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Working Paper

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Manuskripte aus den Instituten für Betriebswirtschaftslehre der Universität Kiel, No. 556

Provided in Cooperation with:

Christian-Albrechts-University of Kiel, Institute of Business Administration

Suggested Citation: Houben, Eike (2002) : Venture capital, double-sided adverse selection, and double-sided moral hazard, Manuskripte aus den Instituten für Betriebswirtschaftslehre der Universität Kiel, No. 556, Universität Kiel, Institut für Betriebswirtschaftslehre, Kiel

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Venture Capital,
Double-sided Adverse Selection,
and Double-sided Moral Hazard[†]

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First Version: March 2002

This Version: December 2002

[†] I am grateful to Thomas Elendner, Peter Nippel, Roland Scheinert, Felix Streitferdt and seminar participants at the Universities of Bochum and Kiel, the Kiel Institute of World Economics, the 14th Australasian Finance and Banking Conference in Sydney 2001, the Annual Meeting of the Association Française de Finance in Strasbourg 2002 and the 14th APFA / PACAP / FMA Finance Conference in Tokyo 2002 for helpful comments and suggestions on an earlier draft of this paper. Financial support by Deutsche Forschungsgemeinschaft is gratefully acknowledged.

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Abstract

The paper offers a new explanation for the widely observed use of redeemable and convertible preferred stock in venture capital finance. Redeemable and convertible preferred stocks can be used to endogenously allocate cash flow and control rights as a function of the state of nature, the entrepreneur's and venture capitalist's effort, and the signals each player has revealed about his private information regarding the project's perspectives. This property can be used to induce both players to reveal their private information truthfully and to spend the efficient effort. This result holds irrespective of the assumed distribution function of the state of nature. The model is consistent with the observation that conversion is often automatic and that there is an inverse correlation between risk and control rights. Furthermore, it explains why venture capitalists can earn positive expected returns in a competitive venture capital market.

JEL Classification: D23, D82, G24, G32

Key words: venture capital, moral hazard, adverse selection, signaling

1 Introduction

The market for venture capital in Germany has grown tremendously in the past few years. In the year 2000 the volume of venture capital funds rose 47.6 % up to more than 20.1 billion Euro while the invested capital was up 43.1 % to nearly 11.5 billion Euro.¹ In comparison to 1999, where the growth rates were 43.2 % and 41.7 %, respectively, this is a further acceleration of the growth of the German venture capital market, and expresses the increasing importance of venture capital for the economy.

However, the financing of start-up companies is bound up with special problems resulting from the extreme information asymmetries between the entrepreneur and the venture capitalist. In our view, these information asymmetries are double sided, i.e. not only the entrepreneur may have a superior information about the value of the investment project resulting from his R&D, but also the venture capitalist may have one. At first glance this is surprising since the entrepreneur is the one who knows his project best. But besides the project's technological quality its success probability – and hence its value – also depends on its economic quality. With economic quality we mean the economic viability of the project, i.e. the question whether there is a market for the project at all, and how big is the competition on this market. In this respect the venture capitalist may have a superior information due to his industry expertise. Together the two kinds of quality determine the project's total quality.

To value the project properly both parties should reveal their private information truthfully. However, it may be advantageous for each side to misstate its private information. By overstating his information the entrepreneur obtains a bigger stake in the financial return of the company since the contribution of his project idea to the value of the project increases. Furthermore, if the entrepreneur receives a private benefit from running the company he can possibly achieve by overstating that also a project with a negative net present value is financed. For the venture capitalist understating his private information can be advantageous since it increases his stake in the financial return of the company. That holds especially if the stake of the venture capitalist is determined by the ratio of his capital contribution to project value. Without understating the venture capitalist gets only his reservation utility.

Besides its technological and economic quality the success, and thus the value, of a start-up company crucially depends on the efforts spent by the entrepreneur and the venture capitalist. On the side of the entrepreneur there can be an incentive problem. While there

¹ BVK (2001).

might be no doubt about the entrepreneur working hard the allocation of his effort may be inefficient. For example the entrepreneur may spend too much time with R&D and too few with marketing, accounting, etc.²

But there may also be an incentive problem on the side of the venture capitalist. As Gorman and Sahlman (1989) report, on average a venture capitalist spends more than one hundred hours a year in consulting a portfolio company. This consulting is one of the main differences between venture capital financing and standard debt or equity financing. The consulting activity of the venture capitalist is an important success factor since entrepreneurs often lack the ability to run a company on the "business" side, i.e., doing marketing, accounting or recruit staff. However, since this counseling is expensive the venture capitalist may have an incentive to spend too few effort if his stake in the company's returns is low.

Since the efficient levels of consulting and entrepreneurial effort may depend on the company's future perspectives, a truthful revelation of the private information is not only necessary for a proper valuation of the company but also for an efficient effort decision.

To solve the truth-revealing and the effort incentive problem special financing contracts are needed. Gompers (1997) and Kaplan and Strömberg (2001) report that convertible securities are widely used in venture capital finance, and that there is often a separation of cash flow and control rights. In our model, we offer an explanation for these stylized facts. It is shown that with a redeemable preferred and a convertible preferred stock contract the private information of both players is revealed truthfully, the efficient investment decision is made,³ and the efficient efforts are implemented.

The economic intuition behind this result is that with a redemption and a conversion clause, respectively, the incentives of the entrepreneur and the venture capitalist can be aligned. This alignment results from the state contingent allocation of the cash flow and control rights inherent to redeemable and convertible preferred stock contracts. The basic mechanism is that conversion is profitable for both players: the entrepreneur gets back control and can then consume private benefits, while the venture capitalist can raise his stake in the company's cash flow. By designing the conversion clause such that conversion can take place only if the efficient decisions have been taken by both players the efficient solution is achieved. The same holds for the redemption clause.

To make our solution clear suppose that the efficient investment decision and the efficient efforts depend on the project's future perspectives, i.e. the state of nature which is de-

² See Schmidt (2000) for this point.

³ That is to start or not to start the project.

terminated by the project's technological and economic quality. In contrast to the huge amount of incomplete contract approaches which can be found in the literature, we assume that the state of nature is already determined at the time of contract closing. However, the state of nature is not common knowledge. Instead, the entrepreneur knows only the project's technological quality while venture capitalist knows only the economic one. By combining their private information, the state of nature can be completely revealed.

In our model there are three possible states of nature. In the bad state the project should not be started since the returns are not sufficient to recoup the investment expenditure. In the medium state the project should be started but effort should be low. Only in the good state of nature both parties should spend high effort.

For the entrepreneur starting the company is a purpose of its own especially if the entrepreneur invests only a little or even nothing of his own capital. That is because he derives private benefits from the control of "his" company.⁴ Thus, there is an incentive for the entrepreneur to overstate his information in order to induce the venture capitalist to finance the company. With a preferred stock contract the control is shifted to the venture capitalist and hence the consumption of private benefits is prevented. However, this shift is inefficient if the project is a success or at least no total loss. With a properly designed redemption or conversion clause the entrepreneur has the opportunity to get back control in the medium and the good state of nature if he told the truth.

Furthermore, these clauses also prevent a misstating by the venture capitalist. If the venture capitalist overstates his private information he cannot convert and thus his stake in the company's cash flow is limited at a lower level. If he understates his preferred stocks are redeemed at a low price and hence the venture capitalist cannot profit from a higher than anticipated cash flow. Hence, his stake in the company's return is limited at a lower level.

To our knowledge this is the first paper analyzing a double-sided adverse selection and moral hazard problem simultaneously. There is one paper by Maskin and Tirole (1992) which focuses on the contract design if both players have relevant private information. However, they do not take a moral hazard problem into account.

Although there is yet no paper dealing simultaneously with a double-sided adverse selection and double-sided moral hazard problem, there is a huge amount of papers explaining the use of convertible securities in venture capital finance. For a survey of these papers we

⁴ See Westhead and Wright (1998).

refer to the surveys by Forman (1998) and Schertler (2000). Here, we just want to comment on two closely related papers.

Schmidt (2002) deals with a double-sided moral hazard problem in an incomplete contracting framework. He shows that with a convertible bond the first best effort can be implemented. As in our model, the project's return depends on the state of nature and the efforts spent by the entrepreneur and the venture capitalist. In contrast to our model, at the time of contract closing the state of nature is unknown to both parties. But it is revealed before efforts are spent and can be observed free of costs by each party. Furthermore, before the venture capitalist spends his effort he can free of costs observe the entrepreneur's effort. Schmidt also considers three possible states where spending effort by the venture capitalist is only efficient in the good state of nature. To provide the venture capitalist an incentive to spend effort in the good state he must be given a cash flow sensitive contract (equity). However, this destroys the entrepreneur's incentives. Schmidt shows that with a properly designed convertible bond this problem can be circumvented.

In the model by D'Souza (2001) at the time of contract closing the state of nature is unknown to the entrepreneur and the venture capitalist. But it is common knowledge that there are three possible states: bad, medium, and good. After the state of nature is realized only the entrepreneur can observe whether the medium or the good state appeared. In D'Souza's model only the venture capitalist has to spend effort. Since the efficient amount of effort depends on the state of nature the entrepreneur has to report the state of nature truthfully. D'Souza shows that a truthful revelation and an efficient effort spending can be achieved with a convertible security. A condition for this result to hold is that the entrepreneur can consume a sufficiently large private benefit in the medium state of nature.

The structure of our paper is as follows. In chapter two the basic model is presented. In chapter three we analyze how debt and equity contracts work in the special venture capital environment and show that they fail in solving the problems described. In chapter 4 we introduce proper designed preferred equity contracts which can solve these problems. In chapter 5 we analyze the impact of renegotiations on contract design and show the robustness of our results. In chapter 6 we conclude our paper.

2 The Model

A risk neutral entrepreneur E has access to an investment project which requires an investment of $I > 0$. Because E has no initial wealth he has to convince a venture capitalist (VC) to

provide I . The venture capital market is competitive and the discount factor is equal to zero. The resulting cash flow v from the project depends on the product quality $\theta \in \{\underline{\theta}; \bar{\theta}\}$ and on the perspectives of the product market $\eta \in \{\underline{\eta}; \bar{\eta}\}$. Since E is the technician we assume that he has a superior private information about the product quality, i.e., he knows the true state of θ . Since VC gained some experience in the venture capital market we assume that he has a superior private information about the perspectives of the product market, i.e., he knows the true state of η . The two private information form a Cartesian product defined as the the state of nature where⁵

$$\begin{aligned}(\underline{\theta} \times \underline{\eta}) &\rightarrow \omega_l \\(\underline{\theta} \times \bar{\eta}) &\rightarrow \omega_m \\(\bar{\theta} \times \underline{\eta}) &\rightarrow \omega_m \\(\bar{\theta} \times \bar{\eta}) &\rightarrow \omega_h\end{aligned}$$

Besides the state of nature the cash flow also depends on the effort $e \in \{\underline{e}; \bar{e}\}$ spent by E at cost of c_e and $c_{\bar{e}}$, respectively, and the effort $a \in \{\underline{a}; \bar{a}\}$ spent by VC at cost of c_a and $c_{\bar{a}}$, respectively. We interpret e as the effort invested in the technological running of the company, e.g. production, and will thus be provided by E . But E may lack the ability to run a company on the business side, e.g. marketing, accounting etc. This business expertise has thus be provided by VC and is modeled by a .

The project, if started, does not only yield a monetary return but also a private benefit B to E if and only if E has the control over the company. Thus, E is in control as long as he holds the majority of the voting rights and the company is not bankrupt.

Assumption 1: *The 12 possible cash flows are ordered as follows*

$$\begin{aligned}v(\omega_h, \bar{e}, \bar{a}) &> v(\omega_h, \underline{e}, \bar{a}) = v(\omega_h, \bar{e}, \underline{a}) > v(\omega_h, \underline{e}, \underline{a}) \\&> v(\omega_m, \bar{e}, \bar{a}) > v(\omega_m, \underline{e}, \bar{a}) = v(\omega_m, \bar{e}, \underline{a}) > v(\omega_m, \underline{e}, \underline{a}) \\&> v(\omega_l, \bar{e}, \bar{a}) = v(\omega_l, \underline{e}, \bar{a}) = v(\omega_l, \bar{e}, \underline{a}) = v(\omega_l, \underline{e}, \underline{a})\end{aligned}$$

where

$$1. \quad v(\omega_l, e, a) - I - c_e - c_a + B < 0 \text{ with } e \in \{\underline{e}; \bar{e}\} \text{ and } a \in \{\underline{a}; \bar{a}\}$$

⁵ We consider only three possible states since, as Sahlman (1990) reports, there is a three class pattern in the stylized facts: one third of all investments end in a total loss, 50 % recoup their investment, and only 15 % earn extraordinary returns.

2. $v(\omega_l, e, \underline{a}) - I - c_{\underline{a}} < 0$ with $e \in \{\underline{e}, \bar{e}\}$
3. $v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{e}} - c_{\underline{a}} + B > v(\omega_m, \bar{e}, \underline{a}) - I - c_{\bar{e}} - c_{\underline{a}} + B$
 $= v(\omega_m, \underline{e}, \bar{a}) - I - c_{\underline{e}} - c_{\bar{a}} + B > v(\omega_m, \bar{e}, \bar{a}) - I - c_{\bar{e}} - c_{\bar{a}} + B > 0$
4. $v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} > 0$
5. $v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{e}} - c_{\bar{a}} + B > v(\omega_h, \bar{e}, \underline{a}) - I - c_{\bar{e}} - c_{\underline{a}} + B$
 $= v(\omega_h, \underline{e}, \bar{a}) - I - c_{\underline{e}} - c_{\bar{a}} + B > v(\omega_h, \underline{e}, \underline{a}) - I - c_{\underline{e}} - c_{\underline{a}} + B > 0$
6. $v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} > 0$
7. $c_{\bar{e}} > c_{\underline{e}} \geq 0$ and $c_{\bar{a}} > c_{\underline{a}} \geq 0$

Assumption 2: $B > c_{\underline{e}}$

Assumption 1 states that an investment in the project should not be undertaken if both parties have received the bad signal. Even spending the high effort will not raise the cash flow in the bad state of nature. Furthermore, the cash flow will never be sufficient to compensate VC for his investment. If only one party has received a bad signal the project should be started but no one should spend the high effort. If both parties have received the good signal than the investment should be carried out and the high effort should be spent by both parties.

To make the model non-trivial assumption 2 expresses the relevance of the private benefits for E . Since B exceeds the cost of the low effort E always wants start the project.

The time structure of the model is as follows. At t_0 nature draws θ and η , and E and VC receive their private information. At t_1 E offers VC a (menu of) contract(s). If VC accepts I is invested. At t_2 E spends effort e and VC spends effort a . At t_3 the cash flow realizes and the contract is executed. By running the company E can consume his private benefits in the period from t_1 to t_3 if he is in control. As we will show with a convertible or redeemable security E may not be in control from t_1 to t_3 but only at point t_3 when and if conversion or redemption takes place. However, we assume that being in control only at t_3 is sufficient to consume private benefits. The time structure is displayed in figure 1.

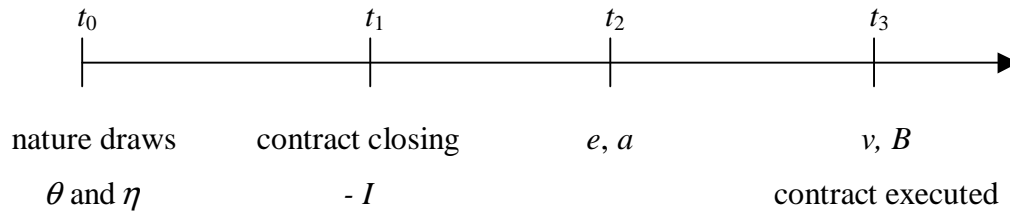


Figure 1: Time structure

From the time structure it becomes clear that a truthful revelation of the private information is a crucial necessity. That is not only because the decision whether the project should be started or not depends on the state of nature but also the efficient levels of effort. Thus, we analyze in the next section if a truthful revelation of the private information can be achieved in the perfect Bayesian-Nash equilibrium with classic finance contracts, i.e., straight debt and equity. After showing that this aim cannot be achieved with classic finance contracts we look at preferred stock contracts as a mechanism.

Before we do so we want to explain the contract offering and accepting stage in more detail. After receiving his signal E knows in which of the possible three states of nature the project is not in. But there are still two possible states of nature. Since E pursues the objective to reveal VC 's private information and to drive down VC to his reservation utility E has to offer two contracts designed for the two possible states. Depending on the signal received there are two possible menus of contracts which E could offer. The first one consists of a contract for the bad state of nature and one for the medium state of nature, the second one of a contract for the medium and a contract for the good state of nature.⁶ The first (second) menu should be offered if E has received the bad (good) signal. From E 's choice of menu VC can conclude the signal E has received. Thus, E transmits his private information through the menu of contracts offered. However, as we will show, with inappropriate designed contracts E may have an incentive to offer the "wrong" menu, i.e., the one which does not reveal his private information truthfully.⁷

⁶ Note that the first menu effectively consists only of the medium state contract. That is because in the bad state the cash flow is not sufficient to compensate VC for his expenditures. Hence, a contract for the bad state would never be signed.

⁷ As we will show, E has never an incentive to offer the first menu indicating that he has received the bad signal if he has received the good one. But E may have an incentive to offer the second menu even if he has received the bad signal. We refer to this behavior as overstating.

From the two contracts offered by E VC signs one. With his contract choice VC reveals his private information.⁸ If both parties transmit their private information truthfully the true state of nature can be concluded from the signed contract. We assume in our model that both parties believe in the equilibrium and choose their efforts according to the contract signed as long as they do not know for sure that the "wrong" one was signed. That is the case if the player lied.

3 Classic Finance Contracts

3.1 Debt contracts

With a debt contract VC receives a fix payment irrespective of the realized cash flow.⁹ To induce VC to sign a debt contract E must offer him a debt repayment obligation D which at least compensates VC for his investment I and his effort cost c_a .

To show that VC cannot always be induced to reveal his private information truthfully and to spend the efficient effort, suppose for simplicity that the project is of good technological quality, i.e. $\theta = \bar{\theta}$. Since E does not know whether the project is of good or bad economic quality but wants to drive down VC to his reservation utility, he offers two contracts. In designing the debt contracts E has to take VC 's participation constraints into account, which is in the medium state of nature

$$(1) \quad D_a - I - c_{\underline{a}} \geq 0$$

and in the good state of nature

$$(2) \quad D_b - I - c_{\bar{a}} \geq 0$$

since E then wants VC to spend the high effort. But because VC receives a fix payment independently from the realized cash flow he has no incentive to spend the high effort if $v(\omega_h, \bar{e}, \underline{a}) > I + c_{\bar{a}}$. Because then the debt is not at risk. Furthermore, since $c_{\bar{a}} > c_{\underline{a}}$ D_b must be

⁸ As we explained, above the first menu consists only of one contract. Hence, VC transmits his private information by accepting or rejecting this contract.

⁹ Of course, if the debt is risky VC 's payment depends on the state of nature.

larger than D_a . But then, VC will always choose D_b and thus overstates his private information if $\eta = \underline{\eta}$. Thus, we can state the following lemma.

Lemma 1: *With debt contracts VC cannot always be induced to reveal his private information truthfully and to spend the efficient effort.*

Proof: *The proof follows directly from the above argumentation.*

With a debt contract E cannot always be induced to reveal his private information truthfully, either. If he has received the bad signal $\underline{\theta}$ E has an incentive to overstate his private information. That is because in the bad state of nature E can by overstating assure himself his private benefit since the project is then carried out. Thus, the self-selection constraint of E in the bad state of nature,

$$(3) \quad \pi_{true}^E = 0 \geq \max[v(\omega_l, \underline{e}, \underline{a}) - D_a; 0] - c_{\underline{e}} + B = \pi_{false}^E,$$

is never fulfilled due to assumption 2. Thus, we can state the following lemma.¹⁰

Lemma 2: *With debt contracts a truthful revelation by E cannot be achieved if $\theta = \underline{\theta}$.*

Proof: *The proof follows directly from the above argumentation.*

3.2 Equity contracts

With an equity contract VC holds a linear stake α in the company's returns. In order to induce VC to sign an equity contract E must offer an equity which at least compensates VC for the investment of I and his effort cost c_a . If E has received the bad signal and offers only one contract for the medium state of nature, a truthful revelation by VC can be achieved with an equity contract. In contrast, if E has received the good signal and thus offers a contract for the medium and a contract for the good state of nature a truthful revelation by VC is not assured. It rather depends on the model's parameters, as it is stated in the following lemma.

¹⁰ See also Houben and Nippel (2001).

Lemma 3: *Depending on the model's parameters there can exist a menu of pure equity contracts inducing VC to reveal his private information truthfully and to spend the efficient effort given that E has received the good signal and reveals it truthfully. In achieving this it may be necessary to pay VC an information rent if $\eta = \bar{\eta}$.*

Proof: *See Appendix A.*

A necessary condition for a truthful revelation of VC's private information is that the equity stake for the medium state of nature is larger than the one for the good state. That is because otherwise VC could gain twice by overstating. On the one hand he raises his equity stake and on the other hand he induces E to spend the (inefficient) high effort which raises the cash flow.¹¹ But the equity stake for the good state must not be "too low" in comparison to the one for the medium state. Because dependent on the model's parameters VC might then have an incentive to understate his private information.

In order to induce VC to spend the high effort¹² or even to sign the contract in the good state of nature it might be necessary to offer him an equity stake higher than the one for the medium state of nature. Obviously, a truthful revelation of the private information and an implementation of the efficient effort is then not possible.

Furthermore, if it is not VC's participation constraint in the good state of nature which determines the size of the equity stake E has to pay an information rent in order to induce VC to select the truth-revealing contract and to spend the high effort, respectively.

We could introduce more assumption on the model's parameters in order to show under which conditions a solution exists. However, since our objective was to show that with a pure equity contract VC cannot always be induced to reveal his private information truthfully and to spend the efficient effort, we pay no further attention to this point.

Whether E can be induced to reveal his private information with pure equity contracts depends on the control rights associated with VC's equity stake. If VC is in control E has no incentive to overstate his private information if $\theta = \underline{\theta}$. That is because E can then never consume private benefits in the bad state of nature. However, granting VC control is inefficient.

But if control is left to E , overstating can no longer be prevented. That is because by overstating the project will always be started, even in the bad state of nature. Instead of getting no utility at all E gets his private benefits and a monetary return on his equity. In the me-

¹¹ We assume that E chooses his effort according to the contract chosen

¹² That is because VC chooses his effort according to his equity stake.

dium state E can by overstating raise his equity stake and the cash flow since by signing the good-state-contract VC is induced to spend the high effort.¹³ A pure equity contract can thus not be the solution to our model, as is stated in the following lemma.

Lemma 4: *With pure equity contracts overstating by E cannot be avoided if $\theta = \underline{\theta}$ and control is left to E . If control is shifted to VC pure equity contracts are inefficient.*

Proof: *See Appendix B.*

Obviously, a combination of debt and equity cannot be a solution to the problem, either. Because to induce E to reveal his private information truthfully control must be shifted to VC . However, this is inefficient. To conclude this section we can hence state the following proposition.

Proposition 1: *With debt and equity contracts it is not possible to simultaneously assure a truthful revelation of the private information, the implementation of the efficient efforts and the efficient allocation of control.*

Proof: *The proof follows directly from lemma 1, lemma 2, lemma 3 and lemma 4.*

4 Preferred stock contracts

In case of pure debt financing a truthful revelation fails because VC can guarantee himself a higher stake in the company's payoff by overstating his information. Furthermore, an implementation of the efficient effort cannot be achieved if $v(\omega_h, \bar{e}, \underline{a}) > I + c_{\bar{a}}$.

In case of pure equity financing there may exist a set of contracts inducing VC to select the truth-revealing contract and to spend the efficient effort. However, this result holds only for a special combination of the model's parameters. Furthermore, E has to pay VC an information rent if VC 's participation constraint in the good state of nature is not the binding constraint for the determination of the equity stake. Therefore, a different type of contract has to be found which reveals VC 's private information independent of the model's parameters, implements the efficient effort, and drives VC down to his reservation utility.

¹³ As we argued above, for a solution to exist a necessary condition is that VC 's equity stake in the medium state contract is higher than in the good state contract.

As we have shown above there is also an incentive problem on E 's side. Since with classic financial contracts E can always consume his private benefits, even in the bad state of nature, a truthful revelation of his private information fails. Furthermore, with pure equity contracts there may be an incentive problem in the good state of nature if E is not the sole residual claimant. Thus, a different type of contracts has to be found which reveals E 's private information truthfully and implements the high effort in the good state of nature.

In the following proposition we show how such contracts have to be designed to truthfully reveal the private information of each player and implement the efficient efforts in the perfect Bayesian-Nash equilibrium.

Proposition 2: *E offers VC the following menus of contracts which are truth-revealing and implement the efficient efforts on both sides if $B > v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a})$ and $v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \underline{e}, \bar{a}) + B > c_{\bar{e}} - c_{\underline{e}} + c_{\bar{a}} - c_{\underline{a}}$.*

- *If $\theta = \underline{\theta}$ E offers VC a redeemable non-voting preferred stock contract*

$$Z_n := \{P_n\}$$

which gives VC a preferred dividend of $P_n = I + c_{\underline{a}}$. Furthermore, the contract contains a redemption clause which gives E the right to redeem the preferred stock at price $P_n = I + c_{\underline{a}}$ instead of paying the dividend.

- *If $\theta = \bar{\theta}$ E offers VC a menu of contracts consisting of*
 1. *a redeemable voting preferred stock contract*

$$Z_m := \{P_m\}$$

which gives VC control and a preferred dividend of $P_m = I + c_{\underline{a}}$. Furthermore, the contract contains a redemption clause which gives E the right to redeem the preferred stock at price $P_m = I + c_{\underline{a}}$ instead of paying the dividend.

2. *and a convertible preferred stock contract*

$$Z_h := \{P_h, \alpha_p; s_p\}$$

which gives VC control and a limited preferred dividend of $P_h = I + c_{\underline{a}}$. Furthermore, the contract contains a conversion clause which gives VC the right to convert

his preferred stock into the fraction $\alpha_p = \frac{I + c_{\bar{a}}}{v(\omega_h, \bar{e}, \bar{a})}$ of the company's cash flow if the cash flow exceeds the strike $s_p = v(\omega_h, \bar{e}, \bar{a})$.

Before proving proposition 2 formally we want to give some basic economic intuition for it.

By offering just one contract E can credibly signal VC that he has received the bad signal. That is because E cannot profit from understating his private information by offering just one contract if E has received the good signal. Since VC then concludes from E 's contract choice that E has received the bad signal, he rejects the contract in the medium state of nature. E thus loses the opportunity to start the project. Although VC accepts the contract in the good state of nature, his incentive to spend the high effort is destroyed which is disadvantageous for E . Since E does not want to induce VC to spend the high effort in the medium state of nature, he can do no better than offering a redeemable non-voting preferred stock contract which fulfills VC 's participation constraint.

In contrast, offering the menu of contracts is no credible signal for receiving the good signal by E if the contracts are not properly designed. Furthermore, offering the menu of contracts leaves room for over- or understating by VC . Thus and since the contract for the good state of nature should induce VC to spend the high effort, the contract design must be more advanced.

As we have seen, in the bad state of nature the driving force behind E 's decision to start the company is his ability to consume private benefits. Thus, by shifting the voting rights to VC , E is prevented from consuming private benefits. Hence, he does not want to start an inefficient project. Technically, the shift of control is achieved by attaching all the voting rights, or at least the majority, to VC 's preferred stocks.

However, this shift of control is only efficient in the bad state of nature. E must be given the opportunity to get back the control in the medium and the good state of nature if he told the truth.

For the medium state this can be achieved with a redemption clause which gives E the right to redeem the preferred stock at an in advance determined price. By setting the redemption price higher than the cash flow in the bad state of nature E cannot profit from overstating

in the bad state of nature since he then lacks the money to redeem the preferred stocks.¹⁴ He thus does not get back control and due to the preferred dividend E does not receive a monetary return on his equity, either. Hence, E cannot gain by overstating.

Furthermore, a redemption clause limits VC 's cash flow participation. By understating VC can then no longer profit from the "unexpected" part of the cash flow since his preferred stocks are redeemed by E . Thus, if VC has received the good signal he does not want to sign the medium instead of the good state contract.

A simple redemption clause for the good state of nature cannot implement the efficient efforts since a redemption clause has the same payoff structure as straight debt. But with a conversion clause the efficient efforts can be induced on each side, if the strike is set at a cash flow level which can only be achieved in the good state of nature if both players have spent the high effort. With such a strike VC 's cash flow participation is limited to the limited preferred dividend if he spends only the low effort. Thus, he cannot profit from high cash flows. But E 's incentive to spend the high effort is strengthened too since by conversion he gets back control.¹⁵ Furthermore, by setting VC 's post conversion equity stake at a level at which he is exactly compensated for his expenditures E becomes the sole residual claimant. However, for an implementation of the efficient efforts it is necessary that the marginal returns exceed marginal costs which is expressed by the condition $v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \underline{e}, \bar{a}) + B > c_e^- - c_e + c_a^- - c_a$.¹⁶

But such a conversion clause does not only implement the efficient efforts, it also assures a truthful revelation of the private information. Given that one party overstates, the other party spends the high effort, which raises the medium state cash flow. But since in the medium state of nature the strike is missed for sure VC cannot profit from inducing E to spend the high effort by overstating his private benefit. In contrast, E may monetarily profit. That is because E receives all the cash flow above the limited preferred dividend. However, since the strike is missed VC cannot convert and E does not get back control. In his decision to overstate E thus faces a trade off which is represented by the condition $B > v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a})$. Hence, E does not overstate if the loss in private benefits exceeds

¹⁴ Note that if E overstates his private information in the bad state of nature, implying that VC has received the good signal, it is the medium state contract that is signed.

¹⁵ In general venture capitalists have special control rights attached to their preferred stocks like the right to determine the CEO. In case of conversion they lose these rights and control is shifted. However, if the preferred are converted into common stock, VC may hold a majority of the voting rights. To exclude this possibility we assume that in this case the preferred stocks are converted into non-voting equity.

¹⁶ At first glance it is surprising to interpret the private benefits as marginal return. But note that E can only consume private if the preferred stocks are converted.

the extra cash flow. It cannot be concluded from the assumptions whether $B > v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a})$ is fulfilled or not but it seems plausible to assume that it is.¹⁷

Proof: We have to proof that it is possible to reveal the private information of a player truthfully and to induce him to spend the efficient effort in the perfect Bayesian-Nash equilibrium. In the proof we have to distinguish two cases, $\theta = \underline{\theta}$ and $\theta = \bar{\theta}$.

1. Bad technological quality $\theta = \underline{\theta}$

If E has received the bad signal the project can either be in the bad or in the medium state of nature.

Bad state of nature

Suppose that both players have received the bad signal, such that the project is in the bad state of nature. From assumption 1 follows directly that VC has no incentive to overstate his private information if E offers just the contract Z_m . Since E 's contract choice indicates the bad state of nature accepting the contract would lead to a certain loss for him.

In contrast to VC , overstating may be advantageous for E . By overstating his private information E induces VC to sign the medium state contract Z_m and hence the project will be carried out. However, it is easy to show that this contract choice is disadvantageous for E . In the bad state of nature the cash flow is not sufficient to pay the preferred dividend since

$$(4) \quad P_m = I + c_{\underline{a}} > v(\omega_l, \underline{e}, \underline{a})$$

E does then not receive a payment on his equity. Thus, the only incentive to start an inefficient project is E 's ability to consume private benefits. However, E can do so only if he is control, i.e., he has the voting rights. But with a preferred equity contract the voting rights are shifted to VC . Since the cash flow is not sufficient to redeem the preferred stock E cannot get back the voting rights. Hence, he cannot consume private benefits.

¹⁷ Barclay and Holderness (1989) report that on average private benefits are around 20 % of company value. Although this number is derived from block trades, in our view it can also be applied to start-up companies.

Furthermore, starting an inefficient project is costly for E since he has to bear effort costs. His total payoff from lying and thus starting an inefficient project is then

$$(5) \quad \pi_{lie}^E = -c_e.$$

In comparison to this E 's payoff from telling the truth is

$$(6) \quad \pi_{true}^E = 0.$$

Obviously, telling the truth is a dominant strategy.¹⁸ It is also easy to see that E will never spend the high effort if the project is started.

Medium state of nature

Suppose now that VC has received the good signal and thus the medium state of nature occurred.

Let us first show that both players are interested in starting the project if E offers only the redeemable preferred stock contract Z_n . It is easy to see that VC 's participation constraint

$$(7) \quad \pi^{VC} = P_n - I - c_{\underline{a}} \geq 0$$

and E 's participation constraint

$$(8) \quad \pi^E = v(\omega_m, \underline{e}, \underline{a}) - P_n + B > 0$$

are both fulfilled for $P_n = I + c_{\underline{a}}$.

With the redeemable preferred contract VC has no incentives to understate his private information since this would imply a rejection of the contract although VC 's participation constraint is fulfilled. Understating would thus be irrational.

¹⁸ This result holds irrespective of the size of c_e . Even for c_e there is no reason to assume that E will overstate his private information.

By offering the menu of contracts and thus overstating E induces VC to choose the convertible stocks. Since the strike is missed for sure the preferred stocks are never converted, even if the high efforts are spent because

$$(9) \quad s_p = v(\omega_h, \bar{e}, \bar{a}) > v(\omega_m, \bar{e}, \bar{a})$$

E does then not get back control and cannot consume private benefits. However, by overstating E induces VC to spend the high effort which raises the cash flow in the medium state of nature in comparison to the case where the correct, i.e. the redeemable preferred stock contract Z_n is signed. Since VC is not compensated for spending the high effort the gain accrues completely to E . Thus, E 's payoff in the medium state is¹⁹

$$(10) \quad \pi_{lie}^E = v(\omega_m, \underline{e}, \bar{a}) - c_e - I - c_a.$$

If E tells the truth the redeemable preferred stock contract Z_n is signed. With this contract E is in control and can consume private benefits. His payoff from telling the truth is then

$$(11) \quad \pi_{true}^E = v(\omega_m, \underline{e}, \underline{a}) - c_e - I - c_a + B.$$

E thus prefers telling the truth if

$$(12) \quad \begin{aligned} \pi_{true}^E = v(\omega_m, \underline{e}, \underline{a}) - c_e - I - c_a + B > v(\omega_m, \underline{e}, \bar{a}) - c_e - I - c_a = \pi_{lie}^E \\ \Leftrightarrow B > v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a}) \end{aligned}$$

If (12) is not fulfilled in his decision to overstate E faces a trade off. On the one hand with lying E has to bear effort cost in the bad state of nature, and opportunity cost in the medium state of nature since he cannot consume private benefits. On the other hand his monetary return in the medium state rises. E 's choice then generally depends on the

¹⁹ Note that the cash flow is sufficient to pay the limited preferred dividend of $P_h = I + c_a$.

probabilities of the states of nature.²⁰ However, as we argued above, (12) is likely to be fulfilled.

2. Good technological quality $\theta = \bar{\theta}$

If E has received the good signal the project is either in the medium or in the good state of nature.

Medium state of nature

Suppose that VC has received the bad signal and thus the medium state occurred. Let us first show that both parties are interested in starting the project, if the redeemable preferred stock contract Z_m is signed. It is easy to see that VC 's participation constraint

$$(13) \quad \pi^{VC} = P_m - I - c_a \geq 0$$

and E 's participation constraint

$$(14) \quad \pi^E = v(\omega_m, e, \underline{a}) - P_m + B > 0$$

are fulfilled for $P_m = I + c_a$.

If E offers the menu of contracts VC can overstate his private information by choosing the convertible preferred stock contract. But since the strike is missed for sure, his payoff is limited to the limited preferred dividend. VC does not overstate if his self-selection constraint

$$(15) \quad \pi_{true}^{VC} = P_m - I - c_a \geq P_h - I - c_a = \pi_{lie}^{VC}$$

is fulfilled, which is obviously the case for $P_m = I + c_a$ and $P_h = I + c_a$.²¹

²⁰ If VC knows B he also knows if (12) is fulfilled or not. If (12) is not fulfilled VC incentives are altered. Since VC cannot conclude from the offered menu of contracts which state of the world occurred his contract and effort choice depends on the probabilities he assigns to the states of world. If VC has received the bad signal then he might even reject the offered contracts in order to protect himself against an inefficient investment. If he has received the good signal then he might understate his private information and / or spend only the low effort since with a positive probability he will not be compensated for spending the high effort.

²¹ Actually, VC is indifferent. However, there is no reason to assume that he does not choose the medium state contract.

It is intuitively clear that E does not understate his private information, since then VC will reject the contract offered by E . The project will not be started although it is efficient. E 's payoff is thus

$$(16) \quad \pi_{lie}^E = 0$$

In contrast, if E tells the truth he gets a monetary return and his private benefits, i.e.

$$(17) \quad \pi_{true}^E = v(\omega_m, e, \underline{a}) - c_e - I - c_{\underline{a}} + B$$

Obviously, understating is disadvantageous for E .

It remains to show that no party has an incentive to exercise the high effort. VC 's incentive constraint

$$(18) \quad \pi_{low}^{VC} = P_m - I - c_{\underline{a}} \geq P_m - I - c_{\bar{a}} = \pi_{high}^{VC}$$

is obviously fulfilled for $P_m = I + c_{\underline{a}}$ and $P_h = I + c_{\bar{a}}$. E 's incentive constraint

$$(19) \quad \pi_{low}^E = v(\omega_m, \underline{e}, \underline{a}) - c_{\underline{e}} - I - c_{\underline{a}} + B \geq v(\omega_m, \bar{e}, \underline{a}) - c_{\bar{e}} - I - c_{\underline{a}} + B = \pi_{high}^E$$

is also fulfilled due to assumption 1.

Good state of nature

If VC has received the good signal, the good state of nature occurred.

Let us again first show that the participation constraint of VC

$$(20) \quad \pi^{VC} = \alpha_p \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} \geq 0$$

and the one of E

$$(21) \quad \pi^E = v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} - I - c_{\bar{a}} + B \geq 0$$

are fulfilled with a the convertible preferred stock contract Z_h . Obviously, VC 's participation constraint is fulfilled for $\alpha_p = \frac{I + c_{\bar{a}}}{v(\omega_h, \bar{e}, \bar{a})}$, while E 's participation constraint is fulfilled by assumption.

If VC understates his private information, the redeemable preferred contract Z_m is signed. Since the cash flow is sufficient to redeem the preferred stocks VC 's payoff is limited to the redemption price, and thus his profit is

$$(22) \quad \pi_{lie}^{VC} = P_m - I - c_{\underline{a}} = 0$$

Comparing VC 's profits from (20) and (22) shows that VC cannot profit from understating.

If E understates his private information, the redeemable preferred contract Z_n is signed instead of the convertible preferred contract. Although E is in control with the contract Z_n and can consume private benefits, he destroys VC 's incentive to spend the high effort. Thus, E 's profit from understating is

$$(23) \quad \pi_{lie}^E = v(\omega_h, \bar{e}, \underline{a}) - c_{\bar{e}} - I - c_{\underline{a}} + B,$$

If E reveals his information truthfully the payment to VC rises but also the cash flow. However, since VC is exactly compensated for his expenditures and spending the high effort is efficient the extra return outweighs the extra cost. E 's profit from telling the truth and spending the high effort is then

$$(24) \quad \pi_{true}^E = v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} - I - c_{\bar{a}} + B$$

Telling the truth and spending the high effort is advantageous if

$$(25) \quad \begin{aligned} \pi_{true}^E = v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} - I - c_{\bar{a}} + B &> v(\omega_h, \bar{e}, \underline{a}) - c_{\bar{e}} - I - c_{\underline{a}} + B = \pi_{lie}^E \\ &\Leftrightarrow v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \bar{e}, \underline{a}) > c_{\bar{a}} - c_{\underline{a}} \end{aligned}$$

which is true by assumption.

However, it could be advantageous for a player to reveal his private information truthfully but to spend only the low effort. For VC the incentive could be to reduce his effort cost. But since the strike is missed for sure his payoff is again limited to the preferred dividend such that his profit in case of shirking is

$$(26) \quad \pi_{low}^{VC} = P_h - I - c_{\underline{a}} = 0$$

while with spending the high effort it is

$$(27) \quad \pi_{high}^{VC} = \alpha_p \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} = 0$$

Hence, VC is in both cases exactly compensated for his expenditures. There is thus no reason to assume that VC will shirk.

For E shirking could be advantageous since it lowers the effort cost and reduces the payment to VC who could not convert his preferred stock. But shirking reduces also the cash flow and prevents E from consuming private benefits. With this E 's profit from shirking is

$$(28) \quad \pi_{low}^E = v(\omega_h, \underline{e}, \bar{a}) - c_{\underline{e}} - I - c_{\underline{a}}$$

In contrast, spending the high effort leads to a profit of

$$(29) \quad \pi_{high}^E = v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} - I - c_{\bar{a}} + B$$

Comparing the two profits shows that playing the Nash equilibrium is still advantageous for E if

$$(30) \quad \begin{aligned} \pi_{high}^E &= v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} - I - c_{\bar{a}} + B > v(\omega_h, \underline{e}, \bar{a}) - c_{\underline{e}} - I - c_{\underline{a}} + B = \pi_{low}^E \\ &\Leftrightarrow v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \underline{e}, \bar{a}) + B > c_{\bar{e}} - c_{\underline{e}} + c_{\bar{a}} - c_{\underline{a}} \end{aligned}$$

It cannot be concluded from the assumptions whether (30) is fulfilled or not.²² However, if (30) is not valid E 's and VC 's incentives are changed so that spending the low effort by E and the high effort by VC is no Nash equilibrium. Furthermore, it can be shown that the only Nash equilibrium is inefficient. To see this imagine first which impact this has on VC 's incentives.

If (30) is not fulfilled VC knows that E will spend only the low effort. But then spending the high effort is disadvantageous for him since he will not be compensated for his high effort for sure. Hence, the combination of low effort spending by E and high effort spending by VC is no Nash equilibrium. But given that VC will spend only the low effort spending the high effort is now a dominant strategy for E since

$$(31) \quad v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \underline{e}, \bar{a}) > c_{\bar{e}} - c_{\underline{e}}$$

It is easy to see that high effort by E and low effort by VC is the only Nash equilibrium.²³ However, this equilibrium is obviously inefficient.²⁴

Q.E.D.

Offering just one contract is a credible signal for the project having the bad technological quality because E cannot profit from understating his private benefit. If he understates the project will not be carried out in the medium state of nature, while in the good state E loses the net cash flow gain from VC 's high effort. Thus, there is no necessity to transfer control from E to VC and a simple redeemable preferred stock contract is optimal.

In contrast, offering the menu of contracts is *per se* no credible signal for the project having the good technological quality. For this to be the case a cash flow contingent alloca-

²² In our view (30) will normally be fulfilled. Since spending the high effort is efficient the opportunity cost from spending only the low effort, measured in foregone profits, offsets the saved effort cost. For (30) to be valid it would be sufficient if the private benefits exceed the difference in payments to VC , i.e., the difference in VC 's effort costs. We think it is plausible to assume that this is true.

²³ There is no Nash equilibrium in mixed strategies. That is because VC is indifferent between spending the low or the high effort given that E spends the high one since he is in both cases exactly compensated for his expenditures. But if VC uses a mixed strategy then using a mixed strategy is the best response for E . However, this implies that VC will not be compensated for his high effort with a positive probability. But then using a mixed strategy is dominated by the pure strategy "low effort".

²⁴ We do not see a contract modification which can solve the problem. Raising the preferred dividend, which weakens (30), can lead to an overstating by VC . Lowering the strike in order to protect VC against E 's opportunistic behavior can lead to shirking by VC . With a lower strike E has no incentive to shirk since by doing so he cannot reduce the payment to VC . But if E spends the high effort and hence the (lower) strike is already reached VC has no incentive to work hard.

tion of cash flow and voting rights is needed. As we have shown, these can be implemented with redeemable and convertible preferred stocks.

A shift of the voting rights to the venture capitalist is necessary to prevent the entrepreneur from consuming private benefits in the bad state of nature. However, this shift is inefficient in the medium and the good state of nature. The entrepreneur must hence be given the opportunity to get back control. This can be achieved with a redemption / conversion clause.

A proper designed redemption / conversion clause works thus as a mechanism to allocate the voting rights cash flow contingent. This prevents the entrepreneur from overstating his private information because it is assured that the entrepreneur can get back control and consume private benefits only if he revealed his private information truthfully. Starting an inefficient project due to a private benefit consuming motive is then not advantageous for the entrepreneur. But also the motivation to overstate his private information in order to raise his stake in the financial return is softened because this rise has to be traded off against the loss of private benefits.

Furthermore, the conversion clause also works as a mechanism to allocate the cash flow rights cash flow contingent. As we have shown the venture capitalist may have an incentive to understate his private information in order to raise his stake in the financial returns. To prevent this understating it is necessary to exclude the venture capitalist from any cash flow which is higher than the anticipated one. Hence, there is the need for a cash flow contingent allocation of cash flow rights. By designing the conversion clause properly it is assured that the venture capitalist can only participate in a high cash flow if he has revealed his private information truthfully.

The conversion clause is not just important for the truthful revelation of the private information but also for the implementation of the efficient efforts. Since it is individual rational for each party to choose his effort according to the marginal return of his stake, with a standard financing contract only the full residual claimant on the margin will spend the efficient effort. Hence, to implement the efficient effort on both sides it would be necessary to make each party the residual claimant on the margin. Of course this not possible. However, with a conversion clause it is possible to "artificially" make the venture capitalist the residual claimant on the margin in the sense that he is induced to spend the efficient effort. That is because by spending only the low effort he cannot convert his preferred stocks and hence only receives the limited preferred dividend. In contrast, by spending the high effort he can convert his preferred stock and receives common equity with a value equal to his expenditures. The venture capitalist is in both cases exactly compensated for his expenditures. Since he is then

indifferent between spending the low or the high effort there is no reason to assume that he will shirk.

At last there is the necessity of a preferred dividend. It is needed to destroy the entrepreneur's last incentive to start an inefficient project. The preferred dividend assures that the entrepreneur will not receive a payment on his equity in the bad state of nature. Since he then gets neither a financial return nor a private benefit his incentive to start an inefficient project is completely destroyed. The limitation of the preferred dividend in the good state of nature is a necessary condition to assure that the venture capitalist will always spend the high effort and convert his preferred stocks into common ones.

5 Renegotiations

Since yet we have not considered the possibility of renegotiations. However, it is plausible to assume that the parties agree to renegotiate the initial contract if both parties can be better off with a new contract. But the possibility of renegotiations influences the strategic behavior of both parties since the negative consequences of following an inefficient strategy are softened. Thus, the contracts have to be modified to make them renegotiation-proof.

In the renegotiations the parties can agree to shift control whenever this not possible under the initial contract. Thus, the possible surplus is equal to B . However, VC is only interested in a renegotiation if E can offer a monetary transfer. For a renegotiation to occur it is thus necessary that E has some money left after paying VC the preferred dividend. Since VC has something to sell which is worthless to him, but valuable for E , it seems plausible to assume that the parties split the surplus in order to their bargaining power in a simple Nash bargaining game.²⁵ Thus, E receives the fraction $(1 - \delta)$ and VC the fraction δ .²⁶ Obviously, each party can force renegotiations by misstating his private information, or by spending only the low effort in the good state of nature. For VC this may be advantageous since in a renegotiation he can receive a monetary payment which exceeds his expenditures. E may have an incentive to misbehave since now there is the possibility to get back control even if the inefficient decisions have been taken. In the following proposition we state how the contracts have to be modified to make them renegotiation-proof.

²⁵ Since VC is the only one who can give E his private benefit the competition on the capital market does no longer drives VC 's bargaining power to zero.

²⁶ If B exceeds E 's cash flow fraction, $B > v(\omega, e, a) - P_i$, then VC 's bargaining power is limited to $\delta = (v(\omega, e, a) - P_i) / B$, because B is not transferable.

Proposition 3: *The contract Z_n is renegotiation-proof. To make Z_m and Z_h renegotiation-proof they must be modified as follows:*

1. *VC's post conversion equity stake in contract Z_h must be raised to*

$$\alpha_{ren.} = \frac{I + c_{\bar{a}} + \delta B}{v(\omega_h, \bar{e}, \bar{a})}.$$

2. *The redemption price and the preferred dividend in contract Z_m must both be raised to $P_m = I + c_{\underline{a}} + \delta B$.*

For a solution to exist the following conditions must be fulfilled:

$$1. \quad v(\omega_h, \bar{e}, \bar{e}) - v(\omega_h, \underline{e}, \bar{a}) > c_{\bar{e}} - c_{\underline{e}} + c_{\bar{a}} - c_{\underline{a}}$$

$$2. \quad \text{prob}(\bar{\eta}) < \frac{c_{\underline{e}}}{v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a}) + c_{\underline{e}}}$$

$$3. \quad v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} > \delta B.$$

Proof:

Obviously, Z_n is renegotiation-proof since it leaves control with E . Thus, there is no room for renegotiations.

To see how Z_m and Z_h must be modified, we first have to check how the incentives of E and VC are influenced by the possibility of renegotiations. Since a transfer of control is possible even if the financial aims are missed, E 's self-selection constraints in the bad and medium state of nature become

$$(32) \quad P_m > v(\omega_l)$$

$$(33) \quad \begin{aligned} v(\omega_m, \underline{e}, \underline{a}) - P_m + B &> v(\omega_m, \underline{e}, \bar{a}) - P_h + (1 - \delta)B \\ \Leftrightarrow \delta B &> v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a}) - P_h + P_m \end{aligned}$$

and his incentive constraint in the good state of nature becomes

$$(34) \quad (1 - \alpha_{ren.}) \cdot v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{e}} + B > v(\omega_h, \underline{e}, \bar{a}) - P_h - c_{\underline{e}} + (1 - \delta)B$$

VC 's self-selection constraint in the medium state of nature becomes

$$(35) \quad P_m \geq P_h + \delta B$$

and his incentive constraint in the good state becomes

$$(36) \quad \alpha_{ren.} \cdot v(\omega_h, \bar{e}, \bar{a}) - c_{\bar{a}} > P_h - c_{\underline{a}} + \delta B$$

Thus, to be renegotiation-proof the modified contracts must at least offer each party the payoff it would receive in a renegotiation. It is easy to see that the only solution to the above inequality system is to increase the preferred dividend / redemption price in the medium state contract to

$$(37) \quad P_m = I + c_{\underline{a}} + \delta B$$

and to raise VC's post conversion equity stake to

$$(38) \quad \alpha_{ren.} = \frac{I + c_{\bar{a}} + \delta B}{v(\omega_h, \bar{e}, \bar{a})}$$

However, for this solution to exist it is necessary that the cash flow in the medium state of nature is sufficient to redeem the preferred stocks at the new price, i.e.

$$(39) \quad v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} > \delta B$$

Furthermore, since there is no contract modification which can solve (33), E can only be prevented from overstating if the expected loss from starting an inefficient project exceeds the expected rise in his payoff. E will not overstate if ²⁷

$$(40) \quad prob(\bar{\eta}) < \frac{c_{\underline{e}}}{v(\omega_m, \underline{e}, \bar{a}) - v(\omega_m, \underline{e}, \underline{a}) + c_{\underline{e}}}$$

If (40) is not fulfilled then the efficient investments cannot be implemented. That is because in order to protect himself VC may reject a contract offer by E if he has received

²⁷ Note that in the bad state of nature there will be no renegotiation since the cash flow is not sufficient to pay VC's preferred dividend.

the bad signal. Furthermore, since VC is not compensated for his high effort with a positive probability he will always spend the low effort.

By inserting $P_m = I + c_{\underline{a}} + \theta B$, $\alpha_{ren.} = \frac{I + c_{\bar{a}} + \delta B}{v(\omega_h, \bar{e}, \bar{a})}$ and $P_h = I + c_{\underline{a}}$ in (34) it follows immediately that spending the high effort is only advantageous for E if

$$(41) \quad v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \underline{e}, \bar{a}) > c_{\bar{e}} - c_{\underline{e}} + c_{\bar{a}} - c_{\underline{a}}$$

If (41) is not fulfilled the efficient efforts cannot be implemented.

Q.E.D.

For the contracts to be renegotiation-proof they must offer each party at least what it would get in a renegotiation. Since in a renegotiation VC participates in E 's private benefit E has to offer VC an information rent. Otherwise he cannot induce VC to reveal his private information truthfully and to spend the high effort, respectively. E will always offer the information rent because in the medium state of nature he avoids spending the inefficient high effort and in the good state of nature he profits from the net increase in cash flow resulting from VC 's high effort. Of course, the size of the information rent depends on VC 's bargaining power in the renegotiation.

6 Conclusion

In our paper we offer an explanation for the widely observed separation of control and cash flow rights and their inverse correlation in venture capital contracts as reported by Gompers (1997) and Kaplan and Strömberg (2001). As we have shown, the inverse correlation is necessary to overcome the severe information asymmetry between the entrepreneur and the venture capitalist. Without a shift of control to the venture capitalist and a preferred cash flow right for him the entrepreneur cannot be induced to reveal his private information truthfully. However, for the mechanism to work the entrepreneur must be given the chance to get back control if he told the truth. Since this can be achieved with a redemption and a conversion clause, respectively, the predominance of redeemable and convertible preferred stocks in venture capital finance can be explained with the information asymmetry.

Besides the information asymmetry, we offer a second explanation for the use of convertible stocks, the double-sided moral hazard problem. To make the company a success an

effort by both the entrepreneur and the venture capitalist is needed. As we have shown, with a convertible stock both parties can be induced to spend the efficient efforts. Since conversion does only take place if it is profitable for both parties the widespread use of automatic conversion provision can be explained as well with the double-sided moral hazard problem.

Furthermore, we can explain why venture capitalists earn expected positive returns on their investments, even in the current venture capital market. This market is characterized by an excess supply of capital, which could lead to the conclusion that due to the competition venture capitalists earn zero expected returns. However, if renegotiations are possible there is room for rents.

7 Appendix

7.1 Appendix A

Proof of lemma 3

Suppose for simplicity that $\theta = \bar{\theta}$ and E offers the menu of contracts. In designing the two contract E has to take VC 's participation constraints into account, which is in the medium state of nature

$$(42) \quad \alpha_a \cdot v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} \geq 0$$

and in the good state of nature

$$(43) \quad \alpha_b \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} \geq 0$$

Furthermore, E has to take VC 's incentive constraints into account, which are

$$(44) \quad \alpha_a \cdot v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} \geq \alpha_a \cdot v(\omega_m, \underline{e}, \bar{a}) - I - c_{\bar{a}}$$

$$(45) \quad \alpha_b \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} \geq \alpha_b \cdot v(\omega_h, \bar{e}, \underline{a}) - I - c_{\underline{a}}$$

as well as VC 's self-selection constraints

$$(46) \quad \alpha_a \cdot v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} \geq \alpha_b \cdot v(\omega_m, \bar{e}, \bar{a}) - I - c_{\bar{a}}$$

$$(47) \quad \alpha_a \cdot v(\omega_m, \underline{e}, \underline{a}) - I - c_{\underline{a}} \geq \alpha_b \cdot v(\omega_m, \bar{e}, \underline{a}) - I - c_{\underline{a}}$$

$$(48) \quad \alpha_b \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} \geq \alpha_a \cdot v(\omega_h, \underline{e}, \bar{a}) - I - c_{\bar{a}}$$

$$(49) \quad \alpha_b \cdot v(\omega_h, \bar{e}, \bar{a}) - I - c_{\bar{a}} \geq \alpha_a \cdot v(\omega_h, \underline{e}, \underline{a}) - I - c_{\underline{a}}$$

It is easy to see that (44) and (46) are fulfilled by assumption. We thus have to show that there is a combination of α_a and α_b for which (42), (43), (45), (47), (48) and (49) are fulfilled simultaneously. From (42), (43) und (45) we obtain the minimum “absolute” values for α_a and α_b , which are

$$(50) \quad \alpha_a \geq \frac{I + c_{\underline{a}}}{v(\omega_m, \underline{e}, \underline{a})}$$

$$(51) \quad \alpha_b \geq \frac{I + c_{\bar{a}}}{v(\omega_h, \bar{e}, \bar{a})}$$

$$(52) \quad \alpha_b \geq \frac{c_{\bar{a}} - c_{\underline{a}}}{v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \bar{e}, \underline{a})}$$

And from (47), (48) and (49) we obtain the relative ones, i.e. the relation between α_a and α_b ,

$$(53) \quad \frac{\alpha_b}{\alpha_a} \leq \frac{v(\omega_m, \underline{e}, \underline{a})}{v(\omega_m, \bar{e}, \underline{a})} < 1$$

$$(54) \quad \frac{\alpha_b}{\alpha_a} \leq \frac{v(\omega_h, \underline{e}, \bar{a})}{v(\omega_m, \bar{e}, \bar{a})}$$

$$(55) \quad \alpha_b \cdot v(\omega_h, \bar{e}, \bar{a}) - \alpha_a \cdot v(\omega_h, \bar{e}, \underline{a}) \geq c_{\bar{a}} - c_{\underline{a}}$$

From (53) follows directly $\alpha_a > \alpha_b$.²⁸ Since (50) is binding, we can substitute α_a from (50) into (53), (54) und (55). We obtain directly that there is only a solution to the problem if

²⁸ This result is intuitively clear. If this relation does not hold VC would always choose the good-state-contract.

$$(56) \quad \alpha_b = \max \left\{ \begin{array}{l} \frac{I + c_{\bar{a}}}{v(\omega_h, \bar{e}, \bar{a})}; \frac{c_{\bar{a}} - c_a}{v(\omega_h, \bar{e}, \bar{a}) - v(\omega_h, \bar{e}, \underline{a})}; \\ \frac{c_{\bar{a}} - c_a}{v(\omega_h, \bar{e}, \bar{a})} + \frac{v(\omega_h, \underline{e}, \underline{a})}{v(\omega_h, \bar{e}, \bar{a})} \cdot \frac{I + c_a}{v(\omega_m, \underline{e}, \underline{a})}; \frac{v(\omega_h, \bar{e}, \underline{a})}{v(\omega_h, \bar{e}, \bar{a})} \cdot \frac{I + c_a}{v(\omega_m, \underline{e}, \underline{a})} \end{array} \right\} < \frac{I + c_a}{v(\omega_m, \bar{e}, \underline{a})}.$$

(56) obviously depends on the model's parameters. E has obviously to pay an information rent if it is not VC's participation constraint which determines the size of the equity stake, i.e.

$$\alpha_b > \frac{I + c_{\bar{a}}}{v(\omega_h, \bar{e}, \bar{a})}.$$

Q.E.D.

7.2 Appendix B

Proof of lemma 4

Suppose $\theta = \underline{\theta}$. E 's profit in case of revealing his private information truthfully is

$$(57) \quad \pi_{wahr}^E = \begin{cases} 0 & \text{falls } \eta = \underline{\eta} \\ (1 - \alpha_a) \cdot v(\omega_m, \underline{e}, \underline{a}) + B - c_{\underline{e}} & \text{falls } \eta = \bar{\eta} \end{cases}$$

while in case of overstating it is

$$(58) \quad \pi_{falsch}^E = \begin{cases} (1 - \alpha_a) \cdot v(\omega_l, \underline{e}, \underline{a}) + B - c_{\underline{e}} & \text{falls } \eta = \underline{\eta} \\ (1 - \alpha_b) \cdot v(\omega_m, \underline{e}, \bar{a}) + B - c_{\underline{e}} & \text{falls } \eta = \bar{\eta} \end{cases}$$

Obviously, E can raise his profit by overstating his private information.

Q.E.D.

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