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Screening and Advising by a Venture Capitalist with a Time Constraint

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Abstract:
This paper proposes an intertemporal model of venture capital investment with screening and advising where the venture capitalist's time endowment is the scarce input factor. Screening improves the selection of firms receiving finance, advising allows firms to develop a marketable product, both have a variable intensity.
In our setup, optimal linear contracts solves the moral hazard problem. Screening however asks for an entrepreneur wage and does not allow for upfront payments which would cause severe adverse selection. Project characteristics have implications for screening and advising intensity and the distribution of profits. Finally, we develop a formal version of the "venture capital cycle" by extending the basic setup to a simple model of venture capital supply and demand.

JEL classification: D82, G24, L19

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1 Introduction

In recent times Venture Capital has received significant attention from politicians and economists. A great amount of today's blue chips like Apple Computers, Compaq, Federal Express, Intel, Microsoft, Raychem and Sun received venture capital in their first stages of development. Although recent work has helped to shed light on some important aspects, see Gompers and Lerner (1999), Gompers and Lerner (2001) and Kaplan and Strömberg (2001) for excellent summaries of the literature, many questions remain unresolved. Recent theoretic papers deal with advising and the double sided moral hazard problem. Selection issues and screening remain to be explored and analyzed. Consequently, predictions for optimal contracting are typically based on moral hazard considerations alone.

This paper combines screening and advising activities using a notion of *time investments* by the venture capitalist into his portfolio firms. At least in recent years, venture capital funds have successfully raised funds in excess of their investments, see EVCA (2002). Some funds are not invested and were not invested even through the boom phase in the late 90s, so that capital supply does not seem to be the scarce production factor of the investment process. Recent research has then emphasized the special importance of the venture capitalist. Given the severe informational asymmetries when financing start-up firms, the venture capitalist as a financial intermediary needs a set of specialized skills in order to be successful. He is highly involved in the selection of potential ventures as well as in supporting the development of the firm afterwards. Many authors have then recognized the number of venture capitalists as the critical resource of the investment process, see Michelacci and Suarez (2002), Kanniainen and Keuschnigg (2003) or Inderst and Müller (2003).

Following Kaplan and Strömberg (2001), we will be more specific in this paper and argue that the *time of venture capitalists* is the scarcity. A variety of empirical work has pronounced the importance of the time constraint, see e.g. Gorman and Sahlman (1989) or Kaplan and Strömberg (2003). Gorman and Sahlman (1989) report that VCs rarely delegate tasks to their staff member but invest significant amounts of their own time in their portfolio of firms. Time that is invested in one projects is missing in other ones. An accurate management of personal evolvement and a focus on the most promising ventures is then an essential task for a venture capitalist. Time investment in ventures typically comes as selection effort before contract signing or as advice following the investment:

- Venture capitalists are involved in the selection of promising ventures. Kaplan and Strömberg (2002) provide evidence on the high degree of screening effort. The selection process is guided by a catalog of requirements defining criterias of a venture that is worth receiving finance. Walking through the different requirements then allows the venture capitalist to eliminate potentially bad investment proposals. Even if screening is very intensive, some uncertainty will stay and "can only be resolved by going forward"(Gorman and Sahlman (1989, p. 238)). It is hard to foresee the commercial consequences of new product introductions so that product market forces will have to decide upon the usefulness of a business idea. While typical theoretical models attach only a fixed monetary cost to the screening process, it is obvious that the productive input is the time that is invested in reading business proposals, evaluating market outlook etc. Although an essential aspect of the investment process, screening has received only few attention in theoretical work where Ueda (2002) and Gehrig and Stenbacka (2003) are noticeable exceptions. Both papers however do not allow for different intensities of screening and only emphasize the cost characteristic of screening, a simplification that omits the scarcity of venture capitalists' time.

- Working together with the entrepreneur, VCs also add value to the venture by advising and monitoring the firm. A variety of theoretical papers has discussed the interaction between the entrepreneur's effort and the venture capitalist's advice. The emerging double sided moral hazard problem has been analyzed in Repullo and Suarez (1998), Schmidt (2002) and Casamatta (2003). Empirical studies provide evidence of value added services. Gorman and Sahlman (1989) and Kaplan and

Strömberg (2002) report on the various margins where venture capitalists improve the management of the firm. According to Hellmann and Puri (2000) and Hellmann and Puri (2002) the VC helps to improve the *professionalization of the firm*. VC financed firms are e.g. faster to bring their products to the market.

Hellmann and Puri (2000) find that venture capital is used by *Innovators*, companies that develop new procedures or new products and operate on new markets. Since there is typically severe competition in innovative markets as many substitutable products are being developed simultaneously, a first mover will be able to capture a higher market share and thus higher profits from a product compared to a market launch later in time. If there are many competing firms working on similar projects, then introducing a product late is harmful since competitors already absorb a large market share. The marketing literature has typically emphasized brand building as the driving force behind this effect.[1] For industries like information technology and biotechnolgy that typically use venture capital, we could add network building, standard setting or patenting as additional arguments for the first mover advantage. In line with this, empirical research shows a distinct decline in market share for later entrants, see Robinson and Fornell (1985) and Urban, Carter, Gaskin, and Mucha (1986). Brown and Lattin (1994) emphasize that the length of time in the market provides additional advantage for a first mover. Gorman and Sahlman (1989) report that a "delay in product development was the major cause of venture failure"(p. 239) besides management problems and was mentioned in more than 50% of all failure cases. Firms operating in evolving industries will thus race to bring their product to the market as soon as possible.

This paper is new in combining a continuous screening and advising decision by a venture capitalist. Based on a model of venture capital investing with a focus on time investments, we will be able to look at market structures following shocks on the demand for venture capital. The paper has some similarities to Michelacci and Suarez (2002) who

[1]Schmalensee (1982) argues that a first mover acquires a stock of users who have experienced the quality of his product and can hardly be convinced to switch to new entrants.

propose a search model of the market for venture capital. A venture capitalist monitors one project at a time and thereby guarantees effort provision by the entrepreneur. Given this interrelationship, the venture moves to a mature state with a constant hazard rate. A similar search approach is also used by Inderst and Müller (2003). These authors incorporate value adding services by the venture capitalist and consider implications of market structures on contracting. Finally, Kanniainen and Keuschnigg (2003) analyze the determinants of VC's portfolio composition. In their model, venture capitalists expand or shrink the number of portfolio firms depending on the demand and supply for venture capital. All previous papers omit a direct view on the scarce time of a venture capitalist. In addition, the combination of a continuous decision between screening and advising has not been analyzed before and results in interesting implication for contracts and market structures.

The paper proceeds by first considering a single investment process. Players and project characteristics are introduced and the optimal outcome together with its implications for contracting and some comparative statics is determined. The following part then considers a simple market environment for venture capital investment and analyses the consequences of demand fluctuations both for the long and short run.

2 An intertemporal model of screening and advising

We consider a partial equilibrium model of an economy with a market rate of return of $\rho = 0$ and a common wage rate $w > 0$. Time is continuous. Two players are introduced both of which are assumed risk neutral and maximizing their expected profit. The general setup follows the early literature on patent races[2] similar to Michelacci and Suarez (2002).

Entrepreneurs have an idea for a risky venture but are fundless and thus need external investments of I to develop their R&D results into a new product. Once the

[2]See e.g. Lucas, Jr. (1971), Loury (1979) and Lee and Wilde (1980).

investment is done, the project moves into a development stage. Given commitment of the players (to be defined below), a final product ready for market introduction then arrives randomly at a hazard rate λ. There are two quality types of business ideas. Market supply consists of good and bad firms in relative shares of x and $1-x$, respectively. We assume that neither entrepreneur nor any outsider know the true type of a specific project. Once a marketable product appears, market forces will decide upon its survival and true quality is revealed. Bad projects fail and yield a liquidation value Q. Good projects succeed when introduced at the market and return a payout in excess to the liquidation value. We take the return payment as decreasing over time reflecting the decrease in market potential over time. A good project then creates a value of $R(t)+Q$. We will assume $R(0) \geq 0$ and $\lim_{t\rightarrow\infty} R(t) = 0$ with $R'(t) < 0$ whenever $R(t) > 0$. This declining formulation implements empirical and theoretical results discussed before. A microeconomic foundation would be based on strategic interactions as in the literature on patent races, but is beyond the scope of this paper. Payouts are ordered $R(0)+Q > I > Q$.

Venture capitalists are specialized financial intermediaries. They have access to the capital market and can raise funds at the market rate of return.[3] In addition to the provision of funds, they have two important core competencies: First, VCs have a deep industry knowledge allowing them to judge the commercial potential of a business idea. We will refer to this as the screening competency of a venture capitalist. Screening is imperfect, its effectiveness depends on the time invested in the screening process. We will assume that the screening process is guided by a list of requirements with an arbitrary level of accuracy. Good projects fulfill all requirements while bad projects fail to meet the standards in a more or less subtle way. Walking through his list and digging deeper into the details of the investment proposal, we thus assume that a venture capitalist can eliminate bad projects at a rate μ so that investing screening time s reduces the share of

[3]This assumption allows us to abstract from two important points of venture capital investment. First the relationship between the venture capitalist and portfolio investors and second the desinvestment decision of the venture capitalist.

bad projects to $(1-x)\exp(-\mu s)$. We calculate the relative share of good projects after screening as $\pi(s) = \frac{x}{x+(1-x)\exp(-\mu s)}$.

Second, venture capitalists have management knowledge and are experienced in building up a commercial infrastructure for infant firms and can thus improve the speed of professionalization. We will call this advising the firm. We assume that product development requests the joint evolvement of entrepreneur and venture capitalist in order to succeed. Since the entrepreneur is commercially inexperienced, he needs external advice $a \in \{0,1\}$ by the venture capitalist in addition to his own effort $e \in \{0,1\}$. At every point in time there are thus digital decisions about the personal involvement of the players. Since we consider a model in continuous time, the time domain will allow for different intensities of the two input factors. We will take the extreme assumption that only the joint effort allows for product development at a rate of $a \cdot e \cdot \lambda$. Both entrepreneur and venture capitalist however face (opportunity) costs. Marginal costs of keeping the firm alive during its development phase are thus the foregone, common wage of the entrepreneur w^{EN} plus effort costs c^{EN} and the venture capitalist's foregone wage w^{VC} and costs of advising c^{VC}.

The time line of a single venture capital investment is as follows: Entrepreneurs are endowed with a business idea with unknown, but predetermined quality. Venture Capitalists announce a contract offer specifying all financial arrangements. Acceptance is however contingent on successful screening.[4] Entrepreneurs with a business idea then apply for venture capital finance. During the following screening period, bad projects will drop out at the hazard rate μ. Once screening is completed, investment takes place and the period of advising starts. Productive input of both entrepreneur and venture capitalist are unobservable. If both comply, a marketable product appears at a hazard rate λ. Uncertainty is resolved after market introduction and payoffs are settled. At some point in time, remaining projects might be liquidated. Screening and advising period are

[4]This timing circumvents the technical difficulties discussed in Gehrig and Stenbacka (2003) and Broecker (1990).

consecutive. Advising only starts once screening is finished and investments are done.

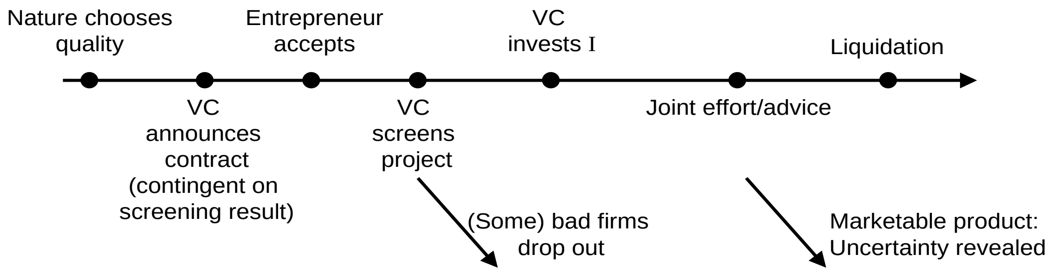

Figure 1: Time line of venture capital investment

A venture capitalist is only able to either screen or advise one project at a point in time. Once he stops his involvement in a specific project, be it that the project fails in the screening stage, succeeds to bring a project to the market or fails to develop a product and is consequently terminated, the venture capitalist will start to look for a new investment opportunity so that the investment process starts afresh. Arranging individual investment projects back-to-back, the model thus describes a repeated, intertemporal venture capital cycle. We will renew this interpretation when discussing market structures and now continue to analyze a single project.

2.1 Productive impact of venture capital investment: Screening and advising

We will solve the model moving backwards in time. We start by deriving the first best solution. In order to replicate the optimal outcome, we will then consider implications for contracting in a decentralized version. We conclude this section with comparative statics describing the impact of key project and industry parameters on real decisions and contract parameters.

2.1.1 Advising

A successful product development is only possible if advice is provided. Since the profit of a successful market introduction declines over time, advice is most productive at the beginning of the firm's lifetime and has decreasing returns over time. Advising will then stop at some time t^* to be determined in the following. To keep things simple, we will assume that the decline in market potential only starts when investments are undertaken and the advising period starts.[5]

Integrating over time, we can now determine the expected payback of a venture $P_t(t^*, \pi)$ at some point in time $0 \le t \le t^*$. Initial firm value $P_0(t^*, \pi)$ will be especially important in the following.

$$P_t(t^*, \pi) = \int_t^{t^*} \lambda \exp(-\lambda(u - t)) \cdot \pi R(u)\, du + Q \tag{1}$$

We thus have that firm value increases with the provided advice $\frac{dP_t(t^*,\pi)}{dt^*} > 0$ but at a declining rate $\frac{d^2 P_t(t^*,\pi)}{d(t^*)^2} < 0$. Since profits from market introduction are bounded $R(t^*) \le R(u) \le R(t)$, we determine $P_t(t^*, \pi) \ge \pi R(t^*)\left[1 - \exp(-\lambda(t^* - t))\right] + Q$.

The venture capitalist will face costs of advising and the entrepreneur has a forgone wage. Total costs of managing the firm including effort costs are then given as

$$C_t^{Ad}(t^*) = \int_t^{t^*} \left(w^{EN} + c^{EN} + w^{VC} + c^{VC}\right) \exp(-\lambda u)\, du. \tag{2}$$

Optimal advising solves the following maximization problem

$$\begin{aligned} &\max_{t^*} \Pi(t^*, \pi) = P_0(t^*, \pi) - C_0^{Ad}(t^*) - I \\ FOC \ &: \ \lambda \cdot \pi R(t^*) = w^{EN} + c^{EN} + w^{VC} + c^{VC}. \end{aligned} \tag{3}$$

Maturity arrives at a hazard rate λ. A project becoming mature after time t^* succeeds with probability π and generates a payout of $R(t^*)$. Optimal advising thus equates

[5] This is a good approximation if the screening period is small compared to a later holding period. Screening costs can nevertheless be big if only few firms pass the screening process so that a venture capitalist has to screen repeatedly until he finds a potentially good investment.

the marginal profit of advice $\lambda \cdot \pi R(t^*)$ to its costs consisting of the joint evolvement of the venture capitalist and entrepreneur. In general, only projects with $\lambda \cdot \pi R(0) > w^{EN} + c^{EN} + w^{VC} + c^{VC}$ are worthwhile receiving at least some advice. All projects that are worse would never receive advice and then would never be financed at all.

2.1.2 Screening

Having determined optimal advising we can now move backwards in time and determine optimal screening which takes the advising decision as given. Screening is assumed to be continuous. For bad quality projects, the venture capitalist receives a perfect signal of bad quality with a constant hazard rate and thus turns them down. Screening costs are then given as

$$C^{Sc}(s^*) = \int_0^{s^*} \left(w^{VC} + c^{VC}\right)[x + (1-x)\exp(-\mu u)]\,du. \tag{4}$$

When screening for a time period of s^*, a fraction of $x + (1-x)\exp(-\mu s^*) = \frac{x}{\pi(s^*)}$ remains and will be financed. We can calculate expected profits and optimize with respect to the screening intensity

$$\begin{aligned} & \max_{s^*} \frac{x}{\pi(s^*)} \cdot \Pi(t^*, \pi(s^*)) - C^{Sc}(s^*) \\ FOC \quad : \quad & \mu(1-\pi(s^*))\left[I - Q + C^{Ad}(t^*)\right] = w^{VC} + c^{VC}. \end{aligned} \tag{5}$$

Notice $\frac{d\Pi(t^*,\pi(s))}{dt^*}\frac{dt^*}{ds^*} = 0$ by the envelope theorem, $\frac{d\pi(s)}{ds} = \mu(1-\pi(s))\pi(s)$ and $1 - \pi(s) = \frac{(1-x)\exp(-\mu s)}{x+(1-x)\exp(-\mu s)}$.

Screening improves the average quality of the selection and thus allows to concentrate investment and advice on good projects. At the margin, additional screening eliminates a fraction μ out of the remaining share $1 - \pi(s)$ of bad quality projects. Eliminating a project in the selection phase allows to save the risky investment $I - Q$ and the joint costs of advice $C^{Ad}(t^*)$ both of which are lost investments for bad quality ventures. Marginal costs of screening are given by the venture capitalists opportunity costs of time

$w^{VC} + c^{VC}$. We request the screening period to be nonnegative. Screening takes place whenever $\mu(1-x)\left[I - Q + C^{Ad}(t^*)\right] > w^{VC} + c^{VC}$ and we will typically assume that the condition is fulfilled. Venture capital financing is profitable if total surplus exceeds aggregate costs, taking into account an optimal screening and advising decision.

$$\frac{x}{\pi(s^*)}\Pi\left(t^*, \pi(s^*)\right) - C^{Sc}(s^*) > 0$$

Since we defined that no projects with good quality are turned down, a decline in the screening process proves bad quality. We have assumed that entrepreneurs initially do not know their true quality. A bad screening result thus informs them upon their quality and should induce them not to try to receive investment funds again.

2.1.3 A decentralized solution with optimal contracting

Implementing the first best outcome derived above in a decentralized setup requests all agents to share profits as well as costs associated with their decisions. Since we have assumed only discrete values of effort and advice, the model does not share the problem of a budget breaker at the margin for a double sided moral hazard problem as analyzed by Repullo and Suarez (1998) and Casamatta (2003). The intertemporal structure allows to separate the incentive compatible allocation of profits and the distribution of profits for early stages of product development. Intramarginal returns generated at the beginning of the cooperation can be divided between the partners within some range without harming either incentive constraint.

We can distinguish between three types of payments between the two partners: Flat transfer payments, payments contingent on the existence of the cooperation and payments contingent on project success where the later two can also change over time. We will assume that neither screening effort nor advising of the venture capitalist nor effort of the entrepreneur can be observed and thus contracted on. However, an entrepreneur cannot earn his common wage some other place.

Detering bad quality entrepreneurs During the screening process, all good projects are selected meaning that projects failing the process receive a perfect signal of bad quality. Since the signal is only observed by the venture capitalist and the entrepreneur but not by the public, reapplication of failed entrepreneurs at different venture capitalists is possible. Since screening is imperfect, there is always a strictly positive probability for any bad entrepreneur to receive finance for his project. Contracting then has to deter this type of entrepreneur from applying. Formally we write a participation constraint for an entrepreneur of bad quality. He receives a fixed up-front payment $T \geq 0$ and some time dependent payment $w(s)$ and has a foregone wage w^{EN}. Knowing his bad quality the entrepreneur will never provide effort and the venture thus will never make it to the mature state. In addition, the entrepreneur is always free to declare his bad quality and leave the firm. Thus

$$\neg PC_{bad}^{EN} \ : \ T + \int_0^t w(s)\, ds \leq \int_0^t w^{EN} ds$$

has to hold to keep bad quality from joining the screening process. Using $t = 0$ we find $T = 0$. No up-front payments are allowed and in addition, the total liquidation value has to go to the venture capitalist. The threat of bad quality entrepreneurs to join the contract does however allow for wage payments up to the outside wage w^{EN}.

Selection issues constitute a huge argument against any kind of flat transfer or up-front payment. A fixed payment generates an incentive to apply for a contract and, once accepted, to cash in the payment and to retract from any further provision of effort. Although many theoretical papers consider up-front payments, we are aware of no empirical work indicating that up-front payments are actually used. Kaplan and Strömberg (2003) on the contrary report that a venture capitalist typically holds liquidation cash flow rights in excess to his initial investments in order to make the entrepreneur's compensation most dependent on success. If contracts themselves are used as a sorting instrument as claimed by Sahlman (1990), then payments have to be made contingent on performance alone and may not allow bad entrepreneurs to generate profits.

VC's screening decision We can then move to the venture capitalist's screening decision itself. Optimal screening takes into account all costs invested in the risky part of the venture, that is investments $I-Q$ and foregone wages and effort costs of entrepreneur and venture capitalist see (5). While the venture capitalist naturally shares investment costs and his own effort and wage costs, costs of the entrepreneur are typically not internalized.

Since screening eliminates bad quality ventures, the screening decision in the centralized as well as in the decentralized version will only be encouraged by fixed payments or time depending payments. Payments made contingent on project success will never change the venture capitalists incentives to screen. Given the additional constraint on payments developed above, incorporating the lost wage of entrepreneurs into the screening decision is possible by paying him a wage equal to his outside option.

Additional payments however are not possible so that screening will fall short of its social optimal intensity by not considering the entrepreneurs lost effort. The venture capitalist will only bear all costs associated with the selection of goods ventures but only receive part of the benefits. It is hard to estimate the severity of the shortcoming. If one believes that screening mainly serves to evade unprofitable investments $I-Q$, then the inefficiency is small.

Joint commitment and the break up decision We can then move on to implement first best levels of advice and effort and induce the first best breakup time. Since we have already argued that the total liquidation value has to go to the venture capitalist, giving him a debt claim of (at least) Q, we now have to determine the distribution of the risky return. We introduce a sharing rule giving $f(R(t))$ to the venture capitalist and $R(t)-f(R(t))$ to the entrepreneur. It will prove sufficient to consider a contract with only three simple components: debt, equity and a success premium for the entrepreneur. The contract parameter are time invariant but given the payoff structure of the project, repayments to both agents potentially change over time. Debt D and success premium S are different versions of a fixed payment contingent on project success whereas the equity contract α specifies a sharing rule for the remaining rent. We request $R(t^*) - D - S \geq 0$.

$$\begin{aligned} f(R(t)) &= \alpha [R(t) - D - S] + D \\ R(t) - f(R(t)) &= (1-\alpha)[R(t) - D - S] + S \end{aligned}$$

Notice that at time t^* joint marginal profits equal joint marginal costs. While costs are constant over time, the marginal product declines so that costs will exceed profits for a later point in time. If renegotiation is possible then, any contract might be renegotiated at time t^* and the project would be liquidated. However, we can implement a contract making both partners willing to liquidate at time $t(s^*)$ without renegotiation. We request

$$PC^{VC} \; : \; \lambda \cdot \pi \, f(R(t^*)) - w^{EN} \geq c^{VC} + w^{VC} \tag{6}$$

$$PC^{EN} \; : \; \lambda \cdot \pi \, [R(t^*) - f(R(t^*))] \geq c^{EN} \tag{7}$$

Adding both inequalities up and comparing their sum to (3) indicates that both conditions are binding. For any equity share $0 < \alpha < 1$ marginal return declines with t so that both players expect to make losses once they continue the venture beyond time t^*.

For times prior to t^* we now define continuation values (given that advice and effort are provided) of $F_t(t^*, \pi)$ and $G_t(t^*, \pi)$ for venture capitalist and entrepreneur respectively.

$$\begin{aligned} F_t(t^*, \pi) &= \int_t^{t^*} \lambda \exp(-\lambda(u-t)) \, \pi f(R(u)) \, du + Q \\ G_t(t^*, \pi) &= P_t(t^*, \pi) - F_t(t^*, \pi) \end{aligned}$$

An entrepreneur providing advice assumes to receive the continuation value $G_t(t^*, \pi)$. When shirking at time t, he will postpone a potential realization of the project, so that the continuation value changes to $G_t(t^*, \pi) + \frac{dG_t(t^*, \pi)}{dt}$. The potential benefit from shirking is a reduction in effort costs where expected future costs summarize to $C_t^{Ad,EN}(t^*) = \int_t^{t^*} c^{EN} \exp(-\lambda(u-t)) \, du$. Shirking reduces effort costs by $\frac{dC_t^{Ad,EN}(t^*)}{dt} = c^{EN} \exp(-\lambda(t^* - t))$ so that the the entrepreneur's incentive constraint for all $t \leq t^*$ is given as:

$$\begin{aligned} IC^{EN} \; : \; 0 &\geq \frac{dG_t(t^*, \pi)}{dt} + \frac{dC_t^{Ad,EN}(t^*)}{dt} \\ \Longrightarrow 0 &\geq (1-\alpha) \lambda \pi [R(t^*) - R(t)] \end{aligned}$$

where we have used the binding participation constraint PC^{EN} and the inequality $P_t(t^*, \pi) \geq \pi R(t^*)[1 - \exp(-\lambda(t^* - t))] + Q$ in the second line. The condition holds for every feasible equity contract, $0 \leq \alpha \leq 1$, since $R(t^*) - R(t) \leq 0$. Intuitively, an entrepreneur will never try to shirk since returns decline over time and he will participate (or at least not suffer) from a higher return today by the equity stake. Since the venture capitalist only pays him a wage equal to the common wage, the entrepreneur has no interest per se in extending the life time of the firm.

A similar condition applies for the venture capitalist. While we assumed that an entrepreneur cannot shirk in his venture and earn the common wage at some other place, we allow the venture capitalist to invest his time somewhere else and receive his common wage there. When shirking, he foregoes a potential realization but saves effort costs, thus

$$\begin{aligned} IC^{VC}: 0 &\geq \frac{dF_t(t^*, \pi)}{dt} + (w^{VC} + c^{VC}) \exp(-\lambda(t^* - t)) \\ \implies 0 &\geq \alpha\lambda\pi [R(t^*) - R(t)] - w^{EN}. \end{aligned}$$

Again, a contract that fulfills the participation constraint will also encourage the provision of advice at earlier points in time.

Distribution of profits There is a variety of different contracts solving (6) and (7), the realization that is chosen will depend on whether entrepreneur or venture capitalist have market power. Since only marginal payouts at time t^* are important to guarantee incentive compatibility and break up, higher payouts at earlier stages can be freely distributed.

Figure 2 can be used to illustrate this: Payouts decline over time. The linear contract will then allocate a declining (or at least non-decreasing) profit to each player in case of a success. Venture capitalist and entrepreneur are indifferent at the break-up point and will strictly prefer to provide effort at earlier stages of the firm development. In order to incentivize venture capitalist or entrepreneur, he will need a payment of $\frac{w^{EN}+c^{VC}+w^{VC}}{\pi\lambda}$ or $\frac{c^{EN}}{\pi\lambda}$, respectively, in case of a success. Since the project return is higher for times $t < t^*$ than the sum of the two, the excessive payout can be distributed freely between the two players, see the gray area. The dotted line represents a possible linear sharing rule.

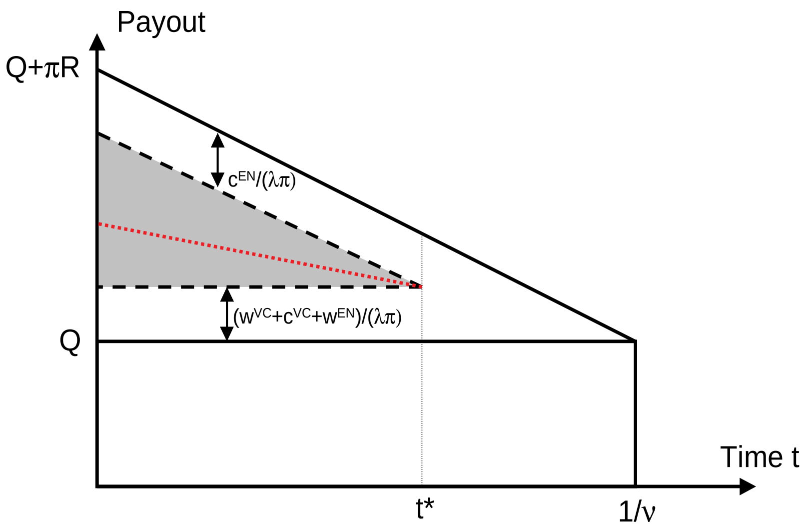

Figure 2: Linear contract

In a competitive environment, a venture capitalist only earns his common wage w^{VC} and thus will break even and make no additional profits.

$$\Pi^{VC} = \frac{x}{\pi(s^*)}\left[F_0\left(t^*, \pi\right) - I - \left(w^{VC} + w^{EN} + c^{VC}\right)\frac{1-\exp\left(-\lambda t^*\right)}{\lambda}\right] - C^{Sc}\left(s^*\right) = 0$$

The venture capitalist thus has to receive some of the intramarginal return to cover risky investment costs $I - Q$ as well as expected screening costs until a potentially good project arrives. The entrepreneur receives a wage payment and, at least, a payment of $\frac{c^{EN}}{\lambda}$ in case of success to induce effort provision. All additional rents that he might receive represent a reward for the development of the product.

The choice between debt, equity and success premium allows for a variety of equivalent contracts. It is possible e.g. to use the fixed payments to guaranty effort and advice provision $D = \frac{w^{EN}+c^{VC}+w^{VC}}{\pi\lambda}$ and $S = \frac{c^{EN}}{\pi\lambda}$ see (6) and (7). The equity component then only serves as a sharing instrument for intramarginal returns.

2.2 Analysis of the model

We will now determine some comparative statics of the model using its centralized version developed above. Optimal advising and screening obeys the two optimality constraints, who jointly determine the screening and advising period. Determining the influence of the exogenous parameter on the equilibrium thus requests to recognize the joint effect on both first order conditions.

$$\begin{aligned} \lambda \cdot \pi(s^*) R(t^*) &= w^{EN} + c^{EN} + w^{VC} + c^{VC} \\ \mu(1-\pi(s^*)) \left[I - Q + C^{Ad}(t^*)\right] &= w^{VC} + c^{VC} \end{aligned}$$

First of all, it is straightforward to see that screening and advising are complements. Screening improves the selection and thus by (3) increases the marginal product of advice inducing a higher advice. Anticipated, higher advice in turn increases the expected costs of advising. Since screening is partly used to eliminate lost advising costs for bad firms, higher advice will also increase the incentive for screening, see (5).

The intensity of screening and advising naturally depends on the (time) costs of the venture capitalist. We calculate partial derivatives of both equations:

$$\frac{\partial t^*}{\partial w^{VC}} = \frac{1}{\lambda \cdot \pi(s^*) R(t^*)} < 0 \tag{8}$$

$$\frac{\partial \pi(s^*)}{\partial w^{VC}} = -\frac{1 - \mu(1-\pi(s^*)) \frac{1-\exp(-\lambda t^*)}{\lambda}}{\mu\left[I - Q + C^{Ad}(t^*)\right]} < 0 \tag{9}$$

If a venture capitalist has high opportunity costs of time, he is more impatient with his portfolio firms, advises them shorter and liquidates them earlier given that they have not yet succeeded in the commercialization of their business idea. A higher wage of the venture capitalist also depresses screening intensity. The nominator of $\frac{\partial \pi(s^*)}{\partial w^{VC}}$ is positive by rearranging the optimality constraint. A higher wage then depresses the screening effort of a venture capitalist and will allow a higher number of bad quality firms to receive finance. The venture capitalist is then willing to forego higher losses of investment funds and advice in order to save some of his precious time in the screening process. Since screening and advising are complements, the two effects will reinforce each other.

Consider now the degree of competitiveness of the project or the time pressure of bringing the product to the market. In the following, we will take a simple linear specification of the decline, so that $R(t) = R(0)(1 - \nu t)$ for $t \leq \frac{1}{\nu}$ and zero later on. The variable ν is then interpreted as a measure of research competition. We determine:

$$\frac{\partial t^*}{\partial \nu} = -\frac{t^*}{\nu} < 0$$

The time of advising naturally declines with the rate of competition. Since the market potential reaches a low value much earlier, project are liquidated earlier. By the complementarity of advice and screening, the screening period will decline as well. In an industry environment with higher competition, market opportunities vanish faster. A firm that misses to commercialize a product within a short window of opportunity will be liquidated early reflecting the severe decline in profits over time.

Quite obviously, the higher the risky investment costs $I - Q$ the higher the venture capitalists interest in screening firms and thus eliminating investments in bad projects.

$$\frac{\partial \pi (s^*)}{\partial (I - Q)} = \frac{1 - \pi (s^*)}{I - Q + C^{Ad} (t^*)} > 0$$

The first order conditions fix the share of good firms after screening $\pi (s^*)$ and the amount of advice t^* as a consequence of external parameters. The screening time s^* will then be chosen in order to reach the average quality $\pi (s^*)$ taking the initial composition of firms x as given. Taking a total derivative of $\pi (s^*)$ with respect to the initial share x and the screening time s^* we find:

$$\frac{ds^*}{dx} = -\frac{1 - \pi (s^*) (1 - \exp (-\mu s^*))}{\mu (1 - x) \pi (s^*) \exp (-\mu s^*)} < 0 \qquad (10)$$

Since screening is used to eliminate bad projects, we find that the screening intensity declines with the share of good firms. Venture capitalists will screen most intensively when facing a bad selection of firms. Screening eventually becomes unattractive at all if the initial selection is very good, see the discussion of (5). On the other extreme, screening costs will deteriorate the total profit from financing a venture. If the selection is too bad, screening costs would be significant and project development becomes unattractive and no projects will be financed at all.

3 The venture capital industry

We will assume that venture capitalists and entrepreneurs are numerous. In a competitive equilibrium then, the market for venture capital will clear and neither excess demand, entrepreneurs without finance, nor excess supply, venture capitalists without investment opportunities, will emerge.[6] If entrepreneurs can choose between a variety of different financiers, then competition will guaranty a zero profit condition for venture capitalists. A venture capitalist will only break even and receive a compensation for his financial and time investment. Our model of the venture capital industry will now concentrate on time as the scarce production factor and endogenize the venture capitalist's wage w^{VC}.

In a repeated investment cycle, venture capitalists will compare the profitability of continuing to work with an entrepreneur with their expected per time reward when financing a new one. They will decide to stop their screening or advising work if the expected rent from continuation falls short of the compensation offered by an alternative investment project, see (3) and (5). The opportunity costs w^{VC} will thus determine the amount of time invested in a single venture and provide a link between individual investment projects and the market for venture capital.

As in Kanniainen and Keuschnigg (2003) we take a short and a long run perspective.

[6] Inderst and Müller (2003), Michelacci and Suarez (2002) or Keuschnigg and Nielsen (2003) have introduced a search friction between entrepreneurs and venture capitalists in order to explain shifts in the distribution of profits between the players. Our approach will share many predictions of these papers while relying on a different line of arguing.

In the long run, a venture capitalist's wage payment in excess of the common wage rate will attract additional entrants. Market entry will eliminate all subnormal profits and venture capitalists will then only earn the common wage rate $w^{VC} = w$ on their screening and advising work. Since becoming a venture capitalist is a long and exhausting process requesting an extensive learning phase and considerable effort and investments, we take the number of venture capitalists as fixed in the short run. Adjustments in the number of venture capitalists occur with a significant lag so that they might earn a rent on the scarce time endowment in the short run.

In the short run with a sticky number of venture capitalists, endogenous adjustments will affect the average time investment of a venture capitalist $\bar{t}$. The opportunity costs of time w^{VC} are taken as given for a single investment project and contract parameter are adjusted adequately.[7] If $w^{VC} > w$ then entrepreneurs pay a higher price for a sought-after time unit of screening or advising. A higher opportunity cost of time will induce the venture capitalist to abort his screening and advising effort early, see (3) and (5). Venture capitalists thus reduce average investment into a single project and increase the frequency of investing in new ventures. In the short run, the industry will balance a supply shortage by an increase in the speed at which the venture capital cycle turns.

Consider a continuous flow of N entrepreneurs meeting a number of M venture capitalists. In equilibrium, the market for venture capital clears. An equilibrium requests

$$N \cdot \bar{t}\left(w^{VC}\right) = M.$$

Notice that $\frac{M}{N}$ $\left[= \bar{t}\left(w^{VC}\right)\right]$ describes the market tightness and is emphasized in papers using a search approach. As argued above, the number of venture capitalists is endogenous in the long run and his wage will equal the market wage $M^{LR} = N \cdot \bar{t}\left(w\right)$. In the short run however, any change to market tightness has to be balanced by the average time investment following a change in the distribution of profits.

[7] An increase in the venture capitalist's compensation requests a lower success premium or a higher equity or debt stake.

Depending on the opportunity costs, a typical project receives an average time investment $\bar{t}$ consisting of an expected screening time $xs + (1-x)\frac{1-\exp(-\mu s)}{\mu}$ and advice of $\frac{1-\exp\left(-\bar{\lambda}t^*\right)}{\lambda}$ where advice is conditioned on a positive screening result.

$$
\begin{aligned}
\bar{t} &= xs^* + (1-x)\frac{1-\exp\left(-\mu s^*\right)}{\mu} + \frac{x}{\pi(s^*)}\frac{1-\exp\left(-\lambda t^*\right)}{\lambda} \\
\frac{d\bar{t}}{dw^{VC}} &= \frac{x}{\pi(s^*)}\left[1-\mu\left(1-\pi\left(s\right)\right)\frac{1-\exp\left(-\lambda t^*\right)}{\lambda}\right]\frac{ds}{dw^{VC}} \\
&\quad + \frac{x}{\pi(s^*)}\exp\left(-\lambda t^*\right)\frac{dt}{dw^{VC}}
\end{aligned} \tag{11}
$$

From (5) it follows that $1-\mu\left(1-\pi\left(s\right)\right)\frac{1-\exp(-\lambda t^*)}{\lambda} > 0$ holds for screening to take place, so that we conclude $\frac{d\bar{t}}{dw^{VC}} < 0$. The market price that equates demand and supply will be the opportunity costs of the venture capitalist's time investment w^{VC}.

A shock on quantity of entrepreneurs We will first consider a shock to the demand for venture capital by an increase in the number of entrepreneurs N. In the short run this will shift market tightness and average time investment towards lower values. We can analyze the long and short run implications using figure 3. We plot supply and demand for time investments of the venture capitalist. According to (11), the venture capitalist stops screening and retracts from advising a venture earlier if his opportunity costs of time are high. The demand curve $\bar{t}(w^{VC})$ for venture capital is downward sloping. As argued before, the supply curve is vertical in the short run and horizontal in the long run.

The analysis starts from an initial long run equilibrium in A where venture capitalists earn the market wage w. An increase in the number of entrepreneurs will shift market tightness towards lower average time investment and, consequently, an excessive rent for the venture capitalist $w^{VC} > w$, see point B. A higher value of w^{VC} will induce less screening and thus result in a worse selection of firms receiving finance. That is, *less bad firms being eliminated* in the screening process which in turn increases the share of firms receiving finance and advice. Given a successful screening, venture capitalist will then be more impatient with firms and stop advising earlier.

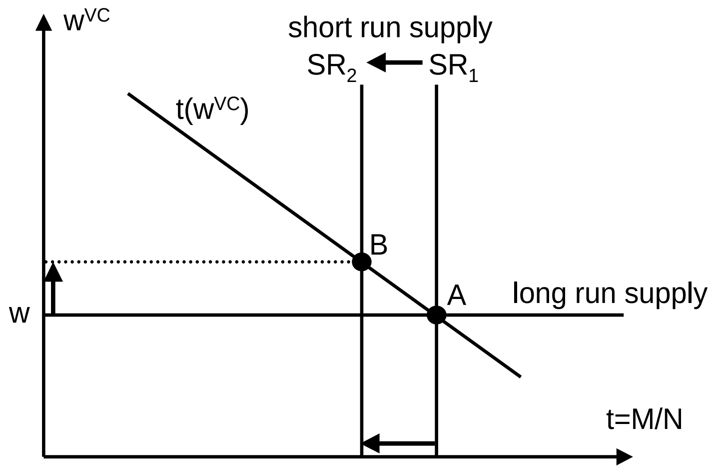

Figure 3: Shock on the quantity of ventures

In the longer run, rents will attract additional individuals to become venture capitalists. The short run supply will move rightwards and the equilibrium moves along the demand curve back to the initial long run equilibrium where venture profits equal the common wage rate and entering the venture capital market is no longer attractive. Since the compensation of the venture capitalist declines, screening intensity will increase and the average quality receiving finance will return to its initial value. Initial and final equilibrium will experience the same market tightness $\frac{M}{N}$ and only differ by the total amount of entrepreneurs and venture capitalists.

Notice that following a drop in the amount of entrepreneurs, the wage rate will not drop below the common wage rate if we allow venture capitalists to leave the market immediately. Changes based on a decline in entrepreneurs will then take place immediately and involve no transition processes. The equilibrium will remain at its long term value depicted in point A.

A shock on quality Consider now an unanticipated shock to the average share of good projects x applying for venture capital while leaving the total number of applicants constant.

The after screening quality π is fixed by (3) and (5) and independent of the initial probability x. A share of $\frac{x}{\pi}$ of all new arriving projects will be financed and the increase in x thus increases the number of financed ventures and tends to increase the total time invested per applying firm. On the other side, an improvement in the initial selection will reduce the venture capitalists incentives for screening and depress the screening intensity, see (10). An improvement in quality has two opposing effects on total time investments. This is also seen formally:

$$\frac{d\bar{t}}{dx} = \frac{\bar{t}}{x} - \frac{1}{\mu}\left[\frac{1}{x} + \frac{1 - \pi\left(1 - \exp\left(-\mu s\right)\right)}{1 - \pi}\right] \tag{12}$$

There is a positive effect $\frac{\bar{t}}{x}$ since more ventures are financed and a negative effect from the depressed interest in screening, see the remaining part of the derivative. The sign of the total effect can not be made rigorous and obviously depends on the parameterization of the model. Formally, assuming that μ is big, screening results arrive at a high rate and screening time for an individual project is low compared to advising time. The right hand side of (12) would be small and we would conclude $\frac{d\bar{t}}{dx} > 0$. On the other side, if one sees the objective of a venture capitalist mainly in the selection stage of the investment process, then improved initial quality will reduce the amount of VC time demanded. In order to reach the quality π, screening intensity can be reduced and less time is invested. The two opposing results seem to offer formidable, testable predictions for empirical work interested in the relative importance of a venture capitalists' screening and advising. Survey results of Gorman and Sahlman (1989) can be interpreted in line with the first view. They report that the management of the portfolio makes up about 60% of the time of a venture capitalist indicating the high importance of advice.

Moving to our graphical interpretation, a change in quality alone leaves market tightness $\frac{M}{N}$ unchanged and shifts the demand representation $\bar{t}\left(w^{VC}\right)$. We graph the case of $\frac{d\bar{t}}{dx} > 0$ only. An improvement in quality then shifts $\bar{t}$ to the right for every value of w^{VC}.

We start in the long run equilibrium A where venture capitalists earn the common wage rate w on their time investments. A change in quality is now assumed to shift the demand

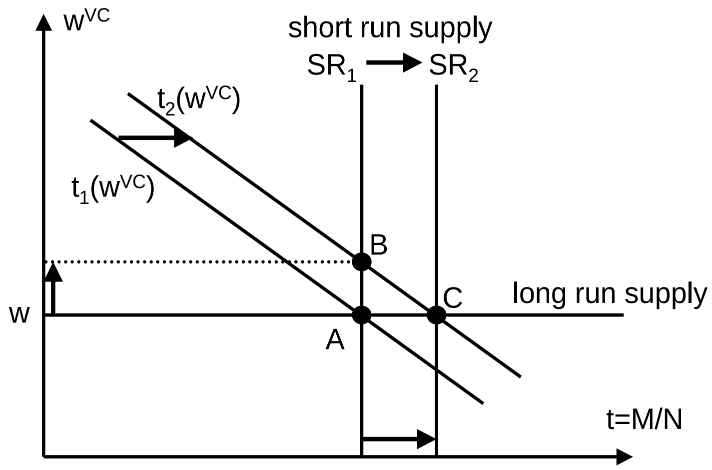

Figure 4: Shock on the average quality of ventures

curve of ventures to the right without changing the number of entrepreneurs or venture capitalists. Since the short run market tightness is constant, increased demand for venture capitalists' time will increase their compensation but leave average investments constant, see point B. The analysis undertaken above indicates that screening time declines and advising increases, both in expected value terms, leaving average investment constant. As time goes by, excessive rents will attract new market entry and shift market tightness to the right. In the new long-run equilibrium C average investments of time have increased and the wage is moved back to the common rate. The decline in w^{VC} implies that both screening and advising are intensified while the market moves towards the new long term equilibrium.

4 Resume

This paper has tried to shed light on the allocation of time by a venture capitalist between his two most important, time consuming duties: screening and advising. Both activities turn out to be complements: A better selection due to a higher screening effort increases the productivity of advice. Similarly, if advice is assumed to be high since it is highly productive, then selection tends to be done more carefully since potential losses from bad firms would be more harmful.

In the setup analyzed in this paper, agency problems can almost completely be eliminated using adequate contracting. The paper however derives important implications for contracting that the literature concentrating on moral hazard only, seems to have neglected. We find that up-front payment cause severe adverse selection in the presence of imperfect screening by attracting bad quality and deteriorating average quality of applicants. Knowing their bad quality this selection of entrepreneurs is only heading for a payment not contingent on quality and would shirk afterwards. In order to induce higher screening efforts by the venture capitalist, we also request him to pay a wage to the entrepreneur equivalent to his outside wage. In line with other work, we find that a liquidation value should go to the venture capitalist and should be covered by a debt claim. The risky part of payouts is optimally distributed using a combination of debt, equity and a success premium. Although we have restricted ourselves to simple linear contracts alone, financial contracting can not only induce optimal effort and advice over time and an optimal break-up time but also allows for different allocations of profits.

The supply and demand for venture capital turns out to be an important determinant of both screening and advice. If venture capitalists maximize their profits in a repeated "venture capital cycle" then an increase in demand will raise their opportunity cost of time and induce both less screening and less advising. This will make the venture capital cycle *turn faster* in order to cope with the high amount of potential firms. In the long run then, new venture capitalists will enter the market and compete away the too high time compensation of established venture capitalists.

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