Innovation, Spillovers and Venture Capital Contracts

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Abstract

Innovative start-ups and venture capitalists are highly clustered: Silicon Valley is probably the best-known example. Clusters differ in the contracts they use, and in how they perform. I explore the link between spillovers, contractual design and performance. I find that more "incomplete" contracts, with fewer contingencies linking entrepreneurs' rewards to performance benchmarks, become optimal when positive spillovers are large. The contracts enable the innovative entrepreneur and his investor to extract some of the surplus they generate through positive spillovers for new entrants. This provides a new rationale for contractual incompleteness, and may help to explain observed contractual practice in Silicon Valley.

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1. Introduction

Venture capital firms and innovative start-ups tend to be highly clustered[1], benefiting from localized spillovers; probably the best-known example is California's Silicon Valley. The greater success of Silicon Valley, even relative to other important clusters like the Route 128 corridor in Massachusetts, has attracted considerable attention[2]. Interestingly, the design of venture capital contracts also exhibits significant regional variation: California contracts, in particular, tend to contain fewer contingencies[3] - for ease of exposition, I will refer to them as being more "incomplete".

Could there be a causal link between regional differences in contract design, spillovers, and differences in performance? I explore this possibility by focusing on one intriguing contractual difference: venture capital contracts in California typically contain significantly fewer contingencies linking entrepreneurs' rewards to explicit performance benchmarks. As documented by Kaplan and Stromberg (2003), rewards include additional equity or options for the entrepreneur, the provision of new funds, or suspension of dividend payments to venture capitalists. Explicit performance benchmarks include: completing clinical tests; completing a new business plan to enter new markets; reaching a threshold number of customers who have purchased the product and given positive feedback; developing new facilities.

I develop a model that endogenizes this "California effect" on contract design: in the presence of sufficiently large and positive spillovers, it becomes optimal to rely on more "incomplete" venture capital contracts that do not tie entrepreneurs' rewards to explicit performance benchmarks. The key advantage of these incomplete contracts is that they enable the innovative start-up (the "incumbent") and its venture capital investor ("$VC1$") to extract some of the surplus that they generate through positive spillovers for new entrants. How? By keeping information about the magnitude of potential spillovers confidential, so that only the informed investor ($VC1$) is willing to fund a new entrant.

In a nutshell, the idea is the following: if the incumbent is successful at the

[1] See Chen, Gompers, Kovner and Lerner (2009).

[2] See Saxenian (1994), and Glaeser, Kerr and Ponzetto (2009).

[3] Kaplan and Stromberg (2003) find that explicit performance benchmarks are used significantly less in California ventures. California contracts are also less likely to contain redemption rights for the venture capitalists or time vesting clauses for the entrepreneur's (founder's) shares. Bengtsson and Ravid (2009) focus on "investor-friendly" contingencies, and find that they tend to be used less in California contracts. Section 5 relates these findings to the model.

intermediate stage, it generates positive spillovers, making entry by a second entrepreneur profitable. For example, the incumbent is successful in developing a product or technology that generates demand for complementary products, or reduces costs for a new entrant. If the incumbent's success is publicly observable, the implications for entry will be clear to everyone, and competition among venture capitalists to fund the new entrant will eliminate any rents. However, in many cases information about a venture-funded innovative start-up is only observed by the venture's entrepreneur and its investor: knowledge about the details, quality, scope and reliability of a newly-developed product or technology is often private, *soft* information[4] (in the absence of a patent, see below). If the information is kept confidential, uncertainty about a new entrant's expected profitability can deter uninformed investors from funding him. It is then possible for $VC1$ to fund him, when entry is efficient, earning an informational rent - i.e., extracting some of the surplus generated by the positive spillovers.

A key condition for this to work is that the incumbent should not be able, at this stage, to engage in a profitable (secret) side deal with another investor at the expense of $VC1$, credibly revealing the confidential information to the other investor in return for a payment or favor. Thus, the incumbent should not possess *hard* evidence that he can show to the other investor. This is where the "completeness" of the financing contract between the incumbent and $VC1$ can become a disadvantage. If the contract specifies a reward contingent on a benchmark that is informative about the potential for profitable entry, payment of the reward becomes hard evidence of the realized contingency, available to the incumbent. For example, the reward can consist of additional equity or options for the incumbent. Since the incumbent does not care whether the entrant is funded by $VC1$ or by another venture capitalist, he would be willing, in return for a payment or favor, to show the evidence to another venture capitalist[5], undermining the equilibrium in which $VC1$ captures all the informational rents while other venture capitalists

[4] Note that, while the entrepreneur and the investor possess only soft information, a complete contract can elicit this information from them by building an appropriate mechanism (see Maskin (1977), Moore (1992)). Such mechanisms are not necessary, on the other hand, if the information is verifiable by a court through other means in the event of a dispute (e.g., in U.S. law, pretrial discovery enables each party in a lawsuit to obtain evidence from the opposing party and from non-parties through a variety of methods, including requests for answers to interrogatories, production of documents or things, admissions and depositions, and inspections).

[5] Note that it is sufficient for the evidence to be *shown* to the venture capitalist. Thus confidentiality clauses are unlikely to be a sufficient deterrent, as breach would be extremely difficult to prove.

remain uninformed. It may then be optimal, *ex ante*, to rely instead on a contract that does not specify rewards contingent on such benchmarks.

The model makes a number of predictions, including:

- "Incomplete" contracts, that do not tie the entrepreneur's rewards to explicit performance benchmarks, should be more prevalent where positive spillovers and the expected profitability of new entrants are higher. These contracts make it possible to relax financing constraints and elicit higher entrepreneurial effort.

- The use of explicit performance benchmarks that are more informative from the perspective of a potential entrant should be more limited, other things held equal.

- Explicit performance benchmarks are more likely to be included, other things being equal, when their achievement is publicly observable.

The first prediction implies that clustering, localized spillovers and incomplete contracts can be mutually reinforcing: when positive spillovers are substantial, incomplete contracts become optimal, relaxing financing constraints and increasing entrepreneurial effort, which in turn leads to more spillovers. This may help to account for the contracting style and performance of venture capitalists in Silicon Valley. The second and third predictions are consistent with the finding by Kaplan and Stromberg (2003) that a significant proportion of financings (over 17%) are contingent on financial performance benchmarks (e.g. revenue and operating profit goals), while many of the non-financial performance benchmarks commonly used would be publicly observable[6].

The remainder of the paper is organized as follows. I complete this section by discussing the relationship with the existing literature. Section 2 introduces the model. Section 3 analyzes the benchmark case without entry (and hence without spillovers). The main analysis is presented in section 4. Empirical implications are discussed in section 5. Section 6 concludes.

[6] Examples include granting of patents, FDA approval of new drugs, and hiring of new key executives. Examples of performance benchmarks that are unlikely to be publicly observable include: completing clinical tests; securing a threshold number of customers who have purchased the product and give positive feedback; completing a new business plan for entering new markets; acquiring a certain technology.

1.1. Relationship to the literature

This paper is related to several important literatures:

(1) *Financial contracts and entry*

Here the closest links are with Aghion and Bolton (1987), and Cestone and White (2003). Aghion and Bolton analyze a setting where a buyer and a seller negotiate a contract under a threat of entry by another seller. They show that an exclusive contract with appropriately designed liquidated damages can be used optimally to extract some of the entrant's surplus: the damages act as an entry fee. In the present paper, contracts between an entrepreneur and a venture capitalist may also be designed strategically to extract surplus from a future entrant, but the mechanism is quite different: the contract is designed to limit information leakage to other venture capitalists, enabling the first venture capitalist to earn informational rents. Cestone and White study instead how financial contracts can be designed to deter product market entry when financial markets are imperfectly competitive. In our model, financial markets are competitive, and entry is efficient in the presence of positive spillovers: contracts are therefore designed not to deter entry, but rather to capture some of the surplus generated by the positive spillovers.

(2) *Venture capital*

A large body of theoretical work has studied the allocation of cashflow rights and control rights[7], with a particular emphasis on explaining the widespread use of convertible securities in venture capital financings. Cuny and Talmor (2005) are perhaps the closest to this paper, since they analyze instead the choice between "milestone" and "round" financing. They focus on a very different issue though, namely the impact of these two forms of financing on the effort incentives of both the entrepreneur and the venture capitalist, in a setting without spillovers or entry.

(3) *Incomplete contracts*

A very large literature examines the causes and consequences of contractual incompleteness[8]. My work is perhaps closest in spirit to papers that have explored the strategic value of incomplete contracts when some aspects of performance

[7] See, among others, Bergemann and Hege (1998), Bottazzi et al. (2005), Casamatta (2003), Cestone (2000), Cornelli and Yosha (2003), Dessí (2005), Hellmann (1998), Kaplan et al. (2003), Lerner and Schoar (2005), Repullo and Suarez (2000, 2004), and Schmidt (2003).

[8] See, among others, Anderlini and Felli (1994, 1999), Battigalli and Maggi (2002), Bolton and Faure-Grimaud, Dye (1985), Grossman and Hart (1986), Hart and Moore (1990, 1999), Klein, Crawford and Alchian (1978), Segal (1999), Tirole (2009), Williamson (1975, 1985).

and/or actions are not verifiable[9], including Holmstrom and Milgrom (1991), Bernheim and Whinston (1998), and Martimort and Piccolo (2010). As in these papers, my focus is on strategic incompleteness, but in a different way. I show that it can be optimal not to specify certain contingencies in a contract because execution of the contract generates hard evidence about the realized contingency *ex post*, and this may lead to damaging leakage of information to other parties. Although I explore the implications in a specific application to venture capital contracts, the point is more general. It applies potentially to a variety of settings where the realization of relevant contingencies is observed by the contracting parties *ex post*, but not by other parties. In such settings information can be elicited from the contracting parties by building an appropriate mechanism into the original contract. I show that this may not be optimal if it permits information leakage that is sufficiently damaging to the parties. This could help to explain why such mechanisms are not often observed in practice.

My work is also related to papers that have explored the informational implications of incomplete contracts. Allen and Gale (1992) consider an environment in which different agents have different abilities to manipulate information about contingencies. Non-contingent contracts emerge in equilibrium because they do not create incentives to engage in such manipulation. Spier (1992) shows how, in the presence of (exogenous) transactions costs, an informed principal may prefer to offer an incomplete contract to signal that his "type" is "good"[10]. My paper focuses instead on the hard information generated *ex post*, when a contractual contingency is realized, and the contract is executed.

(4) *Clustering and spillovers*

An extensive literature explores the importance of entrepreneurship and innovation clusters, and localized spillovers[11]. This literature has been largely separate from the literature on contract design. My paper builds on insights from both, and

[9] On the interaction of explicit and implicit contracts in such settings see also Schmidt and Schnitzer (1995), Pearce and Stacchetti (1998).

[10] See also Aghion and Hermalin (1990), who study the desirability of legal restrictions on contracting to prevent inefficient signaling.

[11] See Audretsch and Feldman (2004) for a review and discussion. Glaeser and Kerr (2009) document the importance of several factors for entrepreneurship clustering: the abundant presence of small independent suppliers, labor market pooling, and knowledge spillovers. Ellison, Glaeser and Kerr (2010) study the impact of these factors on industrial agglomeration. Evidence of the importance of geographic proximity for knowledge spillovers is provided by Acs et al. (1994), Agrawal et al. (2008), Audretsch and Feldman (1996), Audretsch and Stephan (1996), Jaffe (1989), Jaffe et al. (1993), and Zucker et al. (1998). Fallick et al. (2006) and Freedman (2008) document the importance of labor market pooling.

provides a link between the two. In particular, it shows how spillovers and contract design can be mutually reinforcing in clusters of innovative entrepreneurial firms and venture capitalists.

2. The model

The model has three dates, $t = 0, 1, 2$. At date 0, an entrepreneur may enter a new industry and invest in a project, call it project I (I for "incumbent"). At date 1, the state γ is realized (see below). At this stage another entrepreneur may enter the industry and invest in a related project, call it project E (E for "entrant"). The probability of success of project I at date 2 will depend on the state γ and on whether entry occurs. The state γ will also affect the probability of success of the second project E. Entrepreneurs possess no capital and need to raise finance from investors (venture capitalists). For simplicity, there is no discounting. All agents in the model are assumed to be risk neutral and protected by limited liability.

2.1. The incumbent

Project I requires an initial outlay of value K_I. The first entrepreneur (henceforth also called the incumbent) faces considerable uncertainty about his project's returns when he invests at $t = 0$: some of the uncertainty is resolved at $t = 1$, when the state γ is realized. For simplicity, γ is assumed to take one of two values: γ_G ("good" state) or γ_B ("bad" state), with $1 > \gamma_G > \gamma_B > 0$. If there is no entry, project I yields verifiable returns R at $t = 2$ with probability γ, and zero otherwise, where $R > K_I > 0$. Thus γ represents the probability of "success" (high returns) in the second period in the absence of competition. The impact of competition is considered below.

If project I is undertaken at $t = 0$, the incumbent chooses his effort level $e \in [0, e^H]$, where $0 < e^H < 1$. The cost of effort is given by $c(e) \equiv \frac{1}{2}e^2$. Entrepreneurial effort increases the probability of the good state: specifically, the good state occurs with probability e. To capture the uncertainty inherent in innovative activity, I assume that the bad state occurs with some non-trivial probability even when the incumbent exerts the maximal feasible effort. At the same time, entrepreneurial effort is crucially important; I therefore assume that, leaving aside entry considerations, the project is not worth undertaking with zero effort:

- **(A1)** $\gamma_B R < K_I$

In what follows, I denote by $\Delta\gamma = \gamma_G - \gamma_B > 0$ the difference in the probability of success between the good state and the bad state. For ease of exposition, I also assume that[12]

- **(A2)** $(\Delta\gamma + \mu)R \leqslant e^H$

2.2. The entrant

At $t = 1$, a second entrepreneur (henceforth also called the entrant) may enter the industry and invest in a related project. This project requires an initial outlay of value K_E. I assume that if the incumbent has been successful during the first period (i.e. $\gamma = \gamma_G$), this generates new profitable opportunities for prospective entrants. I model this as simply as possible by assuming that the entrant's expected returns are equal to π_H when $\gamma = \gamma_G$ and π_L when $\gamma = \gamma_B$, with $\pi_H > K_E > \pi_L > 0$. We can then think of $\pi_H - \pi_L$ as capturing the magnitude of the positive spillover generated by the incumbent's success. I will denote by $S \equiv \pi_H - K_E$ the expected profits (surplus) from undertaking the entrant's project in state γ_G.

If the second entrepreneur decides to enter, he has an impact on the profitability of the incumbent. I model this by assuming that entry reduces the incumbent's success probability to $\gamma - \mu$, where $\gamma_G - \mu > \gamma_B > \mu > 0$. I further assume that it is nevertheless efficient to fund the entrant when the state is "favorable"; that is, the surplus from the entrant's project outweighs the cost of entry imposed on the incumbent:

- **(A3)** $S > \mu R$

Finally, I assume that:

- **(A4)** *It is not worth funding the entrant unless the state is known to be "favorable"*

[12] As will become clear below, this assumption simply means that the first-best effort level is potentially feasible in most cases of interest for our analysis. The only exception is incomplete contracts in section 3, where for sufficiently high values of S the first-best effort could, in principle, exceed $(\Delta\gamma + \mu)R$. I therefore incorporate the feasibility constraint $e \leqslant e^H$ explicitly into the problem and solution for that case, described by Proposition 2.

A4 seems a reasonable assumption in settings where there is sufficient uncertainty *ex ante* about the incumbent's success at the intermediate stage (regardless of effort), and his success at the intermediate stage is crucial for the entrant's expected profitability - these settings are the main focus of the present paper[13]. In other settings, the assumption can be made for analytical convenience, since it guarantees the existence of a pure-strategy equilibrium[14].

2.3. Investors

Entrepreneurs seek financing from venture capitalists, who possess enough expertise and sector-specific knowledge to be able to evaluate entrepreneurs and their projects. I assume that there are N such investors, identical and competitive *ex ante*, denoted $VC1$, $VC2$... and VCN. If the first entrepreneur succeeds in obtaining funding for his project at date 0, denote by $VC1$ the venture capitalist that provides the funding. As discussed below, thanks to his involvement with the project, $VC1$ will have access to more information at date 1 than other venture capitalists.

2.4. Information

I assume that γ is only observed by the incumbent and $VC1$ at $t = 1$. The notion that firm "insiders", and in particular the firm's entrepreneur and the venture capitalist funding the firm, possess an informational advantage concerning the firm's progress and prospects seems a very reasonable assumption in the context of young, entrepreneurial firms (see, for example, Admati and Pfleiderer (1994), Dessí (2005) and Schmidt (2003)). For example, having been closely involved in the development of a new product or technology, they may possess soft information about its quality and the potential spillovers; they are also likely to have superior information about the quality of the entrepreneur's and the management team's skills.

[13] A sufficient condition for (A4) in our model would be: $e^H S + (1 - e^H)(\pi_L - K_E) < 0$.

[14] Analyses of mixed-strategy equlibria when this assumption is relaxed can be found in the literature on informed lending (see Rajan (1992), Von Thadden (2004)). In these settings the informed investor is still able to exploit his informational advantage, albeit less than in the pure strategy equilibrium analyzed in this paper. The main qualitative insights of our analysis would therefore continue to hold.

2.5. Time line

$t=0$	(First period)	$t=1$	(Second period)	$t=2$
Project I undertaken? Incumbent chooses effort.		Realization of γ. Entry?		Project returns realized.

3. No entry

This section briefly presents the benchmark case where entry is ruled out *a priori*: optimal financial contracts for this case will provide a useful benchmark for comparison. In subsequent sections, I shall allow for the possibility of entry.

Suppose then that no entry can occur at date 1. In this case the only financial contract to be examined is the one agreed at date 0 to provide funding for the incumbent.

Given that γ is a sufficient statistic for effort, the most efficient way to elicit effort from the incumbent is to offer him a reward, $R_e > 0$, contingent on the realization of the "good" state at date 1 (i.e., when $\gamma = \gamma_G$), and zero otherwise (because of limited liability). $VC1$ provides the initial capital K_I at date 0 and receives the project's returns at date 2. Competition among venture capitalists at date 0 ensures that the incumbent obtains the full expected NPV of the project. The optimal financing contract, denoted by $C1$, solves the following problem, $P1$:

$$Max \qquad U = eR_e - \frac{1}{2}e^2 \tag{3.1}$$

$$e = R_e \quad (IC) \tag{3.2}$$

$$e\gamma_G R + (1-e)\gamma_B R - eR_e \geqslant K_I \quad (IR) \tag{3.3}$$

where (IC) is the entrepreneur's incentive constraint and (IR) the venture capitalist's participation constraint. It can be easily checked that the first-best effort level, which maximizes the project's expected returns net of effort costs, is given by $e^{FB} \equiv \Delta\gamma R$. To implement this would require setting $R_e = \Delta\gamma R$ (from (IC)).

This would imply that the maximum income that could be pledged to $VC1$ would be equal to $\gamma_B R$. By assumption $(A1)$, this will not be sufficient to satisfy (IR). Thus (IR) will bind. To make the analysis interesting, I assume that parameter values are such that the project can be funded (see the Appendix for details). Effort will then be equal to:

$$e^N = \frac{1}{2}\Delta\gamma R + \frac{1}{2}\{[(\Delta\gamma R]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{3.4}$$

Effort will be lower than the first-best level: in the absence of entry considerations, this is the only source of inefficiency. Next we consider whether allowing for the possibility of entry introduces further inefficiencies, and whether it also mitigates inefficiency in some cases. In particular, we study how this depends on whether complete or incomplete contracts are used, and the resulting trade-off.

4. Entry

I now allow for the possibility of entry at date 1. I begin by analyzing the case where the incumbent and $VC1$ at date 0 sign a contract contingent on the realization of γ, and execution of the contract at date 1 reveals γ to outside parties ("*complete contracts*"). I will then study the case where the contract is not contingent on the realization of γ, so as to avoid revealing information to outside parties ("*incomplete contracts*"). The end of the section will examine what can be achieved with *secretly-executed* complete contracts.

The timing of the game at date 1 is as follows. The state γ is realized and is observed by the incumbent and his investor ($VC1$). A second entrepreneur (the entrant) seeks financing for a related project, project E. Venture capitalists $(VC1, VC2, ..., VCN)$ make simultaneous take-it-or-leave-it offers to the entrant. The entrant accepts one offer (or zero). If he accepts an offer (other than the null contract), project E is undertaken. Both projects' returns are realized at $t = 2$.

4.1. Complete contracts

The optimal *complete* contract agreed at $t = 0$ between the incumbent and $VC1$ takes the form studied above for the no-entry case: the entrepreneur receives a reward R_e if, and only if, $\gamma = \gamma_G$, while the investor receives the project's final returns. As in the no-entry case, this type of contract is optimal because it elicits effort efficiently from the incumbent. Given this form of contract between the incumbent and $VC1$, we can examine the game between the entrant and investors at date 1 and then solve backwards for the optimal date-0 contract.

4.1.1. The game at date 1

Investors and the entrant learn the realized value of γ at $t = 1$, when the incumbent is rewarded (or not). The game between them therefore takes place under symmetric information. When the realized state is unfavorable for the entrant (i.e. $\gamma = \gamma_B$), nobody is willing to fund his project. When the state is favorable, competition among investors ensures that the entrant is able to fund his project and obtain its full expected NPV. This also implies a loss for $VC1$, because entry reduces the success probability of the incumbent's project. We therefore have the following result.

Lemma 1 (date 1 game with complete contracts). When $\gamma = \gamma_B$, there is no entry. When $\gamma = \gamma_G$, entry always occurs: the entrant's expected gain from his project is equal to its full expected NPV, S, while the expected value of the incumbent's project is reduced by μR.

Proof: see Appendix.

Because he has no informational advantage at date 1, $VC1$ not only cannot extract any rents from the entrant, but he incurs a loss when $\gamma = \gamma_G$, due to the fact that other venture capitalists' funding offers to the entrant do not internalize the costs imposed by entry on the incumbent's project. We can now examine the implications for financing constraints *ex ante*.

4.1.2. The game at date 0

The optimal financial contract between the incumbent and $VC1$ at date 0 will solve the following problem:

$$Max \qquad U = eR_e - \frac{1}{2}e^2 \tag{4.1}$$

$$e = R_e \quad (IC) \tag{4.2}$$

$$e(\gamma_G - \mu)R + (1-e)\gamma_B R - eR_e \geqslant K_I \quad (IR) \tag{4.3}$$

It is straightforward to verify that the first-best effort level is now lower than in the no-entry case, and is equal to $e_C^{FB} = (\Delta\gamma - \mu)R$. This is because entry reduces the expected value of the incumbent's project, and hence the return to effort.

However, *the investor's participation constraint is harder to satisfy*, because pledgeable income is reduced by the possibility of subsequent entry. Thus once again it is not possible to implement the first-best level of effort. We therefore obtain the following result:

Proposition 1. (a) Either (i) the incumbent's project cannot be funded. This happens when K_I is "too large" (see the Appendix for precise details); or (ii) the incumbent's project is funded, and the incumbent's effort level is equal to:

$$e^C = \frac{1}{2}(\Delta\gamma - \mu)R + \frac{1}{2}\{[(\Delta\gamma - \mu)R]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{4.4}$$

where $e^C < e^N$.

(b) The incumbent's expected utility when the project is funded is equal to $U = \frac{1}{2}(e^C)^2$, which is strictly lower than in the no-entry case.

Proof: see Appendix.

Thus with *complete* contracts we find that allowing for the possibility of *entry may make it impossible to undertake the incumbent's project.* Moreover, if the project is undertaken, *entrepreneurial effort on the project will be strictly lower than in the no-entry case, as will the incumbent's expected utility.* Overall then, allowing for the possibility of entry is "bad news" for the incumbent when complete contracts are used.

Can the incumbent be better off with an incomplete contract? We now turn to this question.

4.2. Incomplete contracts

In this section we examine what happens if the incumbent and $VC1$ at date 0 sign a contract that is *not* contingent on γ, and outside parties (entrant, other venture capitalists) do not have access to information about the realized value of γ at date 1.

At date 0, the contract between the incumbent and $VC1$ can only condition on the realization of final project returns. It will therefore take the form $CI = \{R_I, R_V\}$, where R_j denotes the payoff for j $(j = I, V)$ at $t = 2$ when realized final returns are equal to R. I denotes the incumbent and V the venture capitalist. The timing of the game is the same as in the case of complete contracts studied above. As before, we solve the game by backward induction, starting from date 1.

4.2.1. The game at date 1

Only $VC1$ learns the realized value of γ at date 1; the other venture capitalists and the entrant do not. The game between them therefore takes place under asymmetric information. The equilibrium is described by the following result.

Lemma 2 (date 1 game with incomplete contracts). When $\gamma = \gamma_B$, there is no entry. When $\gamma = \gamma_G$, entry always occurs: $VC1$ funds the entrant and extracts all the surplus from him, with expected value S.

Proof: see Appendix.

This result shows the main benefit from incomplete contracts in this setting: in contrast with the complete contracts case examined earlier, $VC1$ here can use his informational advantage to extract the entrant's surplus. We now explore the implications for the contract between $VC1$ and the incumbent *ex ante*, and for the incumbent's choice of effort.

4.2.2. The game at date 0

The optimal financial contract between the incumbent and $VC1$ at date 0 will solve the following problem:

$$Max \qquad U \equiv e(\gamma_G - \mu)R_I + (1-e)\gamma_B R_I - \frac{1}{2}e^2 \tag{4.5}$$

subject to the constraints:

$$e = \arg\max(U) \quad (IC) \tag{4.6}$$

$$e[(\gamma_G - \mu)R_V + S] + (1-e)\gamma_B R_V \geqslant K_I \quad (IR) \tag{4.7}$$

$$R_I + R_V = R \tag{4.8}$$

$$R_I \geqslant 0, R_V \geqslant 0 \quad (LL) \tag{4.9}$$

where the first two constraints represent, as before, the incumbent's incentive compatibility constraint and the venture capitalist's participation constraint, while the following two are the feasibility and limited liability constraints.

There are two key differences relative to the analogous problem with complete contracting. First, the venture capitalist is able to extract the entrant's surplus in the "good" state (γ_G). This makes the incumbent's effort more valuable. Moreover, the expected surplus from the entrant essentially increases pledgeable income, relaxing the investor's participation constraint. Second, the entrepreneur is now rewarded less efficiently through a stake in the project's final returns, rather than a reward directly tied to the realization of the performance signal γ. The interaction between these two effects gives the result summarized by Proposition 2. Let $\alpha \equiv \Delta\gamma - \mu$. Then:

Proposition 2. (a) Either (i) the incumbent's project cannot be funded. This happens essentially when S is "too small" (see the Appendix for precise details); or (ii) the incumbent's project is funded, and the incumbent's effort level is equal to $e^I \equiv \min[e^*, e^H]$, where

$$e^* = \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}] + \frac{1}{2}\{[\alpha R + S - \frac{\gamma_B}{\alpha}]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{4.10}$$

(b) The incumbent's expected utility when the project is funded is equal to: $U = \frac{1}{2}(e^I)^2 + \frac{\gamma_B e^I}{\alpha}$.

Proof: see Appendix.

Intuitively, when the surplus that can be extracted from the entrant is too small, the inefficiency of rewarding the entrepreneur on the basis of final returns rather than intermediate performance dominates and incomplete contracts perform poorly. For higher values of the surplus, however, the venture capitalist's participation constraint is relaxed, making it possible to induce higher effort and better performance.

4.3. Complete contracts or incomplete contracts?

We can now examine the trade-off between complete and incomplete contracts. The essence of the trade-off is the following. Under complete contracting, the incumbent can be given a reward contingent on the realization of γ, which is a sufficient statistic for effort. Under incomplete contracting, his effort incentives can only be provided, less efficiently, by giving him a share of the project's final returns. This represents the disadvantage of incomplete contracting. However, incomplete contracting enables $VC1$ to extract some informational rents from the entrant when $\gamma = \gamma_G$. Moreover, the expectation of this relaxes the venture capitalist's *ex ante* participation constraint, which makes it easier to induce effort. These are the benefits of incomplete contracting.

For some parameter values, the trade-off between complete and incomplete contracts takes a particularly stark form, in the sense that the *incumbent's project can only secure funding with one type of contract.* This is easily seen by noting (see the proof of Proposition 1) that funding can only be secured under complete contracts if

$$K_I \leqslant \frac{1}{4}[\alpha R]^2 + \gamma_B R \tag{4.11}$$

while the corresponding condition under incomplete contracts (see the proof of Proposition 2) is given by:

$$K_I \leqslant \frac{1}{4}[\alpha R + S - \frac{\gamma_B}{\alpha}]^2 + \gamma_B R \tag{4.12}$$

Clearly for sufficiently small values of S, the expected value of informational rents under incomplete contracting, it may be possible to fund the incumbent under complete contracting but not under incomplete contracting. Conversely, for sufficiently large values of S it may be possible to fund the incumbent under incomplete contracting but not under complete contracting.

There is a threshold value of S such that pledgeable income is higher with incomplete contracts above the threshold, and higher with complete contracts below the threshold. This threshold is given by $\hat{S} \equiv \frac{\gamma_B}{\alpha}$. It has an intuitive interpretation: with incomplete contracts, the incumbent's expected returns in the "bad" state γ_B are equal to $\gamma_B R_I = \gamma_B(\frac{e^I}{\alpha})$, while under complete contracts they are equal to zero. Thus from an *ex-ante* perspective, incomplete contracting implies that the incumbent has to be given rents of value $\frac{e^I \gamma_B}{\alpha}$, which reduce the project income that can be pledged to the venture capitalist. On the other hand, incomplete contracting also implies that the venture capitalist expects to earn informational rents (from the entrant) of value S with probability e^I. Pledgeable income will be higher with incomplete contracts if, and only if, $e^I S > \frac{e^I \gamma_B}{\alpha}$.

Consider now the trade-off arising when the two conditions are both satisfied, and the incumbent's project can secure funding with either type of contract[15]. In this case, the incumbent's expected payoff with complete contracting is equal to the NPV of his project (since venture capitalists at date 0 are competitive, so

[15] Obviously when neither condition is satisfied no trade-off arises because the incumbent's project cannot be undertaken with any contract.

that $VC1$ does not earn any rents from the incumbent), taking into account the effect of entry. It is given by:

$$NPV^C = e^C(\gamma_G - \mu)R + (1 - e^C)\gamma_B R - \frac{1}{2}(e^C)^2 - K_I \qquad (4.13)$$

The incumbent's expected payoff under incomplete contracting is equal to the NPV of his project, taking into account the effect of entry, plus the expected value of the investor's informational rents. It is therefore given by:

$$NPV^I = e^I[(\gamma_G - \mu)R + S] + (1 - e^I)\gamma_B R - \frac{1}{2}(e^I)^2 - K_I \qquad (4.14)$$

Thus, incomplete contracts will be preferred if, and only if, the incumbent's net benefit from using incomplete contracts, NBI, is positive:

$$NBI \equiv e^I S + (e^I - e^C)\alpha R - \frac{1}{2}[(e^I)^2 - (e^C)^2] > 0 \qquad (C^*)$$

The first term in this expression represents the expected value of the venture capitalist's informational rents: these rents are the direct benefit of incomplete contracting. The other two terms reflect the impact of any difference between the equilibrium effort levels induced under complete and incomplete contracting. Intuition might suggest that this impact should be negative, because incomplete contracts reward entrepreneurial effort less efficiently than complete contracts. If this is the case, the choice between complete and incomplete contracts will depend on the *trade-off* between the benefit of earning *informational rents* with incomplete contracts and the benefit of *inducing effort more efficiently* with complete contracts. However, effort under complete contracting may be reduced significantly below its first-best level by the need to generate sufficient pledgeable income to satisfy the investor's participation constraint. With incomplete contracts, on the other hand, the expected value of the investor's informational rents becomes part of pledgeable income, making it easier to satisfy the constraint: this is the potential indirect benefit of incomplete contracting. If this effect is sufficiently important, the sum of the last two terms in the above expression may also be positive, enhancing the net benefit of incomplete contracts.

To gain further insight into the trade-off, we can use (8.15) and (8.29) to write the net benefit of incomplete contracts as follows:

$$NBI \equiv \frac{1}{2}\{e^I S + (e^I - e^C)\alpha R + \frac{e^I \gamma_B}{\alpha}\}$$

This expression makes clear that for $e^I \geqslant e^C$ incomplete contracts will be preferred. Indeed, for complete contracts to be preferred instead, e^C has to be sufficiently greater than e^I to offset the other positive terms in the expression. It is immediately apparent from the expressions for the two efforts (given in Propositions 1 and 2) that $e^I \geqslant e^C$ if, and only if, $S \geqslant \hat{S}$. Intuitively, when this condition holds, pledgeable income is at least as high with incomplete contracting as with complete contracting, making it possible to elicit at least as much effort from the incumbent. Thus when the surplus that can be extracted from the entrant is sufficiently large, there is no longer a trade-off: incomplete contracts yield informational rents *and* induce at least as much effort as complete contracts. For lower values of S, the trade-off applies but is still favorable to incomplete contracts. Finally for sufficiently low values of S, the trade-off will switch in favor of complete contracts.

4.4. When does the trade-off apply?

In the next section we will focus on the empirical implications of the analysis. Before we do this, we need to ask two questions:

- can information disclosure be prevented in the presence of complete contracts?
- will information disclosure occur even in the presence of incomplete contracts?

Intuition might suggest that complete contracts with secret execution could do better than any of the contracts considered so far, by combining the benefits of more efficient reward schemes for entrepreneurial effort with the benefits of not revealing information about γ to outside parties. Such "secretly-executed complete contracts" would specify that the incumbent is to be rewarded if, and only if, $\gamma = \gamma_G$, as in the complete contracting case examined earlier. However, the execution of the contract at date 1 would be kept secret; in particular, the incumbent would be rewarded secretly when $\gamma = \gamma_G$, so as not to reveal information about γ to outside parties.

My claim is that this would not work. Suppose the incumbent and $VC1$ sign an *ex-ante* (date 0) agreement to keep contractual execution secret *ex post* (date 1). When they reach date 1, the contract is executed: this requires establishing the realized value of γ and hence determining the value of the incumbent's reward

(R_e or zero). If $\gamma = \gamma_G$, the incumbent receives the reward R_e from $VC1$. Large rewards typically generate *hard* evidence (e.g. granting of equity or options, bank transfers), available to the incumbent. Even if $VC1$ paid the reward privately in cash, the incumbent would want to keep some hard evidence of how and why he received a large sum in cash (e.g. tax authorities, controls on money laundering).

Thus when $\gamma = \gamma_G$, contractual execution will generate hard evidence informative about γ, available to the incumbent. This means that in the equilibrium described by Lemma 2, in which $VC1$ extracts informational rents from the entrant, an uninformed venture capitalist will now have an incentive to "deviate" by offering the incumbent a payment in return for seeing evidence that he has received the transfer R_e from $VC1$. The incumbent would gain by doing this secret side deal with the uninformed venture capitalist when $\gamma = \gamma_G$, and the venture capitalist would gain from becoming informed: he could offer the entrant slightly more favorable terms than $VC1$ and extract most of the surplus. It seems very difficult to rule out such behavior by including a confidentiality clause in the original contract between the incumbent and $VC1$. The "deviation" does not require the incumbent to hand over any evidence to the uninformed venture capitalist: it is enough to show it. This would make it extremely hard to prove *ex post* that the confidentiality clause had been breached.

Agreeing at date 1 to defer payment of the reward until date 2 would not change matters: the incumbent would still have hard evidence that he is due to receive the reward at date 2, which is just as informative as receipt of the reward at date 1. To avoid information disclosure, the incumbent and $VC1$ would need to agree at date 0 to defer until date 2 the very process of establishing whether a reward is due or not. However, whether the information about γ is elicited from the incumbent and $VC1$ through a mechanism based on subgame perfect implementation, or relying on pre-trial discovery in the event of a dispute (see footnote 4), delay will be problematic: in the first case, information may no longer be payoff-relevant and hence could not be elicited; in the second case, pre-trial discovery will be less efficient, because as circumstances evolve over time it becomes difficult to establish what the precise "state of the world" was at a given point earlier in time (people forget information or remember it inaccurately; they move; they die; records are updated and some information is lost; products, facilities and technologies are also updated and modified; etc.).

Turning to the second question: in the presence of incomplete contracts, no evidence concerning γ is generated by *execution of the contract* at date 1, because the contract is not contingent on γ. Information disclosure to outside parties could still occur at date 1 if the contracting parties had access to hard evidence about the realized value of γ irrespective of contractual execution. However, our focus is on settings where this is not the case and the contracting parties have access to soft information.

5. Empirical implications

When are we most likely to observe incomplete venture capital contracts in the sense of this paper (i.e. contracts that make less use of performance contingencies)? The following result provides a first answer.

Lemma 3. The net benefit from incomplete contracts, NBI, increases with S.

Proof: see Appendix.

Thus our model implies that *incomplete contracts will be more attractive when entrants are expected to be more profitable* (higher S). It also implies that when incomplete contracts are used with incumbents, *venture capitalists should be able to extract more surplus from entrants.* To my knowledge, neither of these predictions has been tested. Indeed, empirical evidence on the factors driving the degree of incompleteness of venture capital contracts is very limited. However, as discussed in the Introduction, there is substantial evidence that *venture capital contracts tend to be more incomplete in California.* As shown by Chen, Gompers, Kovner and Lerner (2009), clustering of both venture capital firms and venture capital-financed companies is very high, and California is home to arguably the most important cluster[16]. Chen et al. (2009) point to the benefits of labor market pooling and localized knowledge spillovers as key factors driving clustering. In terms of our model, positive spillover effects of this kind, other things being equal, are going to increase the expected profitability of entrants, hence the value of S. This in turn increases the net benefit of incomplete contracts, providing a rationale for the California effect. Moreover, Hochberg, Ljungqvist and Lu (2010) find that venture capitalists are able to obtain significantly lower valuations, controlling for other value drivers, in more densely networked venture capital markets,

[16] Chen et al. (2009) investigate the geography of venture capital firms and venture capital-backed portfolio companies. They find that in 2005 the San Jose-San Francisco area accounted for 21.6% of all venture capital firm Main Offices, the single biggest share for any location. For a sample of 28,434 venture capital investments between 1975 and 2005, they find that 29.01% were in portfolio companies located in the San Jose-San Francisco area, again the highest share for any location.

such as Silicon Valley[17], suggesting that venture capitalists in these markets tend to pay lower prices for their deals, and therefore extract greater surplus. This is also in line with the model's predictions.

For simplicity, the analysis so far assumed that when the incumbent is successful at date 1, there is a (profitable) potential entrant with probability one. If we allow this probability to vary, the net benefit of incomplete contracts will be increasing in the probability, since incomplete contracts enable the venture capitalist to extract informational rents when there is a potential profitable entrant. The model therefore predicts that incomplete contracts will be more attractive when the probability of a potentially profitable entrant emerging is higher. This probability is likely to be higher in R&D-intensive industries, with substantial investments in innovative projects whose outcomes may be complementary to the incumbent's when successful. The available evidence on this is consistent with the model: Kaplan and Stromberg (2003, 2004) find that incomplete venture capital contracts are significantly more common for firms in industries with a high R&D/sales ratio.

The model, again for simplicity, assumes that there is only one effort decision, made by the entrepreneur at the beginning. Extending the model to allow for a second effort decision, in the second period, would raise the question of whether the intial entrepreneur (founder) should be retained, or a replacement found, who would then take the second effort decision. In general, this will depend on a variety of factors, including the importance of the founder's human capital for the long-term performance of the company. The replacement decision in the venture capital context has been studied by Hellmann (1998). The analysis in the present paper suggests a new issue to consider: the possible information leakage when the original contract specifies that the entrepreneur will be replaced if, and only if, the realized intermediate state is poor ($\gamma = \gamma_B$).

Such explicit contracting is not typically observed, but time vesting of the founder's shares, combined with the allocation of significant control rights to venture capitalists, can often achieve the same purpose, and have similar implications for information leakage. When venture capitalists are given sufficient control rights, they can intervene to have the entrepreneur replaced by the board. This may be worthwhile if the entrepreneur has not been successful in the first period and there is time vesting, implying that he will have a much lower claim

[17] See also Castilla (2003) for evidence that collaboration networks among venture capital firms in Silicon Valley are more dense and dominated by more connected cliques than in Route 128.

on future returns if he is replaced before the vesting date.[18] Replacement of the entrepreneur in this case signals that $\gamma = \gamma_B$.[19] The analysis in this paper thus suggests that, when the gain from avoiding information disclosure is sufficiently large, time vesting combined with the allocation of substantial control rights to venture capitalists should be less prevalent. This is consistent with the evidence on time vesting and control rights in California contracts.[20]

Overall then, the available empirical evidence seems consistent with the theoretical model developed in this paper. This yields some interesting implications. First, our model predicts that when S is sufficiently large ($S > \hat{S}$), it becomes possible to finance the incumbent with an incomplete contract even when the incumbent would be unable to obtain funding for his project with a complete contract. Second, when S is sufficiently large (again $S > \hat{S}$), the optimal incomplete contract will induce a higher level of entrepreneurial effort than the optimal complete contract. Thus when expected positive spillovers are sufficiently important (entrants' expected profitability is sufficiently high), the use of optimally incomplete venture capital contracts can increase the number of start-ups able to obtain funding, and increase innovative effort. This may help to explain the particularly successful performance of venture capital in California.

6. Conclusions

In this paper, we have examined the interaction between innovation, spillovers and contract design in venture capital. When innovative start-up firms generate sufficiently large spillovers for subsequent potential entrants, it can be optimal to

[18]For example, suppose that the founder's human capital is important for continuing the same strategy that has been successful in the first period; on the other hand, if that first strategy has not been very successful, a different strategy is more efficient in the second period and can be implemented at least as well by a replacement.

[19]Note that without time vesting combined with substantial control rights for the VC, the replacement of the founder is much more likely to be due to the founder's voluntary departure, and outsiders cannot typically observe the reasons for a separation.

[20]Kaplan and Stromberg (2003) find a significant negative "California effect" on the sensitivity of the founder's payoff to time vesting. They also find that venture capitalists are less likely to have redemption rights in California. These enable VCs to require repurchase of their shares by the company, and can be used to force liquidation (Gompers (1997)). Presumably they can also be used to put pressure on the board to replace the founder (even when VCs do not have board control and voting control). Bengtsson and Ravid (2009) further find that VCs are less likely to receive a variety of other control rights in California. These too may be used to put pressure on the board.

adopt more "incomplete" contracts. Although these contracts may entail some efficiency loss (in our model, a less efficient reward scheme for the entrepreneur), this loss is more than offset by the efficiency gains. By avoiding information leakage, the contracting parties are able to extract informational rents from subsequent entrants; *ex ante*, the expectation of these rents relaxes financing constraints and makes it possible to provide more high-powered incentives to entrepreneurs, increasing innovative effort.

Thus spillovers and contractual design become mutually reinforcing. Our analysis can therefore shed light on the observed geographical correlations between contractual design and localized spillovers. We view this explanation as a valuable complement to more traditional accounts based on regional cultural differences.

7. References

Acs, Z., Audretsch, D. and M. Feldman (1996) "R&D spillovers and recipient firm size", *Review of Economics and Statistics*, 100(1), 336-367.

Admati, A.R. and P. Pfleiderer (1994) "Robust financial contracting and the role of venture capitalists", *Journal of Finance* 49, 371-402.

Aghion, P., and B. Hermalin (1990) "Legal restrictions on private contracts can enhance efficiency", *Journal of Law, Economics, and Organizations*, 6, 381-409.

Agrawal, A., Kapur, D. and J. McHale (2008) "How do spatial and social proximity influence knowledge flows? Evidence from patent data", *Journal of Urban Economics*, 64, 258-269.

Allen, F. and D. Gale (1992) "Measurement distortion and missing contingencies in optimal contracts", *Economic Theory*, 2, 1-26.

Anderlini, L. and L. Felli (1994) "Incomplete written contracts: undescribable states of nature", *Quarterly Journal of Economics*, 109, 1085-1124.

Anderlini, L. and L. Felli (1999) "Incomplete contracts and complexity costs", *Theory and Decision*, 46, 23-50.

Audretsch, D. and M. Feldman (1996) "R&D spillovers and the geography of innovation and production", *American Economic Review*, 86(4), 253-273.

Audretsch, D. and M. Feldman (2004) "Knowledge spillovers and the geography of innovation", in Henderson, J. and J.-F. Thisse (eds.) *Handbook of Regional and Urban Economics*, Vol. 4, Amsterdam: Elsevier.

Audretsch, D. and P. Stephan (1996) "Company-scientist locational links: the case of biotechnology", *American Economic Review*, 86(4), 641-652.

Battigalli, P. and G. Maggi (2002) “Rigidity, discretion and the costs of writing contracts”, *American Economic Review*, 92(4), 798-817.

Bengtsson, O. and A.S. Ravid (2009) "The geography of venture capital contracts", SSRN Working Paper.

Bergemann, D. and Hege, U. “Venture Capital Financing, Moral Hazard, and Learning.” *Journal of Banking and Finance,* Vol. 22 (1998), pp. 703-735.

Bernheim, D. and M. Whinston (1998) “Incomplete contracts and strategic ambiguity”, *American Economic Review*, 88(4), 902-932.

Bolton, P. and A. Faure-Grimaud (2009) “Thinking ahead: the decision problem”, *Review of Economic Studies*, 76(4), 1205-1238.

Bolton, P. and A. Faure-Grimaud (2010) “Satisficing contracts”, *Review of Economic Studies*, 77(3), 937-971.

Bottazzi, L., Da Rin, M., and T. Hellmann (2005) "What Role of Legal Systems in Financial Intermediation? Theory and Evidence", mimeo, Università Bocconi.

Casamatta, C. “Financing and Advising: Optimal Financial Contracts with Venture Capitalists.” *Journal of Finance*, Vol. 58 (2003), pp. 2059-2085.

Castilla, E. (2003) "Networks of venture capital firms in Silicon Valley", *International Journal of Technology Management*, 25, 113-135.

Cestone, G. “Venture Capital Meets Contract Theory : Risky Claims or Formal Control?.” Mimeo, Institut d’Analisi Economica, Barcelona, 2000.

Cestone, G. and L. White (2003) “Anti-competitive financial contracting: the design of financial claims”, *Journal of Finance* 58, 2109-2142.

Chen, H., Gompers, P., Kovner, A. and J. Lerner (2009), "Buy local? The geography of successful and unsuccessful venture capital expansion", NBER WP 15102.

Cornelli, F. and Yosha, O. “Stage Financing and the Role of Convertible Debt.” *Review of Economic Studies,* Vol. 70 (2003)*,* pp. 1-32*.*

Cuny, C. and E. Talmor (2005) "The staging of venture capital financing: milestone vs. rounds", SSRN Working Paper.

Dessí, R. (2005) “Start-up finance, monitoring, and collusion”, *Rand Journal of Economics*, 36(2), 255-274.

Dye, R. (1985) “Costly contract contingencies”, *International Economic Review*, 233-250.

Ellison, G., Glaeser, E. and W. Kerr (2010) "What causes industry agglomeration? Evidence from coagglomeration patterns", *American Economic Review*, forthcoming.

Fallick, B., Fleischman, C. and J. Rebitzer (2006) "Job-hopping in Silicon Valley: some evidence concerning the microfoundations of a high-technology cluster", *Review of Economics and Statistics*, 88(3), 472-481.

Friedman, M.L. (2008) "Job hopping, earning dynamics, and industrial agglomeration in the software publishing industry", *Journal of Urban Economics*, 64, 590-600.

Glaeser, E. and W. Kerr (2009) "Local industrial conditions and entrepreneurship: How much of the spatial distribution can we explain?", *Journal of Economics and Management Strategy*, 18(3), 623-663.

Glaeser, E., Kerr, W. and A. Ponzetto (2009) "Clusters of entrepreneurship", NBER WP 15377.

Gompers, P.A. (1997) "Ownership and Control in Entrepreneurial Firms: An Examination of Convertible Securities in Venture Capital Investments", Working Paper, Harvard Business School.

Grossman, S.J. and O. Hart (1986), "The costs and benefits of ownership: a theory of vertical and lateral integration", *Journal of Political Economy*, 94, 691-719.

Hart, O. and J. Moore (1990) "Property rights and the nature of the firm", *Journal of Political Economy*, 98, 1119-1158.

Hart, O. and J. Moore (1999) "Foundations of incomplete contracts", *Review of Economic Studies*, 66(1), 115-138.

Hellmann, T. "The Allocation of Control Rights in Venture Capital Contracts." *Rand Journal of Economics,* Vol. 29 (1998), pp. 57-76.

Hochberg, Y.V., Ljungqvist, A. and Y. Lu (2010) "Networking as a barrier to entry and the competitive supply of venture capital", *Journal of Finance*, forthcoming.

Holmstrom, B. and P. Milgrom (1991) "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design", *Journal of Law, Economics and Organization*, 7, 24-52.

Jaffe, A. (1989) "Real effects of academic research", *American Economic Review*, 79(5), 957-970.

Jaffe, A., Trajtenberg, M. and R. Henderson (1993) "Geographic localization of knowledge spillovers as evidenced by patent citations", *Quarterly Journal of Economics*, 63, 577-598.

Kaplan, S.N., Martel, F., and Stromberg, P. (2003) "How Do Legal Differences and Learning Affect Financial Contracts?", mimeo, University of Chicago.

Kaplan, S.N. and P. Strömberg (2003) "Financial contracting theory meets the real world: an empirical analysis of venture capital contracts", *Review of Economic Studies,* 70(243), 281-315.

Kaplan, S.N. and P. Strömberg (2004) "Characteristics, contracts, and actions: evidence from venture capitalist analyses", *Journal of Finance,* 59, 2177-2210.

Klein, B., Crawford, R. and A. Alchian (1978) "Vertical integration, appropriable rents, and the competitive contracting process", *Journal of Law and Economics*, 21(2), 297-326.

Lerner, J. and Schoar, A. (2005) "Does Legal Enforcement Affect Financial Transactions? The Contractual Channel in Private Equity", *Quarterly Journal of Economics*, 120, 223-246.

Martimort, D. and S. Piccolo (2010) "The Strategic Value of Quantity Forcing Contracts", *American Economic Journal: Microeconomics*, 2(1), 204-229.

Maskin, E. (1977) "Nash equilibrium and welfare optimality", mimeo, published in 1999, *Review of Economic Studies*, 66(1), 23-38.

Moore, J. "Implementation in Environments with Complete Information." in *Advances in Economic Theory*, ed. J.J. Laffont, Cambridge University Press, 1992.

Pearce, D.G. and E. Stacchetti (1998) "The Interaction of Implicit and Explicit Contracts in Repeated Agency", *Games and Economic Behavior*, 23(1), 75-96.

Rajan, R. "Insiders and Outsiders: The Choice Between Informed and Arm's Length Debt." *Journal of Finance,* Vol. 47 (1992), pp. 1367-400.

Repullo, R. and Suarez, J. (2000) "Entrepreneurial Moral Hazard and Bank Monitoring: A Model of the Credit Channel", *European Economic Review*, 44, 1931-1950.

Repullo, R. and Suarez, J. (2004) "Venture Capital Finance: A Security Design Approach", *Review of Finance*, 8, 75-108.

Saxenian, A. (1994) *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, MA: Harvard University Press.

Schmidt, K. (2003) "Convertible securities and venture capital finance", *Journal of Finance*, 58(3), 1139-1166.

Schmidt, K. and M. Schnitzer (1995) "The Interaction of Explicit and Implicit Contracts", *Economics Letters*, 48(2), 193-99.

Segal, I. (1999) "Complexity and renegotiation: a foundation for incomplete contracts", *Review of Economic Studies*, 66(1), 57-82.

Spier, K. (1992) "Incomplete contracts and signaling", *Rand Journal of Economics*, 23, 432-443.

Tirole, J. (2009) "Cognition and incomplete contracts", *American Economic*

Review, 99(1), 265-294.

Williamson, O. (1975) *Markets and Hierarchies: Analysis of Antitrust Implications*, New York: Free Press.

Williamson, O. (1985) *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*, New York: Free Press.

Von Thadden, E.L. (2004) "Asymmetric information, bank lending, and implicit contract: the winner's curse", *Finance Research Letters*, 1, 11-23.

Zucker, M., Darby, M. and M. Brewer (1998) "Intellectual human capital and the birth of U.S. biotechnology enterprises", *American Economic Review*, 88, 290-306.

8. Appendix

The optimal contract when entry is ruled out exogenously (problem P1)

The problem is:

$$Max \qquad U = eR_e - \frac{1}{2}e^2 \tag{8.1}$$

$$e = R_e \quad (IC) \tag{8.2}$$

$$e\gamma_G R + (1-e)\gamma_B R - eR_e \geqslant K_I \quad (IR) \tag{8.3}$$

The first-best effort level maximizes the project's expected returns net of effort costs, i.e.

$$e\gamma_G R + (1-e)\gamma_B R - \frac{1}{2}e^2 \tag{8.4}$$

and is given by $e^{FB} \equiv \Delta\gamma R$. To implement this would require setting $R_e = \Delta\gamma R$ (from (IC)). This would imply that the maximum income that could be pledged to $VC1$ would be equal to $\gamma_B R$. By assumption $(A1)$, this will not be sufficient to satisfy (IR). Thus (IR) will bind. We can write (IR) as follows:

$$e\Delta\gamma R + \gamma_B R - e^2 \geqslant K_I \tag{8.5}$$

Differentiating the LHS gives $\Delta\gamma R - 2e$, implying that the LHS increases from an initial value of $\gamma_B R$ for $e = 0$ to $\frac{1}{4}(\Delta\gamma R)^2 + \gamma_B R$ for $e = \frac{1}{2}\Delta\gamma R$, decreasing thereafter.

We assume that parameter values are such that the project can be financed:

$$\frac{1}{4}(\Delta\gamma R)^2 + \gamma_B R \geqslant K_I \qquad (A5) \tag{8.6}$$

Effort will therefore be equal to the largest root of the following equation:

$$(e\Delta\gamma + \gamma_B)R - e^2 = K_I \tag{8.7}$$

i.e.

$$e^N = \frac{1}{2}\Delta\gamma R + \frac{1}{2}\{[\Delta\gamma R]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{8.8}$$

Proof of Lemma 1.

When $\gamma = \gamma_B$, by assumption it is unprofitable to fund the entrant. When $\gamma = \gamma_G$, by the same assumption it is profitable to fund the entrant. Competition among venture capitalists $VC2, ..., VCN$ ensures that they are willing to fund the entrant on terms that give them zero expected profits. Thus the entrant's expected gain from his project is equal to its full expected NPV, S. Entry reduces the expected value of the incumbent's project by μR, implying a corresponding loss for $VC1$ since he receives the final returns from the incumbent's project.

Proof of Proposition 1

(a) The problem is:

$$Max \qquad U = eR_e - \frac{1}{2}e^2 \tag{8.9}$$

$$e = R_e \quad (IC) \tag{8.10}$$

$$e(\gamma_G - \mu)R + (1-e)\gamma_B R - eR_e \geqslant K_I \quad (IR) \tag{8.11}$$

The first-best effort level, e_C^{FB}, maximizes the project's NPV, taking into account costs of entry; i.e.

$$e[\gamma_G - \mu - \gamma_B]R + \gamma_B R - K_I - \frac{1}{2}e^2 \tag{8.12}$$

and is equal to

$$e_C^{FB} = (\Delta\gamma - \mu)R \tag{8.13}$$

Implementing this effort level would require setting $R_e = (\Delta\gamma - \mu)R$, which would not satisfy (IR). Thus (IR) will bind. We can write (IR) as follows:

$$e(\Delta\gamma - \mu)R + \gamma_B R - e^2 \geqslant K_I \tag{8.14}$$

Differentiating the LHS gives $(\Delta\gamma - \mu)R - 2e$, implying that the LHS increases from an initial value of $\gamma_B R$ for $e = 0$ to $\frac{1}{4}[(\Delta\gamma - \mu)R]^2 + \gamma_B R$ for $e = \frac{1}{2}(\Delta\gamma - \mu)R$, decreasing thereafter.

Thus if $K_I > \frac{1}{4}[(\Delta\gamma - \mu)R]^2 + \gamma_B R$, (IR) cannot be satisfied and the project cannot be funded. Otherwise, the project will be funded and effort will be given by the largest root of:

$$e(\Delta\gamma - \mu)R + \gamma_B R - e^2 = K_I \tag{8.15}$$

i.e.

$$e^C = \frac{1}{2}(\Delta\gamma - \mu)R + \frac{1}{2}\{[(\Delta\gamma - \mu)R]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{8.16}$$

To show that $e^C < e^N$, suppose not; i.e. $e^C \geqslant e^N$. From (8.15) we know that

$$(e^C\Delta\gamma + \gamma_B)R - (e^C)^2 = K_I + \mu R e^C > K_I \tag{8.17}$$

This means that e^C would also be feasible in the no-entry case, and indeed that a higher effort than e^C would be feasible in the no-entry case since there is some slack in the investor's participation constraint for the no-entry case evaluated for effort equal to e^C. Thus e^N could not be the solution to problem $P1$.

(b) The incumbent's expected utility with complete contracts is equal to $U = \dfrac{1}{2}(e^C)^2$, his expected utility in the no-entry case is $U = \dfrac{1}{2}(e^N)^2$, and we have just proved that $e^C < e^N$.

Proof of Lemma 2

Consider the following candidate equilibrium strategies:

(i) $VC1$. If the realized state is γ_B, never offer to fund the entrant. If the realized state is γ_G, offer to fund him on terms that extract the full surplus from his project (i.e. $VC1$ provides the initial capital K_E in return for the project's final returns).

(ii) Uninformed venture capitalists. Never offer to fund the entrant.

(iii) Entrant. Accept the best offer.

Given these strategies, if an uninformed venture capitalist deviates by offering to fund the project on more favorable terms for the entrant (i.e. he offers to provide the initial capital K_E in return for a share of the project's final returns, the share being less than one), he knows that his offer will be accepted by the entrant in both states. He therefore expects to make a loss (by assumption $(A4)$). If he offers to fund the entrant on the same terms as $VC1$ (i.e. he offers to provide the initial capital K_E in return for the project's final returns), his offer will be accepted with probability one when $\gamma = \gamma_B$, and with probability $p = \frac{1}{2}$ when $\gamma = \gamma_G$, so again he expects to make a loss[21]. Thus uninformed venture capitalists have no incentive to deviate. $VC1$ has no incentive to deviate either because his strategy yields the highest possible expected return for him in the date 1 game.

Proof of Proposition 2.

(a) The problem is:

$$Max \qquad U \equiv e(\gamma_G - \mu)R_I + (1-e)\gamma_B R_I - \frac{1}{2}e^2 \tag{8.18}$$

subject to the constraints:

$$e = \arg\max(U) \quad (IC) \tag{8.19}$$

$$e[(\gamma_G - \mu)R_V + S] + (1-e)\gamma_B R_V \geqslant K_I \quad (IR) \tag{8.20}$$

$$R_I + R_V = R \tag{8.21}$$

$$R_I \geqslant 0, R_V \geqslant 0 \quad (LL) \tag{8.22}$$

From (IC) we have

$$e = (\Delta\gamma - \mu)R_I \tag{8.23}$$

The first-best effort level, e_I^{FB}, maximizes the project's NPV, taking into account costs of entry and surplus extracted from the entrant; i.e.

$$e[(\gamma_G - \mu)R + S] + (1-e)\gamma_B R - K_I - \frac{1}{2}e^2 \tag{8.24}$$

and is equal to

$$e_I^{FB} = [\Delta\gamma - \mu]R + S \tag{8.25}$$

[21] Obviously this will also be true for any other value of p.

Implementing e_I^{FB} would require setting

$$R_I = R + \frac{S}{\Delta\gamma - \mu} \tag{8.26}$$

which would not satisfy (IR). Thus either (IR) binds or the feasibility constraint $e \leqslant e^H$ binds. Define $\alpha \equiv \Delta\gamma - \mu$. We can then write (IR) as follows

$$e[\alpha R_V + S] + \gamma_B R_V \geqslant K_I \tag{8.27}$$

and replace $R_V = R - R_I = R - \frac{e}{\alpha}$ (using (IC)) to obtain

$$e[\alpha R + S - \frac{\gamma_B}{\alpha}] - e^2 + \gamma_B R \geqslant K_I \tag{8.28}$$

Differentiating the LHS gives $\alpha R + S - \frac{\gamma_B}{\alpha} - 2e$, and differentiating again gives -2. If $\alpha R + S - \frac{\gamma_B}{\alpha} \leqslant 0$, the LHS is maximized at $e = 0$, and the project cannot be funded (by assumption $(A1)$). If $\alpha R + S - \frac{\gamma_B}{\alpha} > 0$, the LHS is maximized at $e = \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}]$. Thus if $\frac{1}{4}[\alpha R + S - \frac{\gamma_B}{\alpha}]^2 + \gamma_B R < K_I$, again the project cannot be funded. When $\frac{1}{4}[\alpha R + S - \frac{\gamma_B}{\alpha}]^2 + \gamma_B R \geqslant K_I$, we have two possibilities: either the feasibility constraint $e \leqslant e^H$ is not binding, implying that the project is funded and e is the largest root of the equation

$$e[\alpha R + S - \frac{\gamma_B}{\alpha}] - e^2 + \gamma_B R = K_I \tag{8.29}$$

i.e.

$$e^I = \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}] + \frac{1}{2}\{[\alpha R + S - \frac{\gamma_B}{\alpha}]^2 + 4[\gamma_B R - K_I]\}^{\frac{1}{2}} \tag{8.30}$$

or the feasibility constraint is binding, implying that the project is funded if, and only if, $e^H[\alpha R + S - \frac{\gamma_B}{\alpha}] - (e^H)^2 + \gamma_B R \geqslant K_I$. In this case $e^I = e^H$.

(b) The incumbent's expected utility is given by

$$U \equiv e[\gamma_G - \mu - \gamma_B]R_I + \gamma_B R_I - \frac{1}{2}e^2 = \frac{1}{2}e^2 + \frac{\gamma_B e}{\alpha} \tag{8.31}$$

Proof of Lemma 3

The net benefit of incomplete contracts is

$$NBI \equiv \frac{1}{2}\{e^I S + (e^I - e^C)\alpha R + \frac{e^I \gamma_B}{\alpha}\}$$

Hence,

$$\frac{dNBI}{dS} = \frac{1}{2}\{e^I + (S + \alpha R + \frac{\gamma_B}{\alpha})\frac{de^I}{dS}\}$$

Using (8.29):

$$e^I[\alpha R + S - \frac{\gamma_B}{\alpha}] - (e^I)^2 + \gamma_B R = K_I \tag{8.32}$$

we obtain

$$de^I[\alpha R + S - \frac{\gamma_B}{\alpha} - 2e^I] = -e^I dS \tag{8.33}$$

Thus $\frac{de^I}{dS} = \frac{-e^I}{\alpha R + S - \frac{\gamma_B}{\alpha} - 2e^I}$ and $\frac{dNBI}{dS} = \frac{1}{2}\{\frac{-2e^I(\frac{\gamma_B}{\alpha} + e^I)}{\alpha R + S - \frac{\gamma_B}{\alpha} - 2e^I}\} > 0$ for $e^I > \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}]$. When $e^I = \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}]$ it is straightforward to verify that a marginal increase in S makes it possible to increase e^I without violating the IR constraint. Thus for $e^I \geqslant \frac{1}{2}[\alpha R + S - \frac{\gamma_B}{\alpha}]$, i.e. the range of values of interest, NBI increases with S.