period t. In this case she gets:

$$R + B - \frac{1}{\gamma\lambda_0} \tag{13}$$

Because σ_{t+1} is an equilibrium the investor must get a payoff of zero. This implies:

$$\begin{aligned} \lambda_0\gamma \textstyle\sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^g,\sigma_{t+1}\}\; p(h_{ij},\sigma_{t+1})\; q(h_{ij},\sigma_{t+1})\; I(h_{ij},\sigma_{t+1})) = \\ \lambda_0 \textstyle\sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^g,\sigma_{t+1}\}\; p(h_{ij},\sigma_{t+1})\; q(h_{ij},\sigma_{t+1}) + \\ (1-\lambda_0) \textstyle\sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^b,\sigma_{t+1}\}\; p(h_{ij},\sigma_{t+1})\; q(h_{ij},\sigma_{t+1}) \end{aligned} \tag{14}$$

If the project is good in each period there is a positive probability that the game ends with success. Therefore the following holds:

$$prob\{h_{ij}|Q^b,\sigma_{t+1}\} \geq prob\{h_{ij}|Q^g,\sigma_{t+1}\} \tag{15}$$

Using this and plugging into (11) yields:

$$\sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^g,\sigma_{t+1}\}\; p(h_{ij},\sigma_{t+1})\; [b + q(h_{ij},\sigma_{t+1})\; \gamma\; (R + B - I(h_{ij},\sigma_{t+1}))] \tag{16}$$

$$\leq \sum_{j=0}^{\infty}\sum_{i=j}^{\infty}\delta^i \sum_{h_{ij}\in H} prob\{h_{ij}|Q^g,\sigma_{t+1}\}\; p(h_{ij},\sigma_{t+1})\; [b + q(h_{ij},\sigma_{t+1})\; \gamma\; (R + B - \frac{1}{\gamma\lambda_0})] \tag{17}$$

Because (17) is at least as big as (13)

$$\begin{aligned} R + B - \tfrac{1}{\gamma\lambda_0} \geq \Pi^g_{t+1} \quad \Rightarrow \\ R + B - \tfrac{1}{\gamma\lambda_0} > \delta\Pi^g_{t+1} \end{aligned} \tag{18}$$

This in turn means that the entrepreneur prefers to exert effort given that the project is good. If the project is bad she is indifferent. Hence, overall, she strictly prefers to exert effort. $\|$

Proof of Proposition 3

Let V^{max} denote the whole surplus in the first best case, i.e.:

$$V^{max} = b + \gamma\lambda_0(R + B) - 1$$

We know from Proposition 2 that one period full information contracts do not implement the first best if inequality (5) does not hold. The reason is that the entrepreneur prefers to get $b + \delta V^{max}$ to V^{max}. Note that her incentive to deviate grows even stronger if she gets a continuation payoff of more than V^{max} after deviating. Therefore any long term, full information contract that implements effort with probability one in the first period must push the continuation payoff after not working in period one below V^{max}. It will be shown, however, that for any long term contract the continuation payoff will be at least V^{max}. This is done by working backwards through the first contract of any series of equilibrium contracts.

Let T be the last period in which the first contract requires investment. Now consider the subgame in which the entrepreneur has never worked in the first $T-1$ periods such that $\lambda^T = \lambda_0$. If $\lambda^{T+1} = \lambda_0$ i.e. if the entrepreneur does not exert effort although there has been investment her continuation payoff is V^{max}. The threatpoint in the renegotiation at the beginning of period T is to go on with the old contract in period T. Under this contract and given that investment takes place it is either optimal for the entrepreneur not to work and to implement the first best starting in period $T+1$. In this case she gets $b + \delta V^{max} > V^{max}$ and the investor gets a payoff of -1 in this period and zero thereafter. If,however, the entrepreneur chooses to work she must get at least a continuation payoff of $b + \delta V^{max} > V^{max}$, which in turn implies a share E_T so high that the investor cannot break even. Therefore again his threatpoint is negative. Renegotiation at the beginning of period T will then implement the first best and push the investor to his (negative) threatpoint possibly by side payment. I.e. the continuation payoff at the beginning of period T (V_T^c) is even bigger than V^{max}.

Note that if in any period $t < T$ with a state $\lambda^t = \lambda_0$ the continuation payoff after shirking

(V_{t+1}^c) is bigger than V^{max} then the continuation payoff at the beginning of this period V_t^c is also bigger than V^{max}. To see this consider a period $t < T$, in which the contract specifies investment. If the entrepreneur does not exert effort he gets $b + \delta V_{t+1}^c$, where $V_{t+1}^c \geq V^{max}$ and the investor gets a negative payoff. If there is no investment the investors threatpoint is $\delta(V^{max} - V_{t+1}^c)$, which again is negative. In both cases the entrepreneur can secure a payoff V_t^c of more than V^{max}.

Consequently under any full information contract the continuation payoff at the beginning of period 2 must be bigger than V^{max} and it follows from Proposition 2 that long term full information contracts do not implement the first best.

It remains to be shown that an infinite contract is not optimal. Consider the last period of any contract. From the above argument it is clear that adding a period, in which there is investment, cannot improve the bargaining position of the investor, which would be necessary to remedy the inefficiency. ||

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