R&D Institutional Arrengements: Start-up vs. Internal Lab?*

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May 2000

Abstract

Why do some firms choose to undertake their RD by financing start-up companies, while other firms do it in their internal labs? An established firm can choose to hire an idea owner as a scientist in its internal labs, or it may finance a start-up company as a corporate venture capitalist with the idea owner being a shareholder in it. We present a model where the choice of RD is driven by information asymmetries on the quality of the project between the corporate venture capitalist and the idea owner. In the complete information case extreme quality projects are developed in the corporation lab and there is an intermediary range of qualities that are developed as a start up. Once we allow for incomplete information, higher quality projects are more likely to be developed via start-up firms, while low quality ones will be assumed internally. This follows the empirical findings of Jensen (1993). Two types of risk are identified. The higher the quality associated risk or the more difficult to monitor the more likely the project to be developed as a new venture. Furthermore, the model is able to replicate the compensation behavior of scientists vis-a-vis start-up entrepreneurs.

*We thank Atila Abdulkadiroglu, Juan Dubra, Federico Echenique and specially Hugo Hopenhayn for extensive and patient discussions. All error are our own.

1 Introduction

Industrial corporations started to support the development of entrepreneurial companies long before the organized venture capital industry existed. For instance seventy years ago Du Pont provided funding for a fledging General Motors Corporation.

Venture capital is becoming an important source of funding for people with ideas for new products and new companies developing them. In particular, in the high tech sector, important players like Microsoft, Compaq and Intel fund much of new product development through venture capital.

Large corporations often invest in smaller companies. They can do so by directly investing in a new venture or investment can be accomplished by the formation of an internal venture within the company. In 1996, venture capital subsidiaries of large corporations were a multibillion dollar segment of the venture capital industry with about a hundred non financial corporations with venture capital subsidiaries and many more involved in some sort of ad hoc investing.

The question we want to address in this paper is, why do these companies choose to fund new product development by such means instead of doing so in their own Research & Development Laboratories? The question seems relevant, first because other prestigious firms in the United States like IBM, AT&T and Xerox have venerable R&D labs that throughout history have developed widely successful products. And the second reason lies in the fact that venture capitalism seems to be much more subject to moral hazard inefficiencies than development in an own lab, but even so the companies mentioned in the beginning choose such form of funding.

Regarding venture capital and R&D, it is possible to point out a few key stylized facts.

- Researchers in corporations receive most of their compensation as a base salary while idea owners developing a new venture receive most as a share of the project.

  According to the 1990 National Compensation Survey of R&D (the latest we are aware of) the average monthly base salary of scientists and engineers is \$4,297 while the monthly total cash compensation is \$4,303. For the Industry sector these figures are \$4,283 and \$4,290 respectively. In contrast, idea owners starting their own firm, have most of their payoff tied to their success. Gompers (1996) reports that the venture capitalist stake in start ups before IPO is around 30%. Radtke and McKinney (1999) state that when corporations finance start ups and an equity investments is part of the relationship, it is between 5% and 20%. Despite the difference in figures, both imply that most of the idea owner payoff is coming from his share in the start up.

- R&D projects in corporations are less profitable than the R&D carried out in start ups. Jensen (1993) finds that R&D results varies a lot over different firms, but on average R&D in corporations is less profitable than the venture capital industry. Gompers and Lerner (1998) find that corporate venture capital is at least as successful as independent venture capital.

- Jensen(1993) also reports labs success stories like Phillip Morris, Wall Mart Stores or General Electric Co., which implies that some of them are able to develope high quality projects.

- It is widely accepted that start up ventures are risky enterprises. Gompers (1995) using data form a random sample of 794 venture capital backed firms between 1961 and 1992 (gathered from the Venture Economics Database) reports that only 22.5% of them went public, 23.8% merge or were acquired, 15.6% were liquidated of went bankrupt and 38.1% remain private. According to Gompers these results understate the proportion of liquidations. First, some of the acquisitions/mergers were distressed firms that provided very low return to the venture capitalist. Also, some of the firms classified as private may have been liquidated since firms without debts have no need to file for bankruptcy.

On the other hand, successful start ups are associated with very high returns.

- Gompers and Lerner (1998) find that the venture capital industry in general and specially corporate venture capital tend to focus on a few high tech industries. Corporate venture capitalist assign most of their funding to areas related to the corporation's main line of business (what Gompers and Lerner call a strategic focus). Quoting Gompers (1995) "venture capitalists concentrate investments in early stage companies and high technology industries where informational asymmetries are significant and monitoring is valuable".

There is of course a sizeable literature on related work, in particular, the decision of "make or buy", franchising and spin-offs. Echoes of the "make or buy" decision can be seen already in Coase's famous 1937 paper, where he discusses the limits of a firm and what activities the firm should and/or will undertake.

An early seminal paper on venture capital financing is the work of Leland and Pyle (1977). Their model contains a financially constrained entrepreneur (what we call in our model the "idea owner") and a capitalist, to whom the entrepreneur asks for funding. The capitalist suffers from asymmetric information regarding the quality of the project. To overcome this, the entrepreneur adopts a signalling strategy to induce the capitalist to finance the venture. This signalling strategy consists of the share the entrepreneur is willing to fund by himself. Furthermore, by assuming mean-variance payoffs, Leland and Pyle are able to explicitly solve for the equilibrium signalling schedule. However, their model does not consider the alternative that the capitalist in our case is a firm, may hire the entrepreneur as an employee scientist in the lab of the firm. On the other hand, our model is not a signalling model, in the sense that the entrepreneur has to "induce" the capitalist to give him funds for project. In our case, the *c.v.c.* finds always profitable to fund the project, but has to decide under what contractual arrangement.

More recently, the two most closely related paper to what we are developing here is the work by Lewis and Sappington (1991) and Hellmann (1998). They set up a model, in which a firm has to decide whether to produce an essential input for production internally, or to hire a subcontractor to do it for them. They analyze two cases. One case, where the subcontractor's skills are idiosyncratic (meaning that his expected earnings are independent of his ability to work for the firm) or transferable (in which case the potential earnings in other sectors increase with his innate ability). Lewis and Sappington find that in the case of idiosyncratic skills it pays for the firm to produce the input internally, while their results become reversed in the case of transferable skills.

Lewis and Sappington's model is very powerful. However, our model has important differences with theirs. First, in the case of Lewis and Sappington, the firm has no interest in the contractor to succeed (make a profit). Its decision is only whether to buy the good (input) from the subcontractor or do it itself. In our case, the firm (or what we will call the corporate venture capitalist) has a financial stake in the venture, no matter if he produces the new good inside or outside the firm.

Hellmann (1998) focus on the entrepreneur decision on how to finance a new venture. The entrepreneur has to decide between a perfectly competitive market of independent venture capitalist or a unique corporate investor. The event of the investor buying the idea is ruled out by assumption. In this model investors beside providing financing, can take several actions that may affect the performance of the new venture. This actions are privately costly. If all actions are verifiable and the new venture is a complement of the core business of the corporation then a corporate investor is preferred. If the entrepreneur is concerned the corporation may invest in a rival venture or if the degree of complementarity between the venture and the corporation main line of business may be affected by investors actions the entrepreneur may prefer an independent venture capitalist even though the projects is complement with the corporations core business. Hellmann's concern is in a way the inverse of ours. He ask the question of why an entrepreneur chooses one investor over others. We take the point of view of the corporation and ask why they prefer one ownership structure over other.

In the model presented in this paper there are two agents: a financially constrained idea owner and a corporation. There is a project that can be developed under two alternative arrangements: as a start up financed by the corporate venture capitalist or in the corporation's lab where the idea owner will work as a scientist. The returns of the project depend on the quality of the idea, the level of effort exercised by the idea owner and a random shock. The contract is lineal: the payoff structure consist on a transfer and a share in the profits.

We begin presenting the basic the model. In section 3 and 4 we solve the lab and start up problem and compare both solutions. Section 3 assumes complete information while in section 4 adverse selection is introduced. Section 5 by comparing the two previous sections, summarizes the effects of introducing adverse selection both in the lab and the start up case. Finally, section 6 discusses the monitoring technology assumption and the assumption over agent's attitude towards risk. Section 7 concludes. To facilitate exposure most proofs are left in the appendix.

2 The Model

There are two agents a financially constrained idea owner (*i.o.* from now own) and a corporate venture capitalist (*c.v.c.* from now own). The *i.o.* has a project in mind that requires an up front investment of I and yields $R(q, e) + u$. Here e is the effort level of the *i.o.*, q is the quality of the idea and u is a shock with mean zero and variance σ_u^2. The *c.v.c.*'s main line of business also has an uncertain part v with mean zero.

The *i.o.* is risk averse and dislikes effort. Epstein (1985) shows that we can represent a decreasing absolute risk aversion utility function in the mean-variance form. In light of that, we write the *i.o.* utility function as $\Pi^{i.o.} - e - \sigma^2$, where $\Pi^{i.o.}$ is the expected profit of his venture, and σ^2 is the variance of this income. The *c.v.c.* is assumed to be a risk neutral profit maximizer. His utility level is $\Pi^{c.v.c.}$.

The project revenue function $R(q,e)$ is increasing in the quality q and effort e at a decreasing rate (that is, $R_1 > 1$, $R_{11} < 0$, $R_2 > 0$, $R_{22} < 0$). Any project with $R_2 < 1$ will not be good enough to compensate the idea owner for his effort and, consequently, will not be carried out. Effort and quality are complements in the sense that $R_{12} > 0$. If it is not possible to get a positive result under this general form we will use the following functional form $R(q,e) = \frac{1}{a}qe^a$.

The ownership structure can take two basic forms. The corporate venture capitalist may contract the idea owner as a researcher in his (the *c.v.c.*'s) own lab or he may finance a start up. If the *i.o.* works inside the firm, the *c.v.c.* can impose the level of effort he wants the idea owner to commit to the project.

If the firm hires the *i.o.* as a scientist, we assume that there is a monitoring technology in place to supervise the effort the *i.o.* is putting into the project. This may come, for example, because the firm already has an internal hierarchy and audit effort in place that makes such monitoring possible.[1] We adopt a very simple monitoring technology. For very low levels of effort, there is zero cost of monitoring, in particular we assume for the lowest quality level, the first best effort is attainable free of monitoring (i.e. $R_2(\underline{q}, e) = 1$). Beyond a certain level $\widehat{e}$ (which is known to the *c.v.c.*), there is a fixed cost m to monitor effort at these higher levels. For technical reasons assume $m > \widehat{e}$. That is to say inside the firm the *c.v.c.* can decide which effort level he wants, but he is not able to observe the actual value of the projects. He observes $R(q,e) + u + v$.[2]

If the *c.v.c.* finances a start up, then he is not able to control effort (because the internal hierarchy of his firm is out of reach of the start up), but he receives a clear signal from the market of the value of the project. He observes both v and $R(q,e) + u$.

[1] See, for example, Williamson (1985) on this issue.

[2] Assuming $E(v) = 0$ is without loss of generality. Equivalently we could assume a positive mean known to everyone, and a shock that is indistinguishable -and therefore uncontractable- form u when the new project is developed in the lab.

Before we continue to the next section, we want to comment on the compensation of the two cases we consider. As mentioned in the introduction, scientists working for companies do get part of their compensation as a percentage of the profits his or her invention produces. Therefore, to be true of this fact, we denote by α the share the scientist gets of the profits and w his or her wage paid by the *c.v.c.*

If the *c.v.c.* decides to finance a start-up, the agreement with the *i.o.* takes the form of a transfer y and a share of profits of the venture kept by the *i.o.* of γ.

3 Complete Information

The fact that the venture capitalist in general and the corporate venture capitalist in particular are very focussed on some industries suggests that the capitalists have some way of evaluating the quality of the ideas in this industries. We start making the extreme assumption that the quality of the idea is perfectly observable by both agents. Informational asymmetries are at the center of our analysis, so that we relax this assumption in the next section. However, we treat the full information case to make later comparisons with other cases easier.

3.1 C.V.C. lab problem

The *c.v.c.* may choose to hire the *i.o.* as a scientist for a lab. In such case, the compensation of the *i.o.* will be a wage w and a share α of the profits the new product may turn out. The *c.v.c.* can control the effort level by incurring in the monitor cost m if she wants to impose an effort level above $\widehat{e}$. Recall that $m > \widehat{e}$. for the lowest quality level, the first best effort is attainable free of monitoring (i.e. $R_2(\underline{q}, e) = 1$). The *c.v.c.* will choose the share α, the payment w and the amount of effort he wants enforced so that to:

$$\max_{\{\alpha,w,e\}} E_{u,v}\left[(1-\alpha)\left[R(q,e)\right]+u+v-w\right]-m(e)-I$$
$$s.t. \quad \alpha R(q,e)+w-e-\alpha^2\sigma^2_{(u+v)}\geq 0$$

The objective function is the expected profit of the *c.v.c.* The *c.v.c.* keeps $(1-\alpha)$ of the observable (contractable) revenue and pays out the wage to the scientist (*i.o.*), the monitoring cost and the fixed cost I. The constraint is the participation constraint for the scientist. His outside reservation utility is normalized to zero. This means that he will only accept the job with the *c.v.c.* if his total compensation net of his costs (effort and risk) are greater or equal to zero.

It is not difficulty to see that the participation constraint will be satisfied with equality. Otherwise, the *c.v.c.* could reduce the wage payment and increase his profit. Substituting the constraint into the objective and eliminating the expectation operator, the problem can be rewritten as:

$$\max_{\{\alpha,e\}} \; R(q,e(q))-e-m(e)-I-\alpha^2\sigma^2_u$$

therefore,

$$\alpha(q)=0$$

and the effort is

$$e(q)=\begin{cases} R_2(q,e)=1 & \text{for all } q<\widehat{q} \text{ and for all } q\geq\widetilde{q} \\ \widehat{e} & \widehat{q}\leq q<\widetilde{q} \end{cases}$$

where $R_2(\widehat{q},\widehat{e})=1$ and $\widetilde{q}$ is finite if exists q that satisfies $R(q,\widehat{e})-\widehat{e}=R(q,\widetilde{e})-\widetilde{e}-m$, otherwise $\widetilde{q}$ is infinite. The left hand side is the profit if the free-to-monitor effort $\widehat{e}$ is exercised. The right hand side is the profit implied by a higher level of profit, where it necessary to pay the monitoring cost.

In general it can not be assure the existence of a finite $\widetilde{q}$. This means that the monitoring is so expensive that it is not worth to make extra effort. But for instance under the functional form $R(q,e) = \frac{1}{a}qe^a$ it is easy to se that it does exist a finite $\widetilde{q}$. In particular if $a = \frac{1}{2}$, $\widetilde{q} = \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$.

Note that the effort is non decreasing in the quality level. and for finite $\widetilde{q}$ it has a discontinuity at $\widetilde{q}$.

At the solution the *c.v.c.* is providing full risk insurance to the *i.o.* and the first best effort level (e^*) is attained for levels bellow $\widehat{q}$ and above $\widetilde{q}$.

Lastly, the payoff of the *c.v.c.* is then:

$$\Pi_{lab}^{c.v.c.} = \begin{cases} R(q,e^*) - e^* - I & \text{for all } q < \widehat{q} \\ R(q,\widehat{e}) - \widehat{e} - I & \widehat{q} \leq q < \widetilde{q} \\ R(q,e^*) - e^* - m - I & \text{for all } q \geq \widetilde{q} \end{cases}$$

where e^* solves $R_2(q,e) = 1$.

3.2 C.V.C. start up problem

The other arrangement the *c.v.c.* and the idea owner can come to is to form a start-up company. Since the idea owner is not part of the internal hierarchy of the firm, the *c.v.c.* cannot monitor the effort level. The *i.o.* will choose his effort e so that to maximize his own payoff:

$$\max_e \quad E_u\left[\gamma R(q,e) + u\right] + y - e - \gamma^2\sigma_u^2 \quad = \max_e \quad \gamma R(q,e) + y - e - \gamma^2\sigma_u^2$$

The optimum condition yields $\gamma R_2(q,e) = 1$. This defines an effort rule $e(q,\gamma)$. Note that this effort level is below the efficient level of effort for all $\gamma < 1$ and that $\frac{\partial e}{\partial \gamma} = -\frac{R_2}{\gamma R_{22}} > 0$.

Recall that under such an arrangement the *c.v.c.* keeps a share $1-\gamma$ of the profits, and pays out a sum y for the idea owner to set up a firm. The larger the share, γ, the closer the effort level is to the first best, but the *i.o.* faces more risk and therefore the transfer, w, needs to be higher to satisfy the participation constraint. The *c.v.c.*'s problem becomes:

$$\max_{\{\gamma,y\}} \quad E_v(v) + E_u\left[(1-\gamma)R(q,e) + u - y\right] - I$$
$$s.t. \quad \gamma R(q,e) + y - e - \gamma^2\sigma_u^2 \geq 0$$

As in the lab case, the objective is the total profit of the *c.v.c.* Note that here we write the profit of sum of separate terms, one for the (expected) profit of the core competence of the *c.v.c.* and the second for (expected) profit of the new venture. This reflects our assumption that in the start-up case the firm can distinguish exactly where the profits are coming from. The constraint is the participation restriction for the *i.o.*

Clearly, again, the participation constraint will be satisfied with equality. Solving for the transfer and taking first order conditions we obtain:[3]

$$\gamma(q) = \frac{(R_2 - 1)\,\frac{\partial e}{\partial \gamma}}{2\ \sigma_u^2} \geq 0$$

Therefore,

$$\Pi_{st.up}^{c.v.c.} = R[q, e\,(\gamma, q)] - e\,(\gamma, q) - \gamma^2\sigma_u^2 - I$$

3.3 Characterization

Proposition 1 .

- *For low quality levels the lab is preferred over the start up.*

[3]If $R_2 < 1$ the in the start up case, $\gamma = 0$ and therefore $e = 0$ and $y = 0$. In the lab case, $e = 0$, $\alpha = 0$ and $w = 0$. In either case we get the trivial result that $\Pi_{st.up}^{cvc} = \Pi_{lab}^{cvc} = R(q,0) - I$.

To have $\gamma \leq 1$ we need the extra assumption that $\frac{(R_2-1)R_2}{R_{22}} \geq 2\sigma_u^2$. In case this is not true, in the start up case $\gamma = 1$, the effort is defined by $R_2 = 1$ attaining the first best e^* yielding $\Pi_{st.up}^{cvc} = R(q,e^*) - e^* - \sigma_u^2 - I$ while in the lab case we have $\Pi_{lab}^{cvc} = R(q,e^*) - e^* - m(e^*) - I$. Here the decision between internal vs. external projects is based just on comparing σ_u^2 with $m(e^*)$, which does not strike us as a particularly interesting case. For the rest of the section we assume $\frac{(R_2-1)R_2}{R_{22}} \geq 2\sigma_u^2$.

- *For high quality levels the start up may be preferred over the lab.*

Given that for low levels of q the implied effort is for free monitoring, complementarity of quality and effort ($R_{12} > 0$) is a necessary condition for a start up. Otherwise, effort will be always at the free monitoring level.

Corollary 1 .

i) The share of profits of the i.o. is higher in the start up than in the lab case

ii) For $q \leq \widehat{q}$ and $q \geq \widetilde{q}$ the effort in the start up case is lower or equal to the lab case, where the first best is attained.

3.4 Effort, shares and profit

Given that a general answer to many interesting questions is not available, let us consider a more specific example in hopes of making more progress. We solve the model with a particular functional form to facilitate later comparison between the complete and incomplete information environments. Specifically, we will work with a multiplicative revenue function, that displays the properties we set out above, and which seems reasonable tractable to derive conclusions, $R(q,e) = \frac{1}{2}qe^a$.[4]

3.4.1 Lab case

Using this particular specification, the following table summarize the results for the lab case:

3.4.2 Start up case

Similarly, for the start-up case:

[4] In what follows, we specifically point out the case for $a = \frac{1}{2}$, because with it many expressions in the parameter a become much more tractable to work with (not so with other values, where algebraic expressions become ridden with non-linearities).

Table 1: Complete Infromation: Lab case

		$\mathbf{a} = \frac{1}{2}$
for all $q < \widehat{q}$ $\widehat{q} \leq q < \widetilde{q}$ for all $q \geq \widetilde{q}$	$e_{lab}(q) = \begin{cases} q^{\frac{1}{1-a}} \\ \widehat{q}^{\frac{1}{1-a}} \\ q^{\frac{1}{1-a}} \end{cases}$	$e_{lab}(q) = \begin{cases} q^2 \\ \widehat{q}^2 \\ q^2 \end{cases}$
for all q	$\alpha(q) = 0$	$\alpha(q) = 0$
for all q	$w = e_{lab}(q)$	$w = e_{lab}(q)$
for all $q < \widehat{q}$ $\widehat{q} \leq q < \widetilde{q}$ for all $q \geq \widetilde{q}$	$\Pi_{lab}^{c.v.c.} = \begin{cases} \left(\frac{1-a}{a}\right) q^{\frac{1}{1-a}} - I \\ \left(\frac{1-a}{a}\right) \widehat{q}^{\frac{1}{1-a}} - I \\ \left(\frac{1-a}{a}\right) q^{\frac{1}{1-a}} - m - I \end{cases}$	$\Pi_{lab}^{c.v.c.} = \begin{cases} q^2 - I \\ \widehat{q}^2 - I \\ q^2 - m - I \end{cases}$

where $\widehat{q} = \widehat{e}^{1-a}$ and for $a = \frac{1}{2}$, $\widetilde{q} = \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$.

Table 2: Complete Infromation: Start up case

	$\mathbf{a} = \frac{1}{2}$
$e_{st.up}(q) = (\gamma q)^{\frac{1}{1-a}}$	$e_{st.up}(q) = \left(\frac{q^3}{\sigma_u^2 + q^2}\right)^2$
$\frac{\gamma^{2-\frac{1}{1-a}}}{1-\gamma} = \frac{q^{\frac{1}{1-a}}}{2\sigma_u^2(1-a)}$	$\gamma = \frac{q^2}{\sigma_u^2 + q^2}$
$y(q) = \gamma^2\sigma_u^2 - \left(\frac{1-a}{a}\right)(\gamma q)^{\frac{1}{1-a}}$	$y(q) = \gamma^2\sigma_u^2 - \left(\frac{1-a}{a}\right)(\gamma q)^{\frac{1}{1-a}}$
$\Pi_{st.up}^{c.v.c.} = (\gamma q)^{\frac{1}{1-a}} \left[\frac{1-\gamma a}{\gamma a}\right] - \gamma^2\sigma_u^2 - I$	$\Pi_{st.up}^{c.v.c.} = \left(\frac{q^2}{\sigma_u^2 + q^2}\right)^2 (\sigma_u^2 + q^2) = \frac{q^4}{\sigma_u^2 + q^2} - I$

Under the extra assumption of $a = \frac{1}{2}$ it is possible to strengthen proposition 1.

Proposition 2 *Let the effort parameter a take the value* $\frac{1}{2}$, *and* $\sigma_u^2 > m$

- *for the lower and higher quality levels the lab is preferred over the start up.*
- *there is an intermediate range of quality levels where the start up is preferred.*[5]

Since the optimal level of effort is increasing in the quality level, higher quality levels imply the paying of the monitoring cost in the lab. In the start up, the level of effort is bellow the first best, that is attainable in the lab. For lower level of quality there is free monitoring therefore the lab is preferred over the start up. The implied level of effort in the start up is increasing in quality, but the first best level of effort increases at a higher rate. Therefore, for higher levels of quality the distortion is higher and eventually this distortion is so large that it is worth to pay the monitoring cost in the lab so that to impose the first best level of effort.

4 Incomplete information

In the previous section we made the usually unrealistic assumption that the quality is perfectly observable. Here we assume the *i.o.* knows the quality of the project but is unknown to the *c.v.c.*. He only knows that the quality level q has support on $[\underline{q}, \overline{q}]$ where $\underline{q}$ is the lowest type that yields non negative profits; q has probability distribution function $p(q)$ and cumulative distribution function $P(q)$. As is common in the literature, $H(q) = \frac{p(q)}{1-P(q)}$ is the hazard rate, which is assumed to be non decreasing in q. To simplify calculations, and

[5]The size of the intermediate range depends on the parameter values. If $\widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} = \widetilde{q} > \frac{m\sigma_u^2}{\sigma_u^2 - m}$ the start up is preferred for all q such that $\frac{\widehat{e}+\sqrt{\widehat{e}(\widehat{e}+4\sigma_u^2)}}{2} \leq q^2 \leq \widetilde{q}^2$, and the lab is preferred otherwise. If $\widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} = \widetilde{q} \leq \frac{m\sigma_u^2}{\sigma_u^2 - m}$ the start up is preferred for all q such that $\frac{\widehat{e}+\sqrt{\widehat{e}(\widehat{e}+4\sigma_u^2)}}{2} \leq q^2 \leq \frac{m\sigma_u^2}{\sigma_u^2 - m}$, and the lab is preferred otherwise. See the appendix for details.

gain insights on the comparative statics, we write $R(q,e) = \frac{1}{a}qe^a$ with $a < 1$ and assume $R(q,e) \geq 2\sigma^2_{(u+v)}$ and $R(q,e) \geq 2\sigma^2_u$. When need a will be assumed to equal $\frac{1}{2}$.

4.1 C.V.C. lab problem

As in the previous lab case the *c.v.c.* can control the effort level by incurring in the monitor cost m if the effort she imposes is more than $\widehat{e}$. Thus the *c.v.c.* has now two instruments: a share of profits and the effort level. The *c.v.c.* objective function is:

$$\max_{\{\alpha,w,e\}} E_{u,v,q}\left[(1-\alpha)\frac{1}{a}qe^a + u + v - w - m(e)\right] - I$$
$$= \max_{\{\alpha,w,e\}} \int_{q_0^l}^{\overline{q}} \left[(1-\alpha)\frac{1}{a}qe^a - w(q) - m(e)\right] p(q)dq - I$$

subject to participation and incentive constraints, where q_0^l is the lowest quality level the *c.v.c.* is willing to develope in his lab

Let $I^l(q,\alpha,w,e)$ be the utility of the idea owner, in the case that he works as a scientist for the corporate venture capitalist. Using our expression for the revenue function, this utility can be written as $\frac{\alpha}{a}qe^a + w - e - \alpha^2\sigma^2_{(u+v)}$.

Lemma 1 *A sufficient condition for implementability is:*

i) α *and* e *non decreasing in* q.

ii) $w(q) = \int_{q_0^l}^q \alpha\frac{1}{a}e^a dx - \alpha\frac{1}{a}qe^a + e + \alpha^2\sigma^2_{(u+v)}$

Since $I_q^l(q,\alpha,w,e) > 0$ is enough to check the participation constraint for the lowest type.

Following standard procedure in the literature, we check if the solution of the *c.v.c.*'s unconstrained problem satisfies the condition of the previous lemma.

Replacing the transfers in the objective function,

$$\int_{q_0^l}^{\overline{q}} \left[(1-\alpha)\frac{1}{a}qe^a - \int_{q_0^l}^q \alpha\frac{1}{a}e^a dx + \alpha\frac{1}{a}qe^a - e - \alpha^2\sigma^2_{(u+v)} - m(e)\right] p(q)dq - I$$

After integrating by parts, and eliminating the integral inside the last expression we can write the relaxed problem as:

$$\max_{\{\alpha(q),e(q)\}} \int_{q_0^l}^{\overline{q}} \left[\frac{1}{a}qe^a - \alpha\frac{1}{a}e^a\frac{[1-P(q)]}{p(q)} - e - \alpha^2\sigma^2_{(u+v)} - m(e)\right] p(q)dq - I$$

Notice that the objective function is strictly decreasing in α. Therefore at any solution for this problem, we must have $\alpha(q) = 0$ for all q. Consequently, the unconstrained problem of the corporate venture capitalist becomes:

$$\max_{\{e(q)\}} \int_{q_0^l}^{\overline{q}} \left[\frac{1}{a}qe^a - e - m(e)\right] p(q)dq - I$$

The optimal effort level is given by

$$e(q) = \begin{cases} q^{\frac{1}{1-a}} & \text{for all } q < \widehat{q} \text{ and for all } q \geq \widetilde{q} \\ \widehat{q}^{\frac{1}{1-a}} & \widehat{q} \leq q < \widetilde{q} \end{cases}$$

where $\widetilde{q}$ solves $\frac{1}{a}q\widehat{e}^a - \widehat{e} = \frac{1-a}{a}q^{\frac{1}{1-a}} - m.$

Since both α and e are non decreasing in q, the solution to the relaxed problem is the solution to the problem of the *c.v.c.*.

This yields a wage payment (contingent on q),

$$w(q) = e(q)$$

and the total expected profit of the venture capitalist is:

$$\begin{aligned} \Pi^{c.v.c.}_{lab} &= \int_{q_0^l}^{\widehat{q}} \left(\frac{1-a}{a}\right) q^{\frac{1}{1-a}}p(q)dq + \int_{\widehat{q}}^{\widetilde{q}} \left(\frac{1-a}{a}\right) \widehat{q}^{\frac{1}{1-a}}p(q)dq + \int_{\widetilde{q}}^{\overline{q}} \left[\left(\frac{1-a}{a}\right) q^{\frac{1}{1-a}} - m\right] p(q)dq - I \\ &= \left(\frac{1-a}{a}\right) \left[\int_{q_0^l}^{\widehat{q}} q^{\frac{1}{1-a}}p(q)dq + \widehat{q}^{\frac{1}{1-a}}\left[P(\widetilde{q}) - P(\widehat{q})\right] + \int_{\widetilde{q}}^{\overline{q}} q^{\frac{1}{1-a}}p(q)dq\right] - m\left[1 - P(\widetilde{q})\right] - I \end{aligned}$$

If $a = \frac{1}{2}$

$$\begin{aligned} \Pi^{c.v.c.}_{lab} &= \int_{q_0^l}^{\widehat{q}} q^2p(q)dq + \int_{\widehat{q}}^{\widetilde{q}} \widehat{q}^2p(q)dq + \int_{\widetilde{q}}^{\overline{q}} \left[q^2 - m\right] p(q)dq - I \\ &= \int_{q_0^l}^{\widehat{q}} q^2p(q)dq + \widehat{q}^2\left[P(\widetilde{q}) - P(\widehat{q})\right] + \int_{\widetilde{q}}^{\overline{q}} q^2p(q)dq - m\left[1 - P(\widetilde{q})\right] - I \end{aligned}$$

where $\widehat{q} = \widehat{e}^{\frac{1}{2}}$ and $\widetilde{q} = \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$.

To have a complete solution to the problems there is one last step that needs to be solved. This step is to determine which is the lowest type of project that is convenient to develope in the lab.

By assumption the lowest type is such that there is free monitoring at the implied level of effort. That is to say $e(\underline{q}) = \underline{q}^{\frac{1}{1-a}} \leq \widehat{e}$ the lowest implementable type is low enough so that the effort recommendation will be at a level that is free to monitor. If this is the case, q_0^l is such that $\left(\frac{1-a}{a}\right) q^{\frac{1}{1-a}} = 0$. And this holds only if $q = 0$. Therefore in this case $q_0^l = \underline{q}$.

4.2 C.V.C. start up problem

Since the *c.v.c.* cannot monitor the effort level, the *i.o.* will choose e that maximizes his utility:

$$\max_{e} \; \gamma \frac{1}{a} q e^a + y - e - \gamma^2 \sigma_u^2$$

Thus $e = (\gamma q)^{\frac{1}{1-a}}$.[6]

Then the *c.v.c.* objective function is

$$\begin{aligned} & \max_{\{\gamma, y\}} E_v(v) + E_{u,q}\left[(1-\gamma)\frac{1}{a} q e^a + u - y\right] - I \\ = & \max_{\{\gamma, y\}} \int_{q_0^l}^{\overline{q}} \left[(1-\gamma)\frac{1}{a} q \left(\gamma q\right)^{\frac{a}{1-a}} - y(q)\right] p(q) dq - I \end{aligned}$$

Let $I^s(q, \gamma, y)$ be the utility of the idea owner in the start up case. $I^s(q, \gamma, y) = \frac{\gamma}{a} q \left(\gamma a q\right)^{\frac{a}{1-a}} + y - (\gamma a q)^{\frac{1}{1-a}} - \gamma^2 \sigma_u^2 = \left(\frac{1-a}{a}\right) (\gamma q)^{\frac{1}{1-a}} + y - \gamma^2 \sigma_u^2$.

Lemma 2 *A mechanism* $\{\gamma(q), y(q)\}$ *is implementable if and only if*

i) γ *is non decreasing in* q

[6] As in the case without adverse selection this effort level is below the efficient level of effort for all $\gamma < 1$.

ii) $y(q) = \frac{1}{a}\int_{q_0^s}^{q} \gamma^{\frac{1}{1-a}} x^{\frac{a}{1-a}} dx - \left(\frac{1-a}{a}\right)(\gamma q)^{\frac{1}{1-a}} + \gamma^2\sigma_u^2$

Since $I_q^s(q,\gamma,y) > 0$ is enough to check the participation constraint for the lowest type.

From the Lemma we can eliminate the transfers from the *c.v.c.* objective function

$$\int_{q_0^s}^{\overline{q}} \left[(1-\gamma)\frac{1}{a}\gamma^{\frac{a}{1-a}} q^{\frac{1}{1-a}} - \frac{1}{a}\int_{q_0^s}^{q} \gamma^{\frac{1}{1-a}} x^{\frac{a}{1-a}} dx + \left(\frac{1-a}{a}\right)(\gamma q)^{\frac{1}{1-a}} - \gamma^2\sigma_u^2\right] p(q)dq - I$$

after integrating by parts and doing some algebra, the *c.v.c.* problem can be rewritten as:

$$\max_{\gamma(q)} \frac{1}{a}\int_{q_0^s}^{\overline{q}} \left[(1-\gamma)\gamma^{\frac{a}{1-a}} q^{\frac{1}{1-a}} - \gamma^{\frac{1}{1-a}} q^{\frac{a}{1-a}} \frac{[1-P(q)]}{p(q)} + (1-a)(\gamma q)^{\frac{1}{1-a}} - a\gamma^2\sigma_u^2\right] p(q)dq - I$$

s.t.

$\gamma(q)$ non decreasing

Notably, for $a = \frac{1}{2}$ the problem becomes:

$$\max_{\gamma(q)} \quad 2\int_{q_0^s}^{\overline{q}} \left[(1-\gamma)\gamma q^2 - \gamma^2 q H(q)^{-1} + \frac{1}{2}(\gamma q)^2 - \frac{1}{2}\gamma^2\sigma_u^2\right] p(q)dq$$

Ignoring for the moment the monotonicity constraint and solving a relaxed problem we get from the first order conditions:

$$\gamma(q) = \frac{q^2}{q^2 + 2qH(q)^{-1} + \sigma_u^2}$$

It is easy to check that $\frac{\partial\gamma}{\partial q} > 0$, therefore the solution to the relaxed problem solves the *c.v.c.* problem.[7]

The total expected payoff to the *c.v.c.* is now

$$\begin{aligned}\Pi_{st.up}^{c.v.c.} &= \int_{q_0^s}^{\overline{q}} \gamma(q) q^2 p(q)dq - I \\ &= \int_{q_0^s}^{\overline{q}} \frac{q^4}{q^2 + 2qH(q)^{-1} + \sigma_u^2} p(q)dq - I\end{aligned}$$

[7] Without the assumption of $a = \frac{1}{2}$, γ is not necessary increasing in q therefore to get the solution some "ironing" needs to be done.

We still need to determine the lowest type of project that is convenient to develope in the start up.

Given the payoff function of the *c.v.c.* q_0^s is such that $\frac{q^4}{q^2+2qH(q)^{-1}+\sigma_u^2}=0$. And this true only if $q=0$. Therefore in this case $q_0^s=\underline{q}$.

4.3 Characterization

We have fully characterized *c.v.c.*'s principal agent problem under both ownership structures. If $a=\frac{1}{2}$,

$$\begin{aligned}\Pi_{lab}^{c.v.c.} &= \int_{q_0^l}^{\widehat{e}^{\frac{1}{2}}} q^2p(q)dq+\int_{\widehat{e}^{\frac{1}{2}}}^{\widehat{e}^{\frac{1}{2}}+m^{\frac{1}{2}}} \widehat{q}^2p(q)dq+\int_{\widehat{e}^{\frac{1}{2}}+m^{\frac{1}{2}}}^{\overline{q}} \left[q^2-m\right]p(q)dq-I \\ &\leq \int_{\underline{q}}^{\overline{q}} q^2p(q)dq-m\left[1-P(\widetilde{q})\right]-I\end{aligned}$$

$$\begin{aligned}\Pi_{st.up}^{c.v.c.} &= \int_{\underline{q}}^{\overline{q}} \gamma(q)q^2p(q)dq-I \\ &= \int_{\underline{q}}^{\overline{q}} \frac{q^4}{q^2+2qH(q)^{-1}+\sigma_u^2}p(q)dq-I\end{aligned}$$

therefore a sufficient condition for the start up to be preferred if is:

$$\int_{\underline{q}}^{\overline{q}}(1-\gamma)q^2p(q)dq\leq m\left[1-P(\widetilde{q})\right] \tag{1}$$

The natural next step is to do comparative statistic over risk and monitoring, to have an idea of what we should expect in industries with different risk or monitoring characteristics. From the point of view of the *c.v.c.* there are two types of risks associated with developing an idea. The realization of the shock u is unknown to both the *c.v.c.* and the *i.o.* The other source of risk is quality related. An increase in the risk associated with an idea has different effects according to the type considered.

A higher shock risk simply means higher σ_u^2. But we need to define more carefully what we mean by an increase in quality risk. Consider two ideas drawn form distributions P_A and

P_B with finite means, P_B is riskier than P_A if P_A second order stochastically dominates P_B. In particular it is convenient to work with exponential distributions. Suppose $P_A \sim \exp(\lambda_A)$ and $P_B \sim \exp(\lambda_B)$ then P_A second order stochastically dominates P_B if and only if $\lambda_B > \lambda_A$ i.e. the larger the parameter λ the riskier the project.[8]

Proposition (3) states the effects of quality and shock risk on the arrangement decision.

Proposition 3 *Assume* $q \sim \exp(\lambda)$ *(with* $\lambda \geq \frac{1}{\bar{q}}$*),*

i) The higher the quality-risk associated with the project, the more likely to be developed in a start up.

ii) The higher the shock-risk associated with the project the more likely to be developed in the lab.

As stated in the introduction, new ventures are extremely risky, therefore the proposition statement for the quality risk effect is in line with the empirical evidence. Interesting both types of risks have different effects over the arrangement and therefore some words on the intuition of this results are necessary. First, note that in the lab case, the *c.v.c.* provides complete insurance to the *i.o.* and the shock has no effect on the effort decision that attains the first best. The effort level in the start up case is bellow that the first best. In this last case an increase in the variance of the shock implies a decrease in the *i.o.* share which implies that the effort lever is farther away from the first best. Therefore, the increase in the shock risk has no effect in the lab case but increase the distortion in the effort decision in the start up. This reasoning follows also for the case of complete information.

The next step is to consider the effects of the monitoring technology. The results in proposition (4) is intuitively appealing. Basically, it says that industries where it is very easy to monitor, for instance due to the fact that have been around for a long time, will

[8] P_A second order stochastically dominates P_B if and only if $\int_0^q P_B(x)dx \geq \int_0^q P_A(x)dx$ for all q, with strict inequality for some q. Graphically it is clear that with exponential distributions this holds if $\lambda_B > \lambda_A$.

develope their projects in their own R&D laboratories while new industries are more likely to be developed as start ups.

Proposition 4 *The better the monitoring technologies, i.e.*

- *the lower* m
- *the higher* $\widehat{e}$

more projects are developed in the lab.

There are different ways to compare projects and be able to say that one is better than the other. In the following proposition we show that good projects are developed as a start up, and we do that under two different approximation to what is a good project.

Proposition 5 *Better projects are developed as a start up, worse projects are developed in the lab.*

i) the lower $\underline{q}$ *the more likely the project is developed in the lab*

ii) the higher $\overline{q}$ *and* $\underline{q}$ *the more likely the project is developed as a start up.*

Alternatively, consider one extreme case where $\overline{q}$ is small enough ($\overline{q} < \widehat{e}^{\frac{1}{2}}$) so that for now quality level in the support the monitoring cost will be paid, then the *c.v.c.* prefers to develop the project in her own lab. Given that $\gamma(q) \leq 1$ the start up effort level will be smaller than the first best and therefore direct comparison of the expected payoffs implies $\Pi_{lab}^{c.v.c.} > \Pi_{start.up}^{c.v.c.}$. Consider now the other extreme case when $\underline{q}$ is big enough (i.e. if the support is all contained in high quality values) then the *c.v.c.* prefers to finance a start up. Note that $\lim_{q \to \infty} \gamma(q) = 1$ therefore for "high quality support" the integral in the profit for the start up case will be arbitrarily close to the first integral in the lab case. Since it will be necessary to pay the monitoring cost in the lab case it follows that $\Pi_{start.up}^{c.v.c.} > \Pi_{lab}^{c.v.c.}$.

Our results on α, γ and γ, w can be summarized in the following corollary.

Table 3: Complete Infromation vs Incomplete Information: shares and effort levels

		Complete information	Incomplete information
Start up	$\gamma(q)$	$\frac{q^2}{q^2+\sigma_u^2}$	$\frac{q^2}{q^2+2qH(q)^{-1}+\sigma_u^2}$
	$e(q)$	$(\gamma q)^2 = \left(\frac{q^3}{q^2+\sigma_u^2}\right)^2$	$(\gamma q)^2 = \left(\frac{q^3}{q^2+2qH(q)^{-1}+\sigma_u^2}\right)^2$
Lab	$\alpha(q)$	0	0
	$e(q)$: for all $q < \widehat{q}$	q^2	q^2
	$e(q)$: $\widehat{q} \leq q < \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$	$\widehat{q}^2$	$\widehat{q}^2$
	$e(q)$: for all $q \geq \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$	q^2	q^2

Corollary 2 .

i) The share of profits of the i.o. is higher in the start up than in the lab case

ii) For $q \leq \widehat{q}$ and $q \geq \widetilde{q}$ the effort in the start up case is lower or equal to the lab case, where the first best is attained, but as quality tends to ∞ the start up effort gets arbitrarily closer to the first best.

5 Complete vs. Incomplete Information

What is the effect of introducing adverse selection into this model? The following table summarizes the results on section 3 and 4.

Proposition 6 *The introduction of adverse selection induces no change in share or the effort level in the lab case but decreases the i.o. share (γ) and the effort level in the start up. With adverse selection in the start up we are farther away from the first effort level.*

Under our parametric assumptions, from proposition (2) if there is complete information, the start up is preferred for intermediate quality projects, and the lab for the extreme good

Table 4: Complete Infromation vs Incomplete Information: corporation's profits

	Complete information	Incomplete information
$\Pi^{c.v.c.}_{st.up}$	$\gamma q^2 = \frac{q^4}{\sigma_u^2+q^2}$	$\int_{\underline{q}}^{\overline{q}} \gamma(q) q^2 p(q)dq - I = \int_{\underline{q}}^{\overline{q}} \frac{q^4}{q^2+2qH(q)^{-1}+\sigma_u^2} p(q)dq - I$
$\Pi^{c.v.c.}_{lab}$	$\begin{cases} \text{for all } q < \widehat{q} & q^2 - I \\ \widehat{q} \leq q < \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} & \widehat{q}^2 - I \\ \text{for all } q \geq \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} & q^2 - m - I \end{cases}$	$\int_{q_0^l}^{\widehat{q}} q^2 p(q)dq + \int_{\widehat{q}}^{\widetilde{q}} \widehat{q}^2 p(q)dq + \int_{\widetilde{q}}^{\overline{q}} \left[q^2 - m\right] p(q)dq - I$

and bad. If there is also incomplete information from proposition (5) the better projects are developed as a start up and the worse ones in the lab.

Finally note, that if q has a degenerate distribution, the incomplete information results are equal to the complete information as expected.

6 Discussion

6.1 Monitoring technology

Several authors report that venture capitalists may get closely involved in the management of the projects they finance. With this involvement, the venture capitalist is able to partially monitor the development of the project. However, it must be true that if the project is developed inside the firm, the monitoring is much closer. In this sense, our assumption of a monitoring technology for the lab case seems to be justified.

Similar results to ours can be obtained if we assume that under both arrangements there is a monitoring technology but that the technology in the lab case is more efficient.

We assume a particular simple form for the monitoring technology. Free monitoring below a certain level and a fix cost above it. If we made different assumption our results may be reversed. For instance if we assumed free monitoring for high levels and a fix cost for low levels of effort we would obtain that the good projects are the ones kept inside the firm and the bad projects the ones financed as a start up. But this kind of monitoring technology makes no sense.

To get results qualitatively similar to our, the only feature that is needed in the monitoring technology is that it should be easier to monitor low levels of effort than higher levels. For instance suppose that it is free to monitor up to a level and the cost above this level is increasing in the effort. This will yield the same kind of results as the ones developed in the previous sections.

6.2 Risk Aversion

What is the role played by our assumption of risk aversion? Since the corporate venture capitalist (*c.v.c.*) is risk neutral, he is providing risk insurance to the idea owner (*i.o.*). The more insurance the *c.v.c.* gives to the *i.o.* the lower the transfer. Therefore the corporation faces a trade off between giving risk insurance and inducing the right incentives to exercise effort. In the lab case, since he is able to fix the effort level he does not need to care to provide optimal effort incentives and therefore the *c.v.c.* takes all the risk (the *i.o.* share is zero) and pays the *i.o.* with a transfer. If the *c.v.c.* gives that last payoff structure in the start up case, the *i.o.* will not make any effort. Therefore, even though the *c.v.c.* is willing to give risk insurance to the *i.o.* he must place the right incentives and therefore the *i.o.* faces some risk in his income.

If the *c.v.c.* is also risk averse, but the *i.o.* risk aversion is higher the *c.v.c.* has still an incentive to give risk insurance to the *i.o.* and results qualitatively similar to the one developed in this paper can be obtained.

If both agents were assumed to be risk neutral the distribution of the shares over the profit in the lab case will be undetermined. Any combination of share-transfer that satisfies the participation constraint will be a solution. However, the effort level will not be affected. In the start up case the choice of the share will be affected. Since the *c.v.c.* has no benefit in providing risk insurance to the *i.o.* he will fix the share so that to provide the best possible incentives for the effort choice. Therefore, the *c.v.c.* will receive a share of zero and give a transfer to compensate the effort disutility. Therefore, under risk neutrality the effort level is the same in the lab and start up case and the payoff to the *c.v.c.* is the same in both cases for low effort levels but the start up case yields a higher payoff for high quality. This is because under risk neutrality there is a "free" way for the *c.v.c.* to induce the best level of effort, fixing $\gamma = 1$ and therefore will never be willing to pay the monitoring cost.

7 Conclusions

We developed a simple model that helps to understand the decision of a corporation on developing a project in their own lab or financing a new venture. This model is able to replicate some of the qualitative features of the real world.

Lower quality projects are mostly developed internally. The corporation's preferred arrangement for higher quality level depends on the degree asymmetric information. If there are non important adverse selection problems and the picture is closer to our complete information section, medium quality projects will be developed as a start up and the highest quality will be developed in the corporation's lab. If adverse selection is relevant then our incomplete information section predicts that better projects will be developed as a new start up company.

These seems to account for the bad results reported by Jensen (1993) of the internal R&D expenditures of General Motors, Ford, British Petroleum, Chevron, Du Pont, IBM, Unisys, United Technologies, and Xerox and the success of corporations like Phillip Morris, Wal-Mart, Bristol Myers, General Electric, Loews, Merck, Bellsourth, Bell Atlantic, Procter & Gamble, Ameritech and Southwestern bell.

If a corporation has some expertise in a particular area, this may help her to control effort. Therefore it may be easier for the *c.v.c.* to impose the right amount of effort in areas of where the *c.v.c.* has some knowledge. Thus the *c.v.c.* may prefer to develop projects in their area of expertise (what we called the main line of business) as is observed in reality.

Newer industries are industries where there is more uncertainty on the quality of an idea and likely it is more difficult (costly) to monitor. Even the agents currently involved in this area have not yet the ability to fully evaluate projects as industries that do exist over a long time do. In that sense the high tech sector -as opposed to more traditional sectors- can be thought of a sector where adverse selection problems are very important.

Finally, the last feature of the real world that the model is able to replicate is the fact that the compensation of an entrepreneur in a start up depends mostly on the success of the project while a scientist in a corporation's lab receives most of his compensation as a base salary.

A Appendix: Proofs

Proof of Proposition 1. For all $q < \widehat{q}$, since $R_{22} < 0$ and from the effort first order conditions, in both cases $e_{st.up} < e_{lab} = e^{*}$. Therefore $R(e_{st.up}) - e_{st.up} < R(e_{lab}) - e_{lab}$.

Recall

$$\begin{aligned} \Pi_{lab}^{c.v.c.} &= R(e_{lab}) - e_{lab} - I \\ \Pi_{st.up}^{c.v.c.} &= R\left(e_{st.up}\right) - e_{st.up} - \gamma^2 \sigma_u^2 - I \end{aligned}$$

Finally, from the fact that low levels of q the implied effort is such that there is no need for monitoring, $\Pi_{lab}^{c.v.c.} > \Pi_{st.up}^{c.v.c.}$ ■

Proof of Proposition 2. Consider first the range where $q < \widehat{q}$, by the same argument in the proof of proposition 1 it is clear that the lab is preferred over the start up.

Next consider q such that $\widehat{q} \leq q < \widetilde{q} = \widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}}$. the start up is preferred if

$$\frac{q^4}{\sigma_u^2 + q^2} \geq q^2$$

i.e. the start up is preferred if

$$q^4 - q^2\widehat{e} - \widehat{e}\sigma_u^2 \geq 0$$

Therefore for all q such that $q^2 < \frac{\widehat{e}+\sqrt{\widehat{e}(1+4\sigma_u^2)}}{2}$ the lab is preferred and for all q such that $q^2 \geq \frac{\widehat{e}+\sqrt{\widehat{e}(\widehat{e}+4\sigma_u^2)}}{2}$ the start up is preferred.

Finally consider all $q > \widetilde{q}$, the start up is preferred if

$$\frac{q^4}{\sigma_u^2 + q^2} \geq q^2 - m$$

$$q^2 \leq \frac{m\sigma_u^2}{\sigma_u^2 - m} \tag{2}$$

Figure 1: Quality Levels for which the Lab and Start up are Prefered

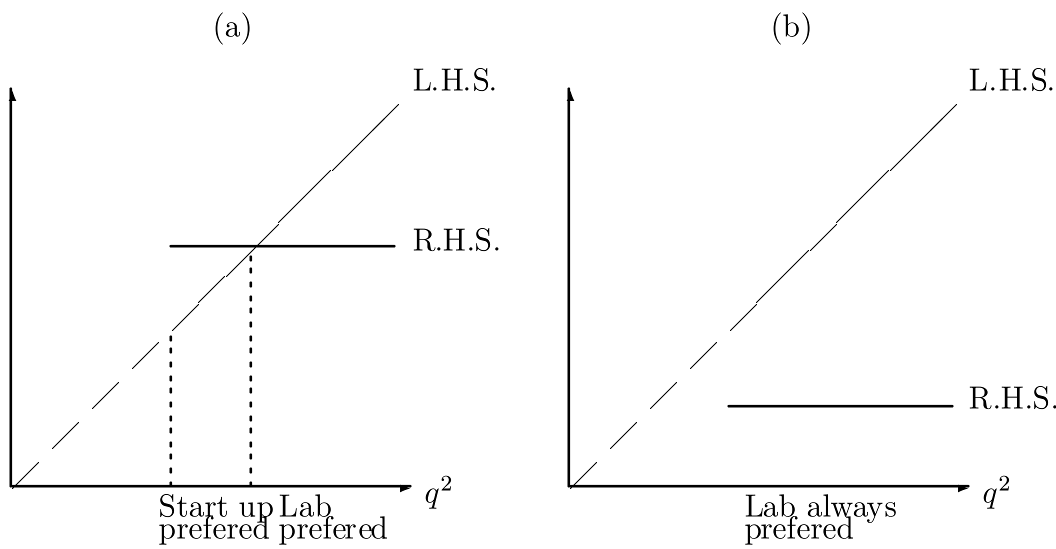

Figure (1) plots the left hand side (L.H.S onwards). and the right hand side (R.H.S onwards) of condition (2) under different parameter specifications. If $\widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} \geq \frac{m\sigma_u^2}{\sigma_u^2-m}$ (figure 1.b), the lab is preferred for all $q > \widetilde{q}$. If $\widehat{e}^{\frac{1}{2}} + m^{\frac{1}{2}} \leq \frac{m\sigma_u^2}{\sigma_u^2-m}$(figure 1.a), there are two different areas. For quality levels such that $q^2 \leq \frac{m\sigma_u^2}{\sigma_u^2 - m}$ the start up is preferred over the lab, and for quality levels such that $q^2 > \frac{m\sigma_u^2}{\sigma_u^2 - m}$ the lab is preferred. ∎

Proof of Lemma 1.

Recall that $I^l(q, \alpha, w, e) = \frac{\alpha}{a} q e^a + w - e - \alpha^2 \sigma^2_{(u+v)}$

Given quasi-linear preferences, using a result in Fudenberg and Tirole (1991) to prove part i) is enough to check the single crossing condition for each instrument.

$$I^l_\alpha(q, \alpha, w, e) = \frac{1}{a} q e^a - 2\alpha\sigma^2_{(u+v)} \geq \frac{1}{a} q e^a - 2\sigma^2_{(u+v)} \geq 0$$

The first inequality follows from $0 \leq \alpha(q) \leq 1$, and the second by assumption.

$$I^l_{\alpha q}(q, \alpha, w, e) = \frac{1}{a} e^a > 0$$

$$I^l_e(q, \alpha, w, e) = \alpha q e^{a-1} - 1 \leq q e^{a-1} - 1 \leq q \left(q^{\frac{1}{1-a}} \right)^{a-1} - 1 = 0$$

The first inequality follows again $0 \leq \alpha(q) \leq 1$ and the second one from the fact that the effort level will not be bigger than the best effort level $e \leq q^{\frac{1}{1-a}}$.

$$I^l_{eq}(q, \alpha, w, e) = \alpha e^{a-1} > 0$$

Differentiating with respect to q, $I^l_q(q, \alpha, w, e) = \frac{\alpha}{a} e^a$. Integrating back and using the boundary condition $I^l(q^l_0, \alpha, w, e) = 0$ we obtain $w(q)$ and part ii) follows. ∎

Proof of Lemma 2.

Recall that $I^s(q, \gamma, y) = \left(\frac{1-a}{a}\right) (\gamma q)^{\frac{1}{1-a}} + y - \gamma^2 \sigma_u^2$.

The proof is standard. Given,

$$\begin{aligned} I^s_\gamma(q, \gamma, y) &= \frac{1}{a} \gamma^{\frac{a}{1-a}-} q^{\frac{1}{1-a}} - 2\gamma\sigma_u^2 = \frac{1}{a} q e^a - 2\gamma\sigma_u^2 \geq \frac{1}{a} q e^a - 2\sigma_u^2 \geq 0 \\ I^s_{\gamma q}(q, \gamma, y) &= \frac{1}{a(1-a)} (\gamma q)^{\frac{a}{1-a}} > 0 \end{aligned}$$

To satisfy the single crossing conditions it must be that $\frac{d\gamma}{dq}(q) \geq 0$

By the Envelope Theorem $I_q^s(q,\gamma,y) = \frac{1}{a}\gamma^{\frac{1}{1-a}} q^{\frac{a}{1-a}}$. Integrating back and using the boundary condition $I^s(q_0^s,\gamma,y) = 0$ we obtain $y(q)$ and the second part follows. ■

Proof of Proposition 3.

i) From condition (1) and using the exponential distribution, the start up is preferred if:

$$\frac{\int_{\underline{q}}^{\overline{q}}(1-\gamma)q^2\lambda e^{-\lambda}dq}{e^{-\lambda\widehat{q}}} \leq m$$

The R.H.S. does not depend on the parameter λ. An increase in quality associated risk implies an increase in λ. After some tedious algebra it is possible to show that the L.H.S. is decreasing in λ. Therefore the higher quality-risk the projects are developed in a start up.

ii) Consider a project where the *c.v.c.* is indifferent between the lab and the start up. Therefore condition (1) is satisfied with equality. Since $\frac{\partial\gamma}{\partial\sigma_u^2} < 0$, an increase in the risk induces a larger L.H.S. of condition (1) while the R.H.S. is constant. Therefore the higher shock-risk projects are developed in the lab.

■

Proof of Proposition 4.

Consider a project where the *c.v.c.* is indifferent between the lab and the start up. Therefore condition (1) is satisfied with equality. Note that $\frac{\partial L.H.S.}{\partial\widehat{e}} = 0$ and $\frac{\partial R.H.S.}{\partial\widehat{e}} < 0$. If the project is indifferent it must be that $\Pi_{lab}^{c.v.c.} = \Pi_{st.up}^{c.v.c.}$. Note that $\frac{\partial\Pi_{st.up}^{c.v.c.}}{\partial m} = 0$ and $\frac{\partial\Pi_{lab}^{c.v.c.}}{\partial m} < 0$. This implies that if there is a decrease in m or an increase in $\widehat{e}$ the *c.v.c.* strictly prefers the lab over the start up. ■

Proof of Proposition 5.

i) Consider a project where the *c.v.c.* is indifferent between the lab and the start up. Therefore condition (1) is satisfied with equality. Now note that $\frac{\partial L.H.S.}{\partial\underline{q}} < 0$, $\frac{\partial R.H.S.}{\partial\underline{q}} = 0$ This implies that if there is a decrease in $\underline{q}$ the *c.v.c.*strictly prefers the lab over the start up.

ii) Suppose the increase in $\underline{q}$ is such that the monitoring cost need to be payed for all quality levels (i.e. $\widehat{q} = \underline{q}$) therefore the $R.H.S. = m$ and therefore $\frac{\partial R.H.S.}{\partial \underline{q}} = \frac{\partial R.H.S.}{\partial \overline{q}} = 0$. Given $\lim_{q \to \infty} \gamma(q) = 1$ if q increases enough $\gamma(q)$ can be made arbitrarily close to 1, so that the integrand is arbitrarily close to 0. If the whole support of the project moves to the right enough the start up is strictly preferred.

■

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