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Personal Capability of Innovators and the Need to Go Public in Venture Capital Financing

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1. On the rational of the exit option via IPO's

Independent economic growth relies crucially on innovations done by entrepreneurs, on their ability and willingness to found new firms and bring new ideas to the market. According to traditional understanding, in Germany this process is often hampered by scarcity of financiers willing to bear high risk. Sometimes it is stated that the unwillingness to finance new ventures is due to cultural peculiarities, e.g. a cultural of risk avoidance in Germany contrasting with a culture of risk seeking in the United States of America.[1] Other authors contribute it to the dominance of universal banks in the German financial system, which are not willing to give money to young, innovative firms lacking a sufficient track record and adequate collateral, two facts colliding with the traditional credit policy of German banks. These arguments seemed useful to explain the discrepancy between the minuscule market for venture capital in Germany and the dynamic expansion and remarkable volume of this market in the US, and equivalent arguing might explain similar differences between other countries. They led the German federal and state governments to found or co-finance a number of funds to give additional equity capital to young firms, with the intention to induce a higher rate of innovation into the (more or less) stagnating German economy.[2] Likewise, banks set up venture capital funds capitalized by the financial resources of the banks.[3] Both concepts were seemingly not very successful. The number and volume of venture capital investment in Germany stayed comparatively small and stagnating through the eighties and much of the nineties.[4] It also contrasts with venture capital financing in the United States, where venture capital funds are mainly organized as limited partnership with predetermined lifetime.[5]

Recent developments in the economic understanding of venture capital financing and the growing vivacity of German venture capital markets in connection with the establishment of a new stock market segment, the "Neuer Markt", cast heavy doubts on the simplistic "lack-of-capital"-explanation. Today, about two years after its launching, the Neuer Markt is the biggest European market for medium sized firms, fuelling wildest hopes for success of young entrepreneurs. About one half of the firms who went public have a venture capital history, and

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[1] For an overview of the arguments see Harrison (1990), who provides much insight into the structural problems of the German venture capital market, and the discussion in Black/Gilson (1998), p. 271-272.

[2] See e.g. the arguments of the scientific committee of the Ministry of Economics (Wissenschaftlichen Beirats beim Bundesministerium für Wirtschaft), Bundesministerium für Wirtschaft (1997), pp. 2-5), on the relationship between innovation and venture capital Kortum/Lerner (1998).

[3] According to Schefczyk (1998), pp. 1-2, only three German venture capitalists get their capital directly from public markets.

[4] See Kitchen (1992), p. 24, for the 1980s and Schefczyk (1998), pp. 95-99, with more recent numbers.

some still maintain venture capitalists as shareholders. At the same time the net investment of venture capitalists soared.[6] Seemingly, it had not been the lack of capital but of innovators willing to found a new firm which had hampered the development of small firm investment, or, to take a more general standpoint, the non-availability of a certain category of financial accords that make the founding of firms attractive.[7] A market for IPOs on a rather early stage of the firm's development seems to be a crucial element of this long-term financial contract. Although the IPO is not the only and not always the most efficient way for venture capitalists to disinvest,[8] the mere existence of this alternative seems to be of great importance for vivid venture capital markets,[9] and the early foundation of the NASDAQ in 1971 might be at the bottom of the stunning success of venture capital in the United States.

An essential property of long term financial contracts about highly risky financial stakes is their incompleteness.[10] Both, riskiness and long term character can be attributed to the type of financing contracts agreed on when founding a new firm. Therefore, it is tempting to use the theory of incomplete contracts to explain the different characteristics of venture capital relationships. Recent contributions to the literature mainly deal with the state contingent allocation of control rights during an ongoing venture capital financing, which is realized through the option of the venture capitalist to replace inefficient managers or to stop inefficient projects (see e.g. Hellmann (1998) or Berglöf (1994)). The use of capital markets has not been motivated by the incompleteness of contracts. However, rather close to such a reasoning is the recent article of Black/Gilson (1998), who assume that an implicit contract about the distribution of control allows the entrepreneur to regain control through an initial public offering in case of a successful venture. The venture capitalist is willing to divest because he thereby serves the need of his financiers for information and liquidity, which are wanted for an efficient allocation of funds to venture capital managers of different capability and to different forms of investments. The idea that the going public serves as a device to build up reputation on the capital markets is strengthened by the observation (Gompers (1996)) that young ven-

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[5] See Gompers/Lerner (1995) and Lerner (1996).

[6] See the actual numbers of the Bundesverband Deutscher Beteiligungsgesellschaften (1998), or in Bohne (1998), and the information about shareholder structure of the firms at the Neuer Markt on the website of the Deutsche Börse AG.

[7] See Weber (1998) and Breuer (1997).

[8] See e.g. the survey of Wall/Smith.

[9] See Jeng/Wells (1998) for cross-country evidence for this statement. Sahlman (1990) states that the gains from venture capital investments are mainly due to the cases where a going public took place.

[10] For a general introduction to the theory of incomplete contracts see Hart (1995).

ture capital firms tend to bring young firms too early to the capital market ("grandstanding"), meaning that they don't maximize the value of their investment when doing so.

In Black/Gilson (1998) entrepreneurs profit from the implicit contract between venture capitalist and entrepreneur to go public through an exogenous value of control. This additional value leads to better incentives for the entrepreneur or might even make the founding of the firm feasible at all. In the following model we argue that such a value stems from a better bargaining position in renegotiation. In our model, renegotiations will take place when the firms needs additional capital at a later date, and if it is not possible to include the conditions for this additional investment in the initial contract.

The special ability of a venture capitalist is to make the firm's investment transparent to external investors. He could do so towards a single investor (or a group of investors), e.g. to a bank in the moment when the additional funds are needed. In this case the entrepreneur suffers a hold up from his financiers when the firm needs additional capital, and this hold up might subtract additional firm value from the entrepreneur. Alternatively, the venture capitalist could make the firm transparent to competitive capital markets through a timely initial public offering, and thus free the entrepreneur from the hold up threat.

In section 2 we outline the basic model of bargaining over equity stakes in venture capital investments and compare the investment incentives if the exit via IPO or some form of continuing intermediation were distinct institutional settings. However, in reality these are alternative ways to divest venture capital investments. Therefore, in section 3, the venture capitalist is to decide if a going public takes place, and going public is costly. The results are illustrated further in section 4 on the basis of a specified production function. Section 5 extends the analysis to the financing problem of the venture capitalist and shows how the decision to go public can serve as a signal for good venture capitalists. In section 6 we discuss some potential extensions, and in section 7 why we did not take other financial contracts apart from equity into account. Section 8 concludes with some political implications of the results

2. Going public and continuing intermediation as exclusive exit channels

In the following chapter we compare the exit via IPO and continuing intermediation as distinct institutional settings. Crucial for the first alternative is that the venture capitalist looses his power for a hold up. The firm can afterwards finance additional investments on a perfect market. The distribution of firm through the initial contract remains valid. Continuing inter-

mediation means that the venture capitalist sells the firm as a monopolist to another financier or powerful new owner (trade sale), making the investment transparent only to him. The additional later stage investment might be either financed by the venture capitalist, some new owners or banks which, like new owners, get exclusive information on the true value of the firm. In any case, the founder of the firm is still exposed to the hold up threat, which will result in a new contract that will make the initial contract obsolete. For simplicity, we assume that all potential gains from the hold up are taken by the venture capitalist.

Let the firm be founded in t_1 by an entrepreneur (EN) with the help of a venture capitalist (VC). The service of the venture capitalist consists of many different elements, like writing a contract, giving some initial capital, advice, interference when needed, maybe even to substitute the original manager or to stop the investment altogether if the chance for a success is ceasing.[11] In the following, we restrict the analysis to equity contracts where the venture capitalist gets a claim on the proportion , the entrepreneur (1 –) of the final pay off. [12] The opportunity costs, representing the best alternative investment from the standpoint of the managers of the venture capitalist, are given by a fixed *R*, and might be understood mainly as the initially invested capital plus the risk premia for the many failed ventures.[13] In the following, we model explicitly only what happens to successful ventures which should be divested the one way or another, and let all failures be represented by *R*.[14]

When the entrepreneur decides to found the firm, he has opportunity costs *O*. Some might say that *O* is negligible small or even negative, because as an entrepreneur one can enjoy fringe benefits and a higher personal reputation. Off course entrepreneurs do so, but when deciding to become an entrepreneur they might deem this advantages to be bought at fairly high price. Entrepreneurs must be willing to invest many years, if not a lifetime of work, and to let all other opportunities be foregone for a long period of time. And they bear a high risk of failure, especially when founding a new firm, with a high probability that their personal fortune and

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[11] For the different functions of a venture capitalist see Sahlman (1990), pp. 506-513.

[12] See section 7 for further discussion.

[13] In the United States, between 16 percent and one third of the projects fail; see Gompers (1995) and Barry (1994), p. 6-7, for an overview over the different studies. For Germany the Bundesverband Deutscher Kapitalbeteiligungsgesellschaft (1997, 1996) states a complete failure of 142 projects out of a total of 3320 in 1996 alone (1995: 147 out of 3093), which should lead to similar numbers with respect to the usual time-length of venture capital investments.

[14] Thus, if we take *S* as the start up capital for a successful projects, *q* as the probability of success and *F* as the average costs of a failure to the venture capitalist, we could calculate *R* as: $R = S + F(1 - q)/q$.

social status might be ruined.[15] This disadvantage is no reason for compassion; entrepreneurs will expect extraordinary gains as compensation. But they have to, otherwise they are not willing to found the firm. The threat that a financier might strip these expected gains from them in a hold up thus can be severe hindrance for the founding of new firms.

Assume that the overall firm value is

$$V = y(m,k) - I - m - \frac{k}{c},$$

with:

y as final payoff, which is increasing, convex and, for simplicity, additive separable in both *m* and *k*,

m as (non verifiable) investment of the venture capitalist VC ("*m*anagerial support") after the firm has been founded (i.e. when R is already sunk), and the costs of this investment to the venture capitalist,

k/*c* as the (non verifiable) cost of the investment of the entrepreneur EN, with *c* (> 0) representing his individual *c*apability and *k* his investment ("*k*nowledge"), which will be made after the firm has been founded (i.e. when R is already sunk),

I an additional (and ex ante, i.e. at the date of the founding of the firm non-contractible) financial investment at a later stage which is necessary to receive a positive payoff.

Everybody knows all parameters and the structure of the game.

Both parties get a final payoff according to an equity contract ,

$\pi(\text{VC}) = (\ y - I)$, and

$\pi(\text{EN}) = (1 - \ )(\ y - I)$.[16]

Thus, when investing they maximize $\pi(\text{VC}) - m$ and $\pi(\text{EN}) - k/c$, which gives the second best efficient investments of both parties according to

$$\frac{\partial y}{\partial m} = \frac{1}{\beta}, \text{ and}$$

[15] With respect to the insolvency costs to be borne by the individual we might expect that the rigid German insolvency system and social codex induces higher opportunity costs than the American system where insolvency does not have to be personal tragedy.

[16] *I* is subtracted from the final pay off because it has to be given as compensation to the financier of the additional investment, whoever this might be.

$$\frac{\partial y}{\partial k} = \frac{1}{(1-\beta)c}.$$

Thus $m'(\ ) > 0$ and $k'(\ ) < 0$. Due to additive separability of the production function, the individual capability c influences only the investment of the entrepreneur, with $k'(c) > 0$. Furthermore, we assume a production technology such that both $(\pi(VC|\ ),\ \pi(EN|\ ))$ and $(\pi(VC|\ ) - m(\ ),\ \pi(EN|\ ) - k(\ ))$ are convex (at least for all relevant parameters).

The investments of the venture capitalist m is needed in particular at a rather early stage, whereas the investment of the entrepreneur k (or at least the part of his investment we are interested in this model) should take place at later date. Consequently, the game has the following time line:

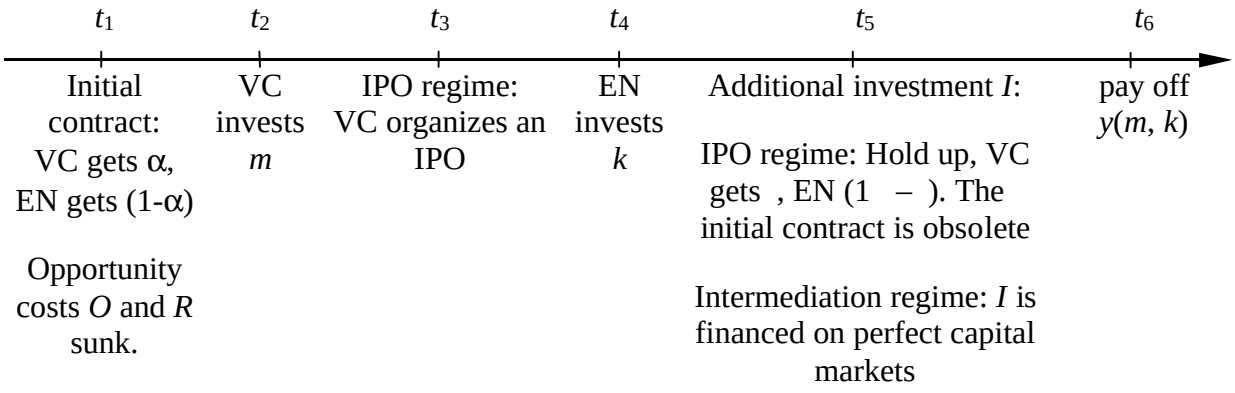

Figure 1

The initial contract is only relevant if the firm has gone public. We call the distribution the parties agree on in the initial contract α. Otherwise, the partners will agree on a new contract in the renegotiation in t_5. In this contract the venture capitalist gets , the entrepreneur (1 –) of the final payoff. Thus, could have the value α if it stems from the initial contracts in t_1, or if it is the result of renegotiation in t_5.

However, is not per se exogenous but result of the negotiation between the two parties. For the negotiation we assume the following bargaining process:

Let the game have a (potentially) big number T of bargaining rounds. In each round the venture capitalist or the entrepreneur makes a proposal for the division of value $_{VC}$ or $_{EN}$ with probability b and $(1 - b)$. Every round is costly, but these costs are marginally small. Nonetheless they serve as incentive to make an acceptable proposal in the first round. If even in the last round T the partners cannot agree, the contract fails and everybody gets the opportunity costs of the respective bargaining situation (i.e. O and R in t_1 or 0 for both in the renegotiation

in t_5). Thus we can solve this game through backward induction from this last round, as will be shown below.

Although we assume the same basic mechanism in the case of the initial negotiation and the renegotiation, they differ with respect to opportunity costs and the relevant budget line. Firstly, we analyze renegotiation in t_5 with the resulting stake of the venture capitalist . Here the opportunity costs are 0 for both parties, because if they cannot agree, the firm value is 0 and all costs are sunk. The person who, by chance, is allowed to make a proposal in the last round T, therefore would take $y(\ ) - I$ and leave 0 to the other party. However, in the round $T - 1$, the respective party will know the expected value she has to give to the other party to make him agree, which is for the venture capitalist $b(y(\ ) - I)$ if the entrepreneur has to make a proposal, and $(1 - b)(y(\ ) - I)$ for the entrepreneur if the proposal stems from the venture capitalist. Because all investments have been made before and therefore the final payoffs are determined, the budget line now is straight with slope –1 through the anticipated $\pi(\text{VC}|\ )$ and $\pi(\text{EN}|\ )$. Therefore, already in round $T - 1$ both parties will make the same proposal, as in all bargaining rounds before, i.e.

$$\beta_{VC} = \beta_{EN} = \gamma = \frac{b\big(y(\gamma) - I\big)}{y(\gamma) - I} = b\,.$$[17]

Thus, can be treated as exogenous parameter representing the bargaining power of the venture capitalist, because it is equivalent to the exegenously set probability b that the venture capitalist makes a proposal. Graphically:

[17] Consequently in the renegotiation case we only needed two bargaining rounds to get a result which is independent of who is going to make the first proposal.

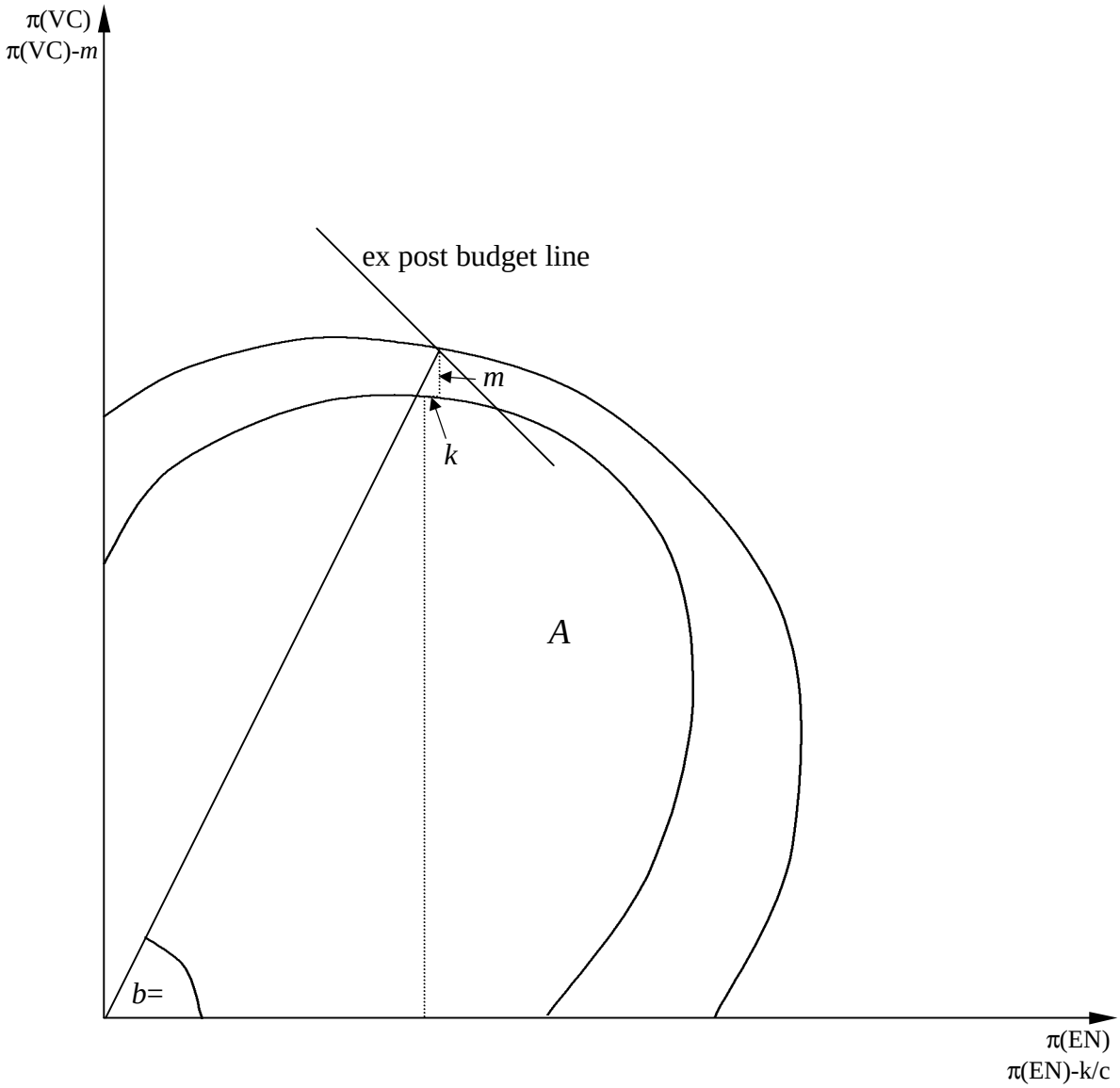

Figure 2

The outcome of the ex ante negotiation is more difficult to determine. The final stake of the entrepreneur in this case is . The opportunity costs are *O* and *R* for the entrepreneur and the venture capitalist respectively. And, because all investment will take place at a later date, the budget line is determined by π(VC|) – *m*( ) and the respective π(EN|) – *k*( )/ *c*. The result in the last round is similar to the renegotiation case: The party in charge of a proposal will offer at least the opportunity costs to the other one. She might offer more than that if she could gain herself by giving her partner better investment incentives thereby. (In the following figure 3, this is the case if the venture capitalist is the last to make an offer, as the representation of this bid in round *T* by s_T(VC) shows). As in the first case, the party making a proposal in *T* – 1 will give her opponent his expected value from *T*, which again depends on the probabilities *b* and (1 – *b*). But because the budget line is convex, the contracts both parties

would propose still differ. However, as can be seen below, the solutions the entrepreneur proposes and the proposals of the venture capitalist converge to a common solution *s* with a growing number of bargaining rounds. Therefore, the bargaining gains are distributed according to ∈ (0, 1). Taking into account that the final payoff must include investments *m* and *k*/*c* of the respective level of , we can graphically solve for the the parties will accept:

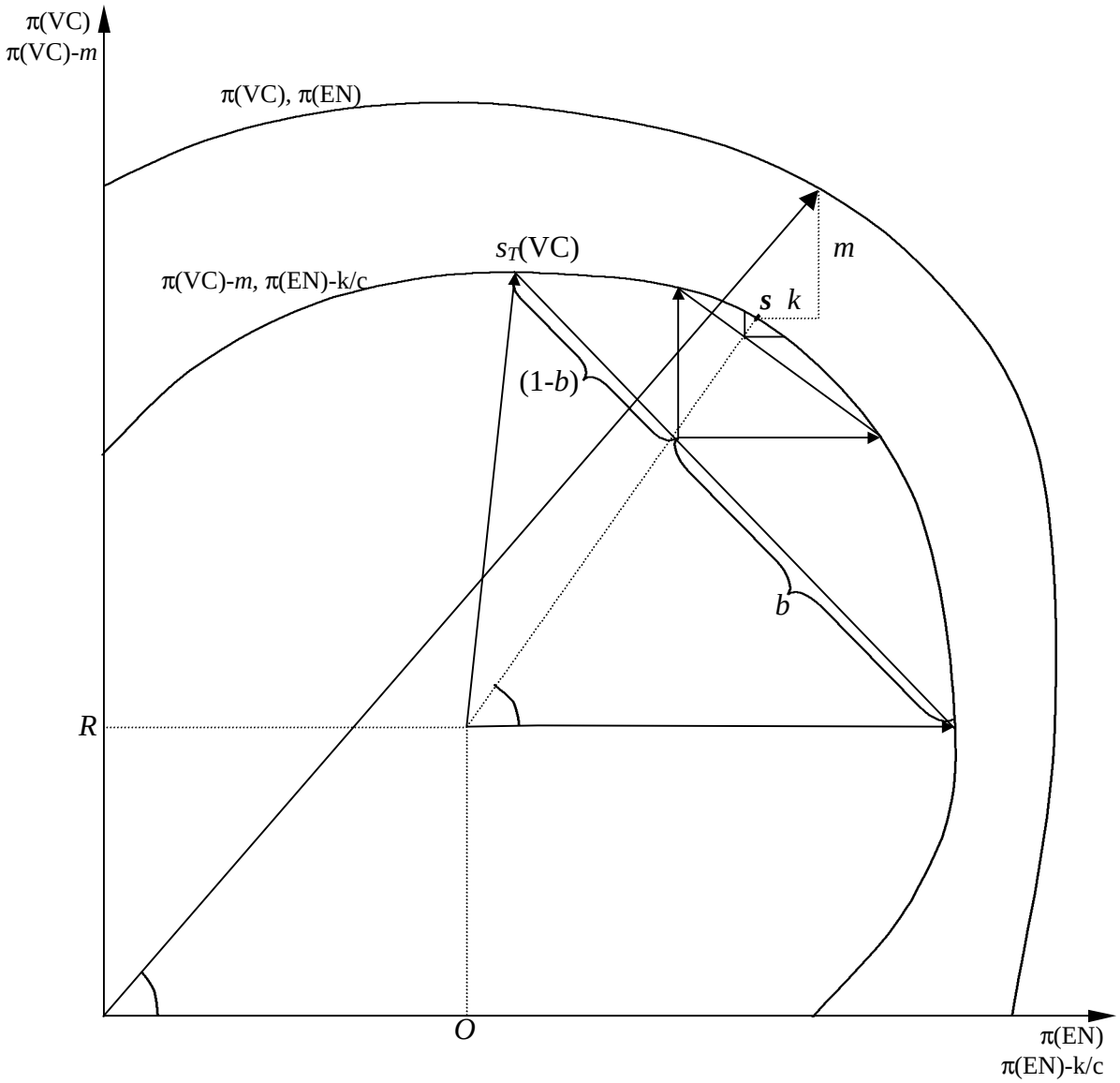

Figure 3

We cannot solve this problem analytically without further specifications. Nonetheless, it can be seen that the solution will be always pareto efficient with respect to the limitation that there exist no other contracts but pure equity contracts. This pareto efficiency is to be expected from a comprehensive contract.

In a first step, we want to compare these two regimes, assuming that the venture capitalist can not choose between going public or continuing intermediation but has, according to the insti-

tutional setting, to use one of these exit channels. An immediate result is that the number of feasible projects is weakly greater under the going public regime. This follows from comprehensiveness of an enforceable ex ante contract, which allows to always find an equity contract where both parties receive at least their opportunity costs whenever such an equity contract exists. In the case of continuing intermediation, the partners might fail to do so, because the distribution of value is fixed at the end of the game, when all investments and opportunity costs are sunk. Thus, especially for high bargaining power of one of the two parties (*b* close to one or close to 0) projects might fail due to the hold up threat. In the graphical example above this would be the case for all projects where the initial threat point (*O*, *R*) is in the region *A*.[18]

As a conclusion, many projects might fail in the continuing intermediation regime because the partners cannot find a contract guaranteeing everybody a positive gain. Therefore, we get a first hint that the lack of an adequate exit market can be seen as a fundamental reason for the different size of venture capital markets in the US and in Germany in the past and why the founding of equity markets for young firms in Europe led to such a surge in venture investment.

Nonetheless, this result is not equivalent to saying that venture capital in combination with going public is always more efficient.[19] Because the first best efficient investments are given by the conditions $\partial y/\partial m = 1$ and $\partial y/\partial k = 1/c$, both lead to underinvestment, with different degrees. Note that α will be chosen such that the utility of the parties expressed in monetary terms, *U*(EN) and *U*(VC), is equivalent to the opportunity costs plus the respective proportion of the overall surplus from bargaining,

$$U(\mathrm{EN}) = O + (1 - \delta)(V - O - R), \text{ and}$$

$$U(\mathrm{VC}) = R + \delta(V - O - R).$$[20]

From the perspective of the venture capitalist, this monetary utility must be equivalent to the proportion of the final payoff he receives according to the initial contract minus his investment costs given this contract,

$$U(\mathrm{VC}) = (\ y(\ ) - I) - m(\ ).$$

Thus, is a solution to

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[18] If (*O*, *R*) is in the region *A*, the contract would fail because the opportunity costs of the entrepreneur are too high. The region where the contract fails because *R* is too high is very small in this example.

[19] See Burghof/Rudolph (1998) for an earlier version of the following discussion.

[20] If the parties cannot agree to a contract and the firm is not founded, *U*(*EN*) = *O* and *U*(*VC*) = *R*.

$$\alpha = \frac{R + \delta\big(V(\alpha) - O - R\big) + m(\alpha)}{y(\alpha) - I}$$

We can use this expression to describe the differing investment incentives:[21]

Going public	Continuing intermediation
$\frac{\partial y}{\partial k} = \frac{1}{(1-\alpha)c} = \frac{y - I}{(1-\delta)V + \delta O - (1-\delta)R + k/c}$	$\frac{\partial y}{\partial k} = \frac{1}{(1-\gamma)c}$
$\frac{\partial y}{\partial m} = \frac{1}{\alpha} = \frac{y - I}{\delta V - \delta O + (1-\delta)R + m}$	$\frac{\partial y}{\partial m} = \frac{1}{\gamma}$

Table 1

We observe that continuing intermediation is particularly bad if investment of both parties is needed, but one has most of the bargaining power (γ (= *b*) close to 1 or to 0). The going public solution has a tendency to avoid extreme incentives because both the individual investments and the opportunity costs are taken into respect when deciding about α. Therefore, α has a tendency to be smaller than the respective δ for high δ and higher for low δ.

In the going public case, incentives are particularly high if the opportunity costs of the respective party are relatively high. Thus, we could identify a situation when the investment of the entrepreneur is crucial and his opportunity costs are high, whereas his bargaining power is weak, as a typical case for a going public. If a going public is essential or not therefore depends on industry characteristics like the importance of the entrepreneur's knowledge to the success of the firm. Standard technologies might do well without, whereas small high tech firms with their investment of a lot of specific knowledge are in particular need to enhance the investment incentives of the entrepreneur through an IPO.

3. Going public as strategic decision of the venture capitalist

In Germany in the past, the institutional setting consists of continuing intermediation as the only alternative. However, in the US and, since the founding of the Neuer Markt in Germany as well, venture capitalists can use (and do use) both exit channels, early going public or continuing intermediation (i.e. trade sale or disinvestment at a later date). What are the incentives

[21] Note that in the moment the parties have to decide about their investment, their share has either been fixed already in the initial contract ( ) or is exogenously given by the hold up (γ). Thus their are no second order effects.

for a venture capitalist to use the IPO although he thereby looses his potential gains from a hold up? We can distinguish two different reasons: Firstly, maybe his bargaining power in the hold up situation is not very strong and he can get a higher proportion of the firm's value in the initial contract. And secondly, he might prefer the IPO to give better investment incentives to the entrepreneur. We are particularly interested in the second argument.

Again, we use the bargaining mechanism described above to get to our conclusions. Before doing so, some additional assumptions about the going public are necessary:

1. We already mentioned above that the willingness of the entrepreneur to let the firm go public is not contractible, i.e. the entrepreneur cannot write a contract in which he bribes the venture capitalist to do so through giving him additional equity stakes. This seems to be a very strong assumption. However, even if an IPO were organized formally, this will not prove that the venture capitalist really gave away his information and bargaining power to the markets and did not merely allow some close friends of him to get some cheap shares. To assume that the informational contents of an IPO are not verifiable and thus not contractible seems rather sensible. Nonetheless, these aspects are the only reasons why the entrepreneur would want to pay for an IPO. Thus, he could only give the venture capitalist some shares as a present to make him organize an IPO at free will, which can be anticipated in the initial bargaining process in t_1. As consequence, the outcome of bargaining in the IPO case will differ from what we had above.

2. IPOs are, as many empirical results show, rather costly to the person who has to sell his shares, mainly because he suffers from a substantial underpricing.[22] In the model, it is particularly important that the venture capitalist sells some shares to loose bargaining power. Likewise, he will have to make some additional efforts to organize the going public and make the firm transparent to market participants. Thus we make the simplifying assumption that the going public will cost the venture capitalist (and only him) an additional amount u. (Note that the entrepreneur is poor and can only indirectly contribute to the costs of the IPO through getting only a smaller share of the firm.)

Putting these two assumptions together, we get the following guidelines for the decision of the venture capitalist: If the maximum gain he could get from agreeing to an arbitrary α (on a

[22] Lerner (1994) observes that venture capitalists have a special ability in the timing of initial public offerings, Megginson/Weiss (1991) state that they successfully play a certification role allowing less underpricing and lower underwriting compensation. Both aspects might contribute to a going public at comparatively low cost.

range limited only by the participation constraints due to opportunity costs O and R) and organizing an IPO afterwards in t_3 is smaller than his gain from renegotiation, he will never let the firm go public and the initial contract is irrelevant. Thus, the condition for him to let the firm go public is

$$\pi(VC|\alpha_{VC}) - m(\alpha_{VC}) - u \geq \pi(VC|\gamma) - m(\gamma), \text{ with } \alpha_{VC} = \arg\max\left(\pi(VC|\alpha_{VC}) - m(\alpha_{VC})\right).$$

If, on the contrary, this condition is fulfilled, the parties will always find an equity contract which makes the venture capitalist exit through an IPO. The threat points of the parties in the last round of the bargaining game, s_T(VC) and s_T(EN), are now determined by the values for α for which the entrepreneur will organize a going public with maximum value for himself or for the entrepreneur. The bargaining solution again converges to some s if the number of rounds is sufficiently high:

However, ongoing work of Habib and Ljungquist casts doubt on the result of Megginson/White, and the recent experience with IPOs on the Neuer Markt is that they show massive underpricing.

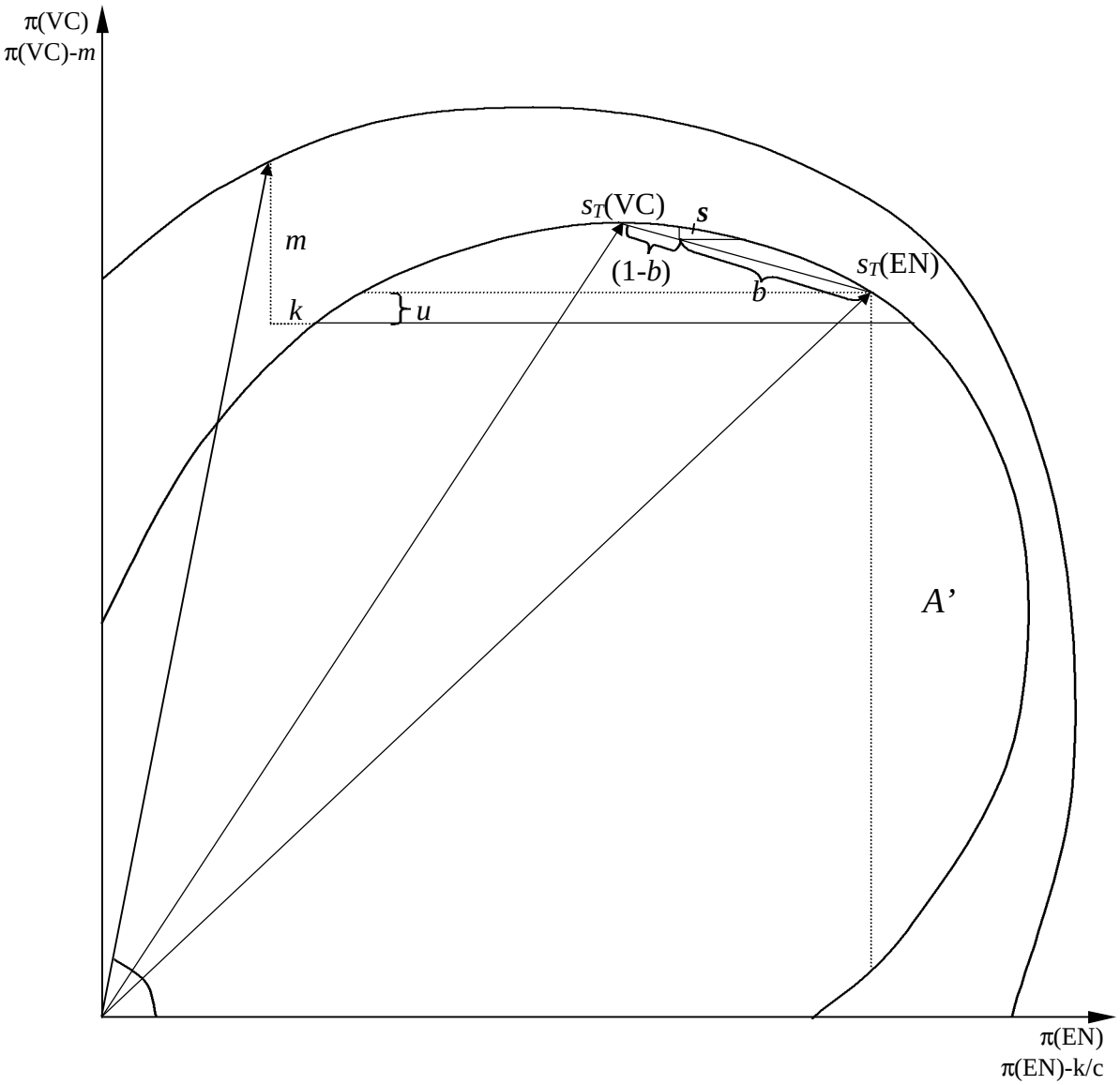

Figure 4

In this figure, we did not take the opportunity costs *O* and *R* into account, which might modify s_T(VC) and s_T(EN) if they are on the respective range. Of greater importance is that, in contrast to the result for the going public regime with its comprehensive contract in section 2, if $O > \pi(EN|s_T(VC)) - k(s_T(VC))$, that is if (*O*, *R*) is in the region *A'* in figure 4 above, the contract will fail altogether even though equity contracts exist where both would like to participate.[23] However, $A' \subset A$, with *A* being the set of opportunity cost combinations (*O*, *R*) where the parties will not participate in the case of continuing intermediation because the entrepreneur does not get a profit as large as his or her opportunity costs *O* (see figure 2). Also, the contract will never fail because the entrepreneur gets his opportunity costs, as might hap-

pen if continuing intermediation is the only exit channel. Thus, although in a world with alternative exit channels projects might fail due to the hold up problem, the number of feasible projects is weakly larger than in a institutional setting without adequate markets for a going public on a early stage of development. The founding of the Neuer Markt and the growing vivacity of the German venture capital markets can still be related to each other.

Venture capitalists might get into contact with entrepreneurs with different personal capabilities *c*. Their decision to go public or not therefore depends on this *c*. To get a straightforward result we make the following assumptions. Let ^{VC} be the distribution of value where the gains for the venture capitalist are maximal, thus where

$$\partial\left(\pi(VC|\beta) - m(\beta)\right)/\partial\beta = 0 .$$

It can be shown that under the convexity assumptions above an interior solution for ^{VC} exists.[24] However, this interior solution might react in different ways on a change of *c*. Assume that

$$\frac{\partial\beta^{VC}}{\partial c} < 0 .$$

Intuitively, we would expect this to be the case, because the venture capitalist should be interested in higher incentives for the entrepreneur if the entrepreneur is more efficient. However, with growing efficiency of the entrepreneur giving him higher incentives either gets more and more expensive for the venture capitalist, or he needs him less to achieve a positive value at all. We assume that the first effect dominates the second one. Nonetheless, even if we make this assumption, ^{VC} might still converge to a value that is to high to make a going public attractive.[25] Thus, to guarantee that venture capitalists use both exit channels, we need the additional assumption that

$$\lim_{c\to 0}\beta^{VC} > \beta(\underline{c}), \text{ and}$$

$$\lim_{c\to \infty}\beta^{VC} < \beta(\underline{c}),$$

with $\beta(\underline{c})$ such that $\pi(VC|\beta(\underline{c}) = \beta^{VC}) - m(\beta(\underline{c}) = \beta^{VC}) - u = \pi(VC|\gamma) - m(\gamma)$.

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[23] Likewise, the costs of going public *u* reduce the efficiency of this solution and might cause the failure of projects. But these projects would fail anyway if only continuing intermediation was available.

[24] See appendix 1.

Given these assumptions, the venture capitalist will go public with projects with highly efficient entrepreneurs (c $\underline{c}$) and chooses to continue intermediation for less efficient entrepreneurs (c < $\underline{c}$).

After defining the criteria for the venture capitalist to organize an IPO, what are the efficiency effects of the opportunity to go public with respect to the total gains *V*? In our model, going public reduces the share the venture capitalist receives if and only if the distribution of value maximizing *V* is below . However, we might fear that the re duction of bargaining power of the entrepreneur "overshoots", i.e. that from the going pub lic will fall below the efficient level on a level which is even less efficient than . The figure 5 below shows that this is not possible: We call the minimum value for where a going public is at least as good as co n-tinuing intermediation $\hat{\alpha}$. Some simple considerations prove that $\hat{\alpha}$ is always below the threat point of the entrepreneur in round $T-1$ (which is s_T(EN)) and thus obviously below the value for the parties will agree to:

[25] Conditions for these different alternatives will be shown in the example with specified production function below.

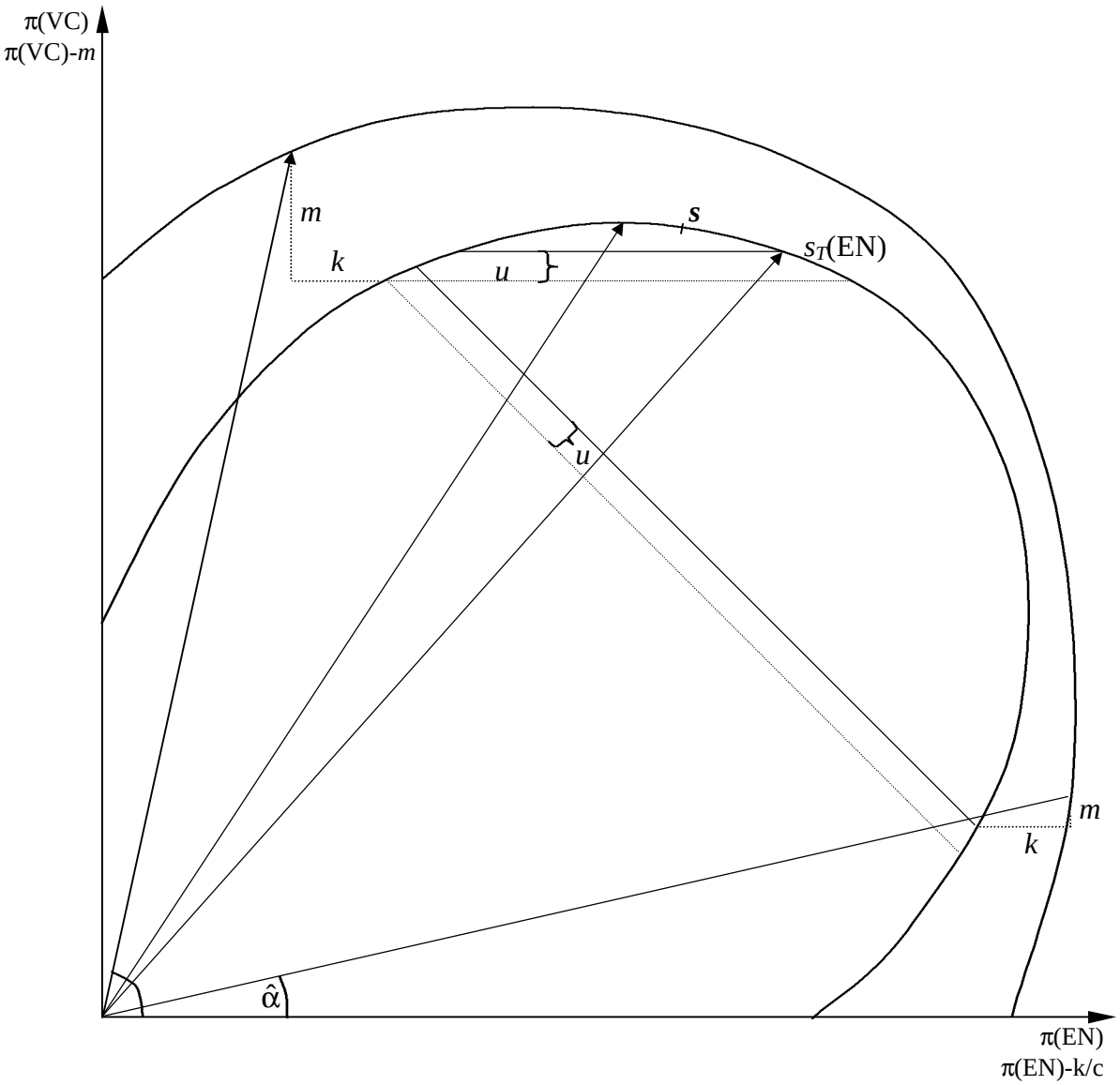

Figure 5

However, if there are always positive gains from going public with respect to overall efficiency, the threshold level $\underline{c}$ cannot be second best efficient. On the contrary, going public always takes place "too late", i.e. should be done even at lower efficiency levels $c < \underline{c}$. Seemingly, a mechanism which induces excessive going public might enhance efficiency. How this could be done will be discussed in section 5. Before doing so, we show in an explicit example that production functions and parameter constellations with the wanted properties are rather plausible.

4. An example with a specified production function

Let the payoff y be defined by $y = \sqrt{m} + \sqrt{k}$, and the overall result be

$$V = \sqrt{m} + \sqrt{k} - I - m - \frac{k}{c}(-u).$$

First best investments are given by $m^* = ¼$ and $k^* = c^2/4$: Because we allow only equity contracts according to some β (called α in the case of an IPO at an early stage and γ in the case of continuing intermediation), we get underinvestment for both parties:

$$m^{SB} = \frac{\beta^2}{4}, \text{ and}$$

$$k^{SB} = \frac{(1-\beta)^2 c^2}{4}.$$

Therefore the overall result is

$$V(\beta) = -\beta^2\left(\frac{1+c}{4}\right) + \frac{\beta}{2} + \frac{c}{4} - I(-u),$$

which is maximal in

$$\beta^* = \frac{1}{1+c}.$$ [26]

The venture capitalist gets

$$\pi(VC) - m = \beta^2\left(\frac{1-2c}{4}\right) + \beta\left(\frac{c-2I}{2}\right)(-u),$$

which has a maximum on (0, 1) in

$$\beta^{VC} = \frac{c-2I}{2c-1}$$

if, from the second order condition, $c > ½$,[27] and $c > 1 - 2I$ to be not above |1|. We can see immediately that ^{VC} converges to ½ for high c. Because

$$\frac{\partial \beta^{VC}}{\partial c} = \frac{2I-1}{(2c-1)^2},$$

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[26] The second order condition for a maximum is fulfilled: $V''(\ ) = -(1 + c) < 0$.

[27] For $c < ½$ we get corner solutions.

which is positive for $I > ½$ and negative for $I < ½$, ^{VC} approaches its limit ½ from above or from below.

For the further analysis it is interesting to know the relationship between ^{VC} and *. In pa r-ticular, $\beta^* < \beta^{VC}$ if and only if

$$I < \frac{c^2 - c + 2}{2 + 2c},$$

which at first sight might not always be the case. However, if c is low and I high, we could doubt that the value of the firm is positive at all. Testing for this, we get that for positive firm value $\beta^* < \beta^{VC}$.[28] Thus if we observe that the venture capitalist is willing to reduce his share through a going public and have in mind that he has to pay the costs of a going public u alone, we might expect an overall efficiency gain because the evolving distribution of the fi-nal payoff is closer to β^*.

Results differ depending on above or below ½. We will analyze the case > ½ only, being particularly interested in the question if the existence of market for early going public and reduce the inefficiency from intermediaries with too strong bargaining power. The condition for a going public $\pi(VC|\beta(\underline{c}) = \beta^{VC}) - m(\beta(\underline{c}) = \beta^{VC}) - u = \pi(VC|\gamma) - m(\gamma)$, can be solved for c now, which is a rather complicated term,[29] but, as computation shows, increases linear in u and overproportionally as approaches ½ from above, as the figure below shows for the p a-rameters $I = 0{,}1$ and $u = 0{,}05$.

[28] See appendix 2.

[29] See appendix 3.

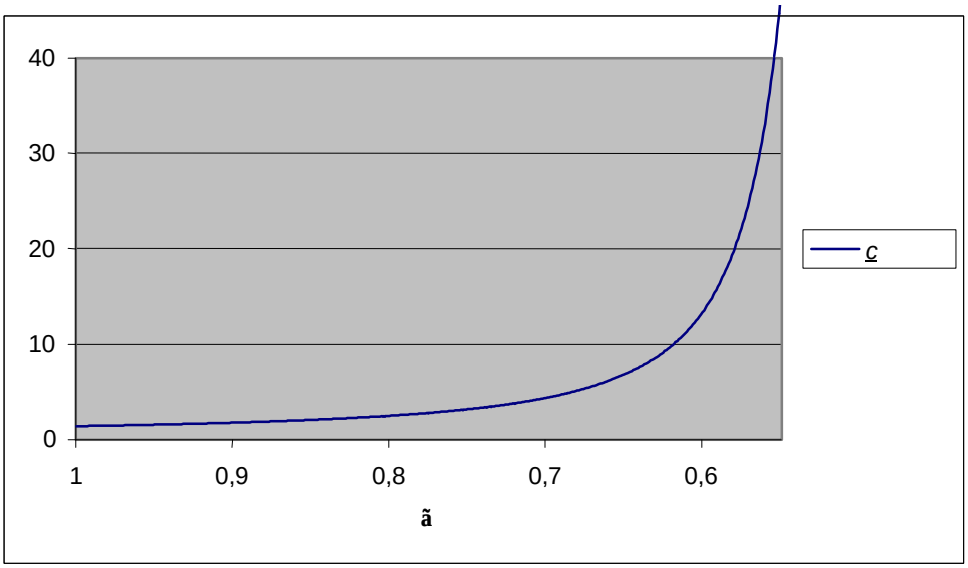

Figure 6

However, even if we set close to ½ or *u* extremely high, we always get a level $\underline{c}$ beyond which a going will take place. Interestingly, $\underline{c}$ decreases in , thus the greater the bargaining power of the venture capitalist, the greater are his incentives to reduce it through a going public.

For $I > ½$ all $^{VC} < ½$, because ^{VC} converges to ½ from below. Thus, from figure 5 we see immediately that for $u = 0$ (and $> ½$, as assumed above) a going public always takes place, and we expect a going public to take place for any constellation with positive payoff for both parties, but do not prove this here, because in this constellation the venture capitalist starts with such a low level of ^{VC} because he needs an essential investment of the entrepreneur to get enough surplus to compensate for the high value of *I*. If it is the case, all efficiency statements apply even for both cases, ^{VC} increasing or decreasing in *c*.

5. Grandstanding and investment incentives

The decision of the venture capitalist to organize an IPO might also be influenced by a totally different problem, which is how the venture capital firm is financed itself. The basic idea of the following is that a venture capitalist who often organizes a going public thereby signals his good type to his financiers. Venture capitalists can make higher profits if they persuade the capital markets that they are of a good type, because they can finance additional projects easier and cheaper. Therefore, they have a tendency towards more frequent going public, to

"grandstanding" in discordance with their short-term profit maximization goal.[30] However, although grandstanding is costly to the venture capitalist and his financiers, it might enhance overall welfare not only because it reduces the information asymmetry between financiers and the venture capitalists (as would be standard argument for costly signaling), but also because it reduces the loss from the third best allocation of the firm's profit. This is because without grandstanding venture capitalists tend to bring firms to the market "too late", meaning that $\underline{c}$ is inefficiently high, and, even if a going public takes place, because they might take a greater share of the firms value than is efficient with respect to investment incentives.

Assume that there are two types of managers of venture capitalists, good ones (VC_g) and bad ones (VC_b), who face two successive projects P_1 and P_2. The decision about the going public of the second project P_2 will always be taken according to $\underline{c}$ and the distribution of value will be done according to or as deduced above, because now the managers of the venture capitalist maximize short term gains. However, when deciding about P_1, both the managers of the venture capitalist and the entrepreneur will take the long-term effect of their decisions on P_2 into account.

To align the incentives of the managers of the venture capitalist with the interest of the financiers, we assume that the managers are paid by getting a small fraction of (VC) $- m - R$ (- u in the case of going public) and therefore maximize this value, as was assumed implicitly above.[31] Financiers could use their money for an alternative investment not available to the managers of the venture capital firm, which would yield them, besides the opportunity costs R, an additional K, representing in a simple way the additional costs to the financiers to delegate their investment decision to the managers.[32] Thus, the conflict of interest between the managers of the venture capitalist and its financiers is not totally resolved, because managers do not take these costs into account.

The financiers do not know the type of venture capitalist they finance, nor do they observe the payoffs of the projects directly. They obviously realize if the venture capitalist brought the project to the stock market or not.[33] Nevertheless, financiers know the expected value of a

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[30] See Gompers (1996).

[31] At least in the United States, it is rather common to compensate managers of venture funds with shares of the projects they work on.

[32] Or, taking the opposite stance, K represents the fact that the managers of the venture capitalist enjoy what they do, i.e. get private value from their work)

[33] This might be due to the fact that venture capitalists, after selling in the IPO as many shares as needed to create a liquid market and loose their bargaining power, will sell the remaining shares only bit by bit and during a longer period of time for several reasons (e.g. to keep underpricing low through a commitment effect). But even

project of a good or a bad venture capitalist. Because good venture capitalists find good projects with greater probability, in a one period game

$$E(\pi(VC_g) - m_g - u) - R > E(\pi(VC_b) - m_b - u) - R.$$[34]

(For simplicity of notation, we call these expected gains of the good and bad venture capitalists from P_2 E_g and E_b.) Both types of managers would prefer to continue operation because their expected gains from the second projects are positive:

$$E_g > E_b > 0.$$

However, if the financiers knew about the type of the venture capitalist, in a one period game they would finance good ones, but not bad ones:

$$E_g - K > 0 > E_b - K.$$

The financiers do not know the type of venture capitalist they are dealing with, but assign a certain probability to each type. Therefore there exists a critical probability p_c below which they are not willing to finance the firm because

$$p(E_g - K) + (1-p)(E_b - K) < 0 \forall p < p_c.$$

In the following, we concentrate on the question if going public could serve as a costly signal which allowed the financiers to distinguish better between good and bad venture capitalists in the second period, i.e. only on the potential existence of the respective equilibrium. Let the ex ante-probability with whom the financiers expect the venture capitalist to be of the good type be *p*. Assuming that the venture capitalist uses grandstanding as signal for his quality, the financiers update their probability to *p*( ) if the venture capitalist went public, and to *p*( ) if not. Signalling is possible if *p*( ) p_c and *p*( ) $< p_c$. If this condition is fulfilled, the financiers will make their financing decision for P_2 conditional on the going public, i.e. will finance only projects of venture capitalists who went public with the first project. With respect to the baysian update of expectation, we must have *p*( ) > *p* > *p*( ).

If the financiers finance second projects only if the venture capitalist went public with the first one, how will the venture capitalists react? Assume that

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if payoffs are more transparent, it might be difficult for investors to evaluate the capability of projects and management teams.

[34] Note that all the realization of the terms in the expectation *E*(..) depend crucially on the result of the respective bargaining process and in particular on the decision to go public.

$E_g \geq u > E_b$.[35]

Thus, for a good venture capitalist the expected gains of a second project are higher than the costs of going public, whereas for the bad venture capitalist these gains are not sufficiently high. The consequences of this relation on the behavior of the different types of venture capitalists with respect to the first projects are fundamentally different if c is high, in particular above $\underline{c}$, or if it is below some value $\underline{\underline{c}}$ below $\underline{c}$:

1. c $\underline{c}$: All types of venture capitalists organize a going public of such good projects. Therefore this range of parameters does not directly contribute to a better distinction between good and bad venture capitalists. However, good venture capitalists get projects with c $\underline{c}$ with a higher probability.

   Because the entrepreneur knows that the venture capitalist plays a signalling game and is therefore willing to trade future gains against actual losses, the threat point of the entrepreneur from the last bargaining round T changes. If he were the last to make a proposal, he would not only take all actual additional value the venture capitalist would receive from a going public, but also the expected gains of the venture capitalist from the next project. Consequently, according to the new bargaining outcome the entrepreneur will get a higher proportion of the firm value than without signalling: $_s <$. If $>$ *, the di s-tribution of value which maximizes V, choosing a lower value $_s$ could enhance V.

   A third effect is that, because the parties can bargain over the second period gains of the venture capitalist, the opportunity costs O and R are less restrictive. Consequently, more projects become feasible.

2. $\underline{c} > c$ $\underline{\underline{c}}$: In this range of parameters, the immediate gains from going public for the entrepreneur are positive, but less than u, or above u only if the parties agree to a contract with above . In a one period game the venture capitalist would not or ganize an IPO. However, as long as the expected gains from P_2 are sufficiently high, even bad venture capitalists and entrepreneurs will find a range of parameter for where a going public can take place and where both gain from this deal. As already said, this kind of equilibrium could exist with be low or even above . For the second kind of equilibrium (above) to exists we must assume that the venture capitalist can force the entrepreneur to a c-

[35] To express this condition in another way, one could say that good venture capitalists are those where E_g u and bad one where $E_b < u$.

cept a going public in t_3, because otherwise the entrepreneur would prefer continuing intermediation. This assumption seems to be rather implausible, therefore we will not analyze this equilibrium more closely. For the first kind of equilibrium (be low) the i mplications are mainly the same as for $c > \underline{c}$.

3. $\underline{c} > c$: With respect to the signalling game, this is the most important range: If c is sufficiently low, no value exists for bad entrepreneurs where they could make enough profit from organizing a going public and from continuing operation to compensate for the loss of u. Thus only good entrepreneurs might let the project go public. As can be seen in the figure below, bargaining ends up in the usual offers for the last bargaining round T, s_T(VC) and s_T(EN) (which might again be modified by opportunity costs O and R), and a solution s in the first round where both get some weighted average of their payoff according to their respective offers in T. The willingness of good venture capitalist to let the firm go public is only restricted by the opportunity costs, which will hinder them to bring extremely bad projects to the market. The bargaining process is illustrated by the figure below:

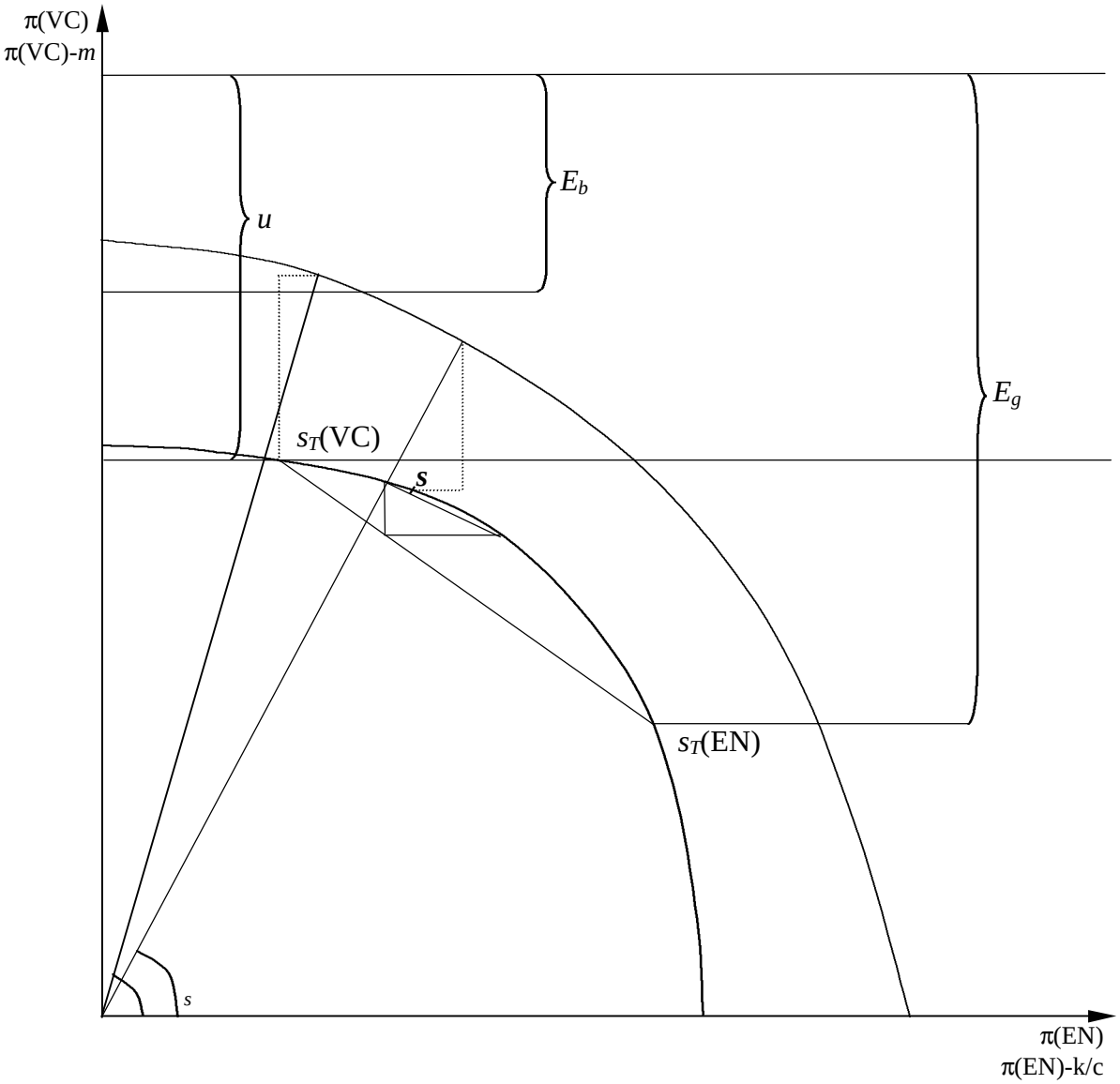

Figure 7

Again the proportion the venture capitalist receives is reduced in comparison to the solution without signalling (which is now, in contrast to the case $c > \underline{c}$, continuing intermediation, thus $_s <$), which might lead to more efficient investment. And again the number of feasible projects increases because the restriction through the opportunity costs O and R are less severe because the parties can trade the expected gains of the venture capitalist from P_2 against them.

Putting the result together, we observe with respect to the signalling game that the proportion of good venture capitalists organizing a going public is greater than the proportion of bad ones, because good venture capitalists encounter projects with c $\underline{c}$ with higher probability, and because they are the only ones who might bring bad projects ($c < \underline{c}$) to the market. Simple

baysian calculation yields the relation $p(\ ) > \ p > p(\ )$, which is the crucial precondition for the existence of a signalling equilibrium.[36]

We can draw some conclusions from the signalling game: It explains grandstanding as a rational behavior of venture capital firms on market with information asymmetry between these firms and their financiers. Although costly for financiers and managers of the venture capital firms, the signalling could enhance overall welfare through better investment incentives and a greater number of feasible projects.[37] The attractiveness of venture capital markets and of the respective stock exchanges for entrepreneurs will thereby increase.

A remark should be made on the costs of going public u. They are essential for the signalling game, because otherwise bad venture capitalists could mimic good ones at no costs just by anticipating the outcome of a potential renegotiation in the initial contract, i.e. by choosing = and organizing a going public afterwards. Furthermore, u determines the accurateness of the signalling. In reality, much of the costs of going public can be attributed to underpricing of IPOs. We do not get an explanation for the existence of underpricing from the modal. However, it could explain why managers and authorities of stock exchanges itself should not bother too much about heavy underpricing. Although some market participants loose thereby, the overall effect of underpricing could be positive because it contributes to the information efficiency of the market through enabling venture capitalist (or other participants) to signal their quality, and to overall surplus through better incentives and a greater number of feasible projects. Maybe the amount of underpricing is potentially a strategic parameter for stock exchange authorities, which could try to increase or decrease the amount of underpricing in accordance with the informational and incentive needs of their market. However, we will not speculate here on how this could be done.

6. Some potential extensions: Many project or many periods

Typically venture capitalists finance more than one project at a time. A strategy of the financiers could then be to finance the second period projects if and only if the venture capitalist

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[36] Off course, a signalling equilibrium exists only if p_c is on the range between $p(\ )$ and $p(\ )$, and if on any stage of the game all participation constraints of the three parties are fulfilled (which are made tighter in particular for financiers through the costly signalling). An analysis of these conditions will not be provided here. It would, in a more specified formulation of the model, lead to additional constraints on parameters and maybe on the type of production function.

[37] The investment incentives are not necessarily better in all cases because the effect of signalling on might "overshoot", i.e. might reduce it to an inefficiently low level (below $\hat{\alpha}$ in section 3).

brings a certain percentage of the first period projects to the market, e.g. at least $\underline{n}$ out of n projects. Now potential equilibria are highly dependent on the distribution of c and rather complex. In every state of the world we get n realizations c_n for every first period project from a total of n projects. To find the respective level of $\underline{c}$, which is now given by the project i with the lowest value for c the venture capitalist is willing to bring to the capital market to guarantee continuing financing, the venture capitalist had to take into account not only the expected gains from continuing operation in the next period, but also the costs he had incurred by bringing other projects with values of c in-between $\underline{\underline{c}}$ and $\underline{\mathrm{c}}$ to the market. Thus, for every state of the world there is a different value for $\underline{c}$. To determine their own behavior, entrepreneurs would either have to know c for all projects and thus the respective $\underline{c}$, which is rather implausible, or make up expectations about the distribution of $\underline{c}$.

However, we still expect that going public could serve as a signalling device for good venture capitalists, because for them the expected gains from continuing operations are higher than for bad venture capitalists and bad venture capitalists have to bring more bad projects to the market. Thus the probability of good type venture capitalists among the venture capitalists who brought more than $\underline{n}$ projects to the capital markets will usually be greater than p. In their strategy choice, the financiers will choose $\underline{n}$ such that the difference between the costs of signalling and expected gains from a better differentiation between good and bad venture capitalists is maximal. Given that the number of projects is high enough, signalling through going public might even differentiate perfectly between good and bad types due to the law of large numbers.

Another potential extension is to take more than two periods into account. Such model would coincide with the idea of reputation building like in Diamond (1991). Transferring the results of Diamond to the described situation, we would expect that young venture capitalists will tend to use grandstanding as a signalling device, whereas older firms with a solid reputation as good venture capitalists don't. This plausible (and observable, see Gompers (1996)) result has the consequence that established venture capitalist firms might produce less overall value because some grandstanding enhances effiency.

7. Optimal contracts beyond equity

To restrict available contracts to equity arrangements seems to be a very severe assumption. Much better results could be expected from the use of debt or some forms of convertibles. Suppose e.g. that in the beginning the entrepreneur only had a fixed claim D_{EN} against the

firm, and the venture capitalist had the right to make a take it or leave offer to swap his equity-like claim against a debt claim D_{VC}, with D_{VC} freely chosen by him. Of course, the entrepreneur will only agree if $y - I - k/c - D_{VC} \quad D_{EN}$. If he does, he afterwards has a claim on the total residual and consequently chooses k^*. If not, he chooses $k = 0$. To maximize the value of his claim, the venture capitalist will offer (marginally more than) $D_{VC} = y - I - k^*/c - D_{EN}$. Thus, he will either get $y(m, k^*) - I - k^*/c - D_{EN} - m$, if he offers a swap, or $y(m, k=0) - I - m - D_{EN}$, if not. Due to the additive separability of the technology in k and m,[38] in both cases he will chose m^* and, because $y(m^*, k^*) - k^*/c > y(m^*, k=0)$, he will always offer a debt for equity-swap. The result of the initial bargaining can be regarded through choosing the right D_{EN}, which determines D_{VC} and thereby the total distribution of value. As a result, we get first best.

Such an arrangement resembles very much what happens in a buy back of shares by managers, which is one of the most important exit channels for venture capital investments.[39] Likewise, the use of convertibles by Anglo-Saxon venture capital firms shows that we might expect efficiency gains from similar, more sophisticated contracts.[40] There are two arguments to omit this alternative nonetheless. Firstly, it does not solve the problem how to finance the investment I in t_5. A going public is still valuable to reduce the hold up threat connected with this problem, even if the described swap contract were initially implemented. In the setting of the model, the swap contract cannot be enforced if the venture capitalist does not let the firm go public, because otherwise all contracting in t_1, be it about an equity contract or any other agreement, is irrelevant for the final outcome. In this case, incentives can be influenced only through measures changing the bargaining outcome, e.g. through the allocation of property rights or, as discussed above, of bargaining power through market changes. Off course we would expect that the parties use all available instruments to minimize inefficiencies, but to describe the effect of one of these instruments, i.e. the switch from a bilateral monopoly to a competitive market for funds, should suffice here. Also, the use of other instruments like property rights suffers - in the case of young technology firms we usually have in mind when

[38] However, we do not need this assumption to get first best with the swap contract.

[39] However, according to the numbers of the Bundesverband Deutscher Kapitalbeteiligungsgesellschaften (1996, 1997, 1998), the relative importance of buy backs decreases sharply in the last few years from above 60% in 1995 to about 30% in 1997.

[40] There exists an extended theoretical literature on the use of convertible debt or convertible preferred equity to address incentive problems arising in venture capital contracts. See e.g. Berglöf (1994), Marx (1994), Cornelli/Yosha (1997) or Gompers (1997), and in particular Bascha/Walz (1998) on the decision to go public.

talking about venture capital - from the highly specific character of investment and the little value of the firms assets outside the existing relationship.[41]

Nonetheless, it is tempting to rewrite the analysis, now taking the debt for equity-swap instead of the initial equity contract with claims and (1-). H owever, there exists a second and crucial argument for the limitation of the analysis to equity contracts, especially with respect to the real world problems of young firms: Higher incentives for one of the parties and debt claims for the other effect a higher leverage of the whole firm. Assume that the managers could make a different investment with a lower mean, but much higher risk, e.g. take as much money as possible out the firm and gamble. If they accept the swap offer of the venture capitalist, they will afterwards tend to gamble, because now risky investments profit from limited liability. For any leverage with in this sense risky debt we could construct a risky investment with a expected value below the one of the original investment project with first best investments, which will nonetheless be chosen by the entrepreneur due to limited liability. The possibility to implement such swap arrangement thus depends on either the lack of attractive risky projects or on the availability of own money to invest, that is the possibility of a real buy back. Especially in fast growing and technology oriented firms the founders, e.g. successful inventors or scientists, might have neither initial money nor substantial early dividends to invest into the reduction of the risk incentive problem. For them, equity remains the only alternative.

8. Conclusion and policy implications

The first and straightforward result is that going public can reduce the hold up threat to young firms and thus can induce better investment incentives. Going public is particularly valuable for very successful projects with very able entrepreneurs where this ability is particularly relevant for success. Likewise, the opportunity to go public makes a greater number of projects feasible because it allows, to some degree, an adjustment of contracts to different opportunity costs. Thus, stock markets for young firms managed by their owners are essential for venture capital investments and a vivid venture capital market, and this the more, the greater the growth expectations for young firms are.

[41] Other restrictions on the feasible contract schemes arise from wealth restriction especially on the side of the entrepreneur.

The second main result is about grandstanding and deals with how venture capital firms should be financed. Grandstanding is described in this paper as the tendency of venture capital firms to bring projects to the stock exchange although they would yield a higher value for financiers if the managers of the venture capitalist kept the firm in their portfolio - and thus kept their opportunity for a hold up. This kind of grandstanding is attributed to the need of the managers of the venture capital firm to signal their quality to their financiers. Because otherwise venture capitalists brought their projects to the market "too late" and gave entrepreneurs to little incentives, grandstanding can enhance the overall efficiency. And it might even make projects feasible that would otherwise fail because, without grandstanding, no equity contract could guarantee both parties their opportunity costs.

With respect to financing policy, it interesting to note that grandstanding is only sensible if there exists asymmetric information between the financiers and the venture capital firms, and if venture capital firms cannot be sure to get their next projects financed. Therefore venture capital financing by the state or closely connected firms like banks in financial conglomerate might be less efficient because the relationship either lacks the information asymmetry or the pressure to signal quality. The better financing of venture capital firms would be through the stock markets or through funds with a predetermined lifetime and outside investors.

Lastly we note a specific function of underpricing, because it makes initial public offerings costly, which is essentially if the IPOs should serve as signalling device. This result might be of interest for the future discussion about market structures and procedures, which might be inspired by the high underpricing of IPOs on the Neuer Markt.

Appendix 1

Assume that (VC) – *m* is convex and differentiable on the relevant range. To show that an interior solution exists, we deviate (VC) – *m* with respect to , taking into account the se c-ond best conditions for the investment levels *m* and *k*:

$$\frac{\partial\left(\pi(VC|\beta)-m(\beta)\right)}{\partial\beta} = y - I + \beta\frac{\partial y}{\partial m}\frac{\partial m}{\partial\beta} + \beta\frac{\partial y}{\partial k}\frac{\partial k}{\partial\beta} - \frac{\partial m}{\partial\beta}$$

$$= y - I + \frac{\beta}{(1-\beta)c}\frac{\partial k}{\partial\beta} \stackrel{!}{=} 0.$$

We get the maximum value for (VC) – *m* in

$$\beta^{VC} = \frac{c\left(y(\beta^{VC}) - I\right)}{c\left(y(\beta^{VC}) - I\right) - \frac{\partial k(\beta)}{\partial \beta}},$$

which is in (0, 1) because $\frac{\partial k(\beta)}{\partial \beta} < 0$.

Appendix 2

The condition for $\beta^* > \beta^{VC}$ is

$$I > \frac{c^2 - c + 2}{2 + 2c}.$$

The value of the firm is

$$V = \sqrt{m} + \sqrt{k} - I - m - \frac{k}{c} = \frac{\beta}{2} + \frac{(1-\beta)c}{2} - I - \frac{\beta^2}{4} - \frac{(1-\beta)^2 c}{4}.$$

Assuming that $\beta^{SB} > \beta^{VC}$, from $V > 0$ we get the condition

$$\frac{\beta}{2} + \frac{(1-\beta)c}{2} - \frac{\beta^2}{4} - \frac{(1-\beta)^2 c}{4} > \frac{c^2 - c + 2}{2 + 2c},$$

which is equivalent to

$$A = -c^2\left(1 + \beta^2\right) + c\left(3 + 2\beta - 2\beta^2\right) + 2\beta - \beta^2 - 4 > 0.$$

This function is convex in both c and . To find its maximum value, we first solve

$$\frac{\partial A}{\partial c} \stackrel{!}{=} 0,$$

and get

$$c(A_{\max}) = \frac{3 + 2\beta - 2\beta^2}{2 + 2\beta^2}.$$

Substituting c in A, we get

$$-7 + 20\beta - 28\beta^2 > 0.$$

However, the maximum for this function can be found in $\beta = \frac{20}{56}$, and is –3.47, which is less than 0. Thus, $\beta^* < \beta^{VC}$ for any $V > 0$.

Appendix 3

Inserting $\beta^{VC} = \frac{2-2I}{2c-1}$ in $\pi(VC|\beta(\underline{c}) = \beta^{VC}) - m(\beta(\underline{c}) = \beta^{VC}) - u = \pi(VC|\gamma) - m(\gamma)$ yields

$\frac{(c-2I)^2}{4(2c-1)} - u = \gamma^2\left(\frac{1-2c}{4}\right) + \gamma\left(\frac{c-2I}{2}\right)$, which can be solved for

$\underline{c} = \frac{\sqrt{A^2 + BC}}{B}$, with

$A = \gamma + 4\gamma I - 2I - 4u - 2\gamma^2$,

$B = 1 + 4\gamma^2 - 4\gamma$, and

$C = 4(\gamma I - I^2 - u) - \gamma^2$.

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