R&D Institutional Arrangements: Start-up Ventures vs. Internal Lab

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Abstract

Why do firms sometimes choose to undertake their R&D by financing start-up companies, while other times they do it in their internal labs? We present a model where the choice of R&D is driven by information asymmetries on the quality of the project between the corporate venture capitalist and the idea owner. In an incomplete information environment, higher quality projects are more likely to be developed by start-up firms, while low quality ones are exploited internally. Also, two types of risk are examined, intrinsic quality risk and external shock risk. Riskier project quality and more difficult project monitoring make a project more likely to be developed as a new venture. Finally, the model is able to show why corporate lab scientists get most of their compensation as a fixed salary, while idea owner-entrepreneurs working for start-up companies have a profit sharing agreement.

Keywords: asymmetric information, in-house development, start-up

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1 Introduction

Big corporations have supported the development of entrepreneurial companies long before the rise of the organized venture capital industry. For instance, some seventy years ago Du Pont provided funding for a young General Motors.

Venture capital has become 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. For example, in the United States, at its peak in the year 2000, venture capital investment by corporations added up to $17 billion, or approximately 16% of total venture capital invested. This was a dramatic increase from six years earlier, when corporate ventures were about 3% of total venture investments in 1994. In the years after the stock market slump of 2000, all of venture capital investments fell dramatically. Corporate venture investment was no exception to such decrease. However, in 2003, corporate venture capital still managed to invest $1.2 billion dollars, or 6% of total venture capital funds, still a significant share (about double from ten years earlier).

Why do prestigious companies (as those mentioned above) choose to fund new product development by venture capital instead of doing so in their own Research & Development Laboratories (like IBM, AT&T and Xerox have or have had at one time)? We want to offer in this paper a model that generates a prediction of when a corporate venture capitalist would want to fund a project internally or via a start-up.

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 (or sometimes called “entrepreneurs” in the literature) developing a new venture are mostly compensated with profit and ownership sharing. In contrast, idea owners starting their own firm have most of their rewards tied to their firms’ success. Gompers (1996) and Radtke and McKinney (1999) report that venture capitalists’ stake in start-ups before IPO varies from 5 to 30%, with the idea owner taking the rest.

- R&D projects in corporations are less profitable than the R&D carried out in start-ups. Jensen (1993, section VII) finds that R&D returns have a high variance across firms, but

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1 For an account of the history of corporate venture capital see Gompers and Lerner (1998) or Gompers and Lerner (1999, ch. 5).
3 See National Compensation Survey of R&D (1990). Merges (2000) emphasizes that for employees “hired to invent” it is understood that such employees have already been compensated through wages, and that the firm will retain title to any patentable invention the R&D staff develops.
on average in-house R&D 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 and General Electric, which implies that some in-house labs are able to develop highly profitable projects.

- It is widely accepted that start-up ventures are quite risky enterprises. Gompers (1995), using data from a random sample of 794 venture capital-backed firms between 1961 and 1992, reports that only 22.5% of them went public, 23.8% merged or were acquired, 15.6% were liquidated or went bankrupt and 38.1% remained private.\(^4\)

- Gompers and Lerner (1998) find that the venture capital industry in general, and corporate venture capital in particular, tend to focus on a few high tech industries. Corporate venture capitalists assign most of their funding to areas related to the corporation’s main line of business (which Gompers and Lerner call a “strategic focus”). As Gompers (1995, p. 1462) states: “[...] Venture capitalists concentrate investments in early stage companies and high technology industries where informational asymmetries are significant and monitoring is valuable.”

Our objective is to build a model that shows some of these stylized facts. We focus in particular on the case where a corporate venture capitalist (that is, a company which already produces an array of goods and/or services, also holds a venture fund) is faced with the possibility of developing an idea internally or externally. In particular, our model has two agents: a financially constrained idea owner and a corporation. [Note: We are assuming that the corporation is the only financier for this project. Thus, we are ruling out competitive bidding among different types of possible financiers. This is admittedly a very interesting issue (in the context of private information), but we leave it for further research.] The financial constraint of the entrepreneur may arise because the idea owner has neither sufficient reputation nor an ability to convey his financier about the quality of the idea. 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 would 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. In both cases the contract is linear: the payoff structure consists of a transfer and a share

\(^4\)According to Gompers, these results understate the proportion of liquidations. First, some of the acquisitions/mergers were distressed firms that provided very low returns to venture capitalists. Also, some of the firms classified as private may have been liquidated, since firms without debts do not need to file for bankruptcy. On the other hand, successful start-ups are associated with very high returns.
in the revenue. The model is based on four key assumptions: a) the entrepreneur (or idea owner) is risk-averse; b) the project involves moral hazard by the entrepreneur; c) for internal projects, the firm (or the corporate venture capitalist) has some monitoring capabilities; and d) the idea owner has private information about the quality of the project.

Although venture capitalists are often very involved in the monitoring of its ventures, the idea owner has no way to credibly convey the actual quality of the project to the corporate venture capitalist (see Ambec and Poitevin (2001) and Leland and Pyle (1977); for the case of outsourcing, see Lewis and Sappington (1991)). The corporate venture capitalist only knows the support set of the quality and its distribution. Recall also that venture capital start-ups are considered quite risky enterprises. We suggest two different types of risk: one is the realization of a random shock; this shock is external, unknown to the corporate venture capitalist and the idea owner, and may affect the payoffs of the project. A second type of risk we consider is what we call “quality risk”. Informally, this is risk in the quality itself. Formally, an idea is less risky than another if the quality distribution function of one, second order stochastically dominates the distribution of the other. We find that the two types of risk work in opposite directions: the higher the shock risk, the more likely it is that the project is developed in the lab; however, the higher the “quality risk”, and the higher the expected return (driven by a higher expected quality), the more likely it is the project is developed as a venture start-up.

There is, of course, a sizeable literature on related work, in particular on the decision to “make or buy”, franchising and spin-offs.\(^5\) Echoes of the “make or buy” decision can already be perceived in Coase’s famous 1937 paper, where he discusses the limits of a firm and which activities the firm should undertake. (Holmström and Roberts (1998) give a modern survey on the boundaries of a firm.) However, the literature on financing projects in the presence of asymmetric information is rather scarce.\(^6\) An early seminal paper is the signaling model of Leland and Pyle (1977). More recently, Qian and Xu (1998) develop an interesting model with “soft” and “hard” budget constraints. The authors show in a model with soft and hard budget constraints that less certain innovations will be produced by large corporations (with soft budget constraints) and highly uncertain innovations will be undertaken by small venture capital firms (with hard budget constraints). While they focus on the issue of cost (budget constraint) of the innovation, in our case the driving asymmetry is on the quality of it. Ambec and Poitevin (2001) also examine the case of a firm that considers financing a project internally or externally. Our model differs from theirs in the fact that in our case the corporate venture capitalist submits


\(^6\)For papers that deal with financing of projects under perfect and symmetric information, see Aghion and Tirole (1994) and Hellmann (1998).
the offer first, and the idea owner either accepts or rejects, while in their model, it is the idea
owner moving first. Finally, Wiggins (1995) presents a model where he concludes that large
firms cannot replicate entrepreneurial incentives internally, which in turn, is the explanation of
the existence of an entrepreneurial enterprise (a start-up). His model does not focus on the
financing of a project, though. In our case at hand, we have a firm that has to decide how to
finance a project whose quality is not perfectly known. In other words, Wiggins’ model is driven
by moral hazard considerations, while in our case it is the asymmetric information regarding the
quality.

The paper proceeds as follows. The next section presents the basic model. In section 3 the
two institutional arrangements are considered and discussed. Section 4 concludes the paper. To
facilitate exposure, all proofs are relegated to the appendix.

2 The Model

Agents

There are two agents: a financially constrained idea owner (denoted as i.o.) and a corporate
venture capitalist (abridged as c.v.c. or simply “capitalist”). The i.o. has a project in mind that
requires an up-front investment of \( I \) and yields revenue \( R(q, e) + u \). The variable \( e \) denotes the
effort level of the i.o., \( q \) is the quality of the idea and \( u \) is a shock with mean zero and variance
\( \sigma_u^2 \). There is a range of qualities \([q, q_f] \in \mathbb{R}^+\), with \( q \) the lowest quality possible for the project,
and \( q_f \) the highest possible quality achievable. The project revenue function \( R(q, e) \) is increasing
in quality \( q \) and effort \( e \) at a decreasing rate. In order to obtain crisp and tractable comparative
static results, we will use the form \( R(q, e) = 2q\sqrt{e} \). In addition, we make the standard assumption
that the c.v.c. has a main line of business (a “strategic focus” or “core competence”), whose
revenue \( \nu \) we normalize to have mean zero and variance \( \sigma_v^2 \). Below we are going to argue that
in the “lab case” the c.v.c. is not able to observe the actual value of the project; thus the joint
variance of \( u \) and \( \nu \) is denoted to be \( \sigma_{u+v}^2 \).\(^7\)

The i.o. is risk averse and dislikes effort. Epstein (1985) shows that decreasing absolute risk
aversion preferences can be represented in the mean-variance form.\(^8\) Thus, the i.o.’s preferences

\(^7\)For technical reasons that will be clear later on, we will require that \( R(q, e) \geq 2 \max \left\{ \sigma_{u+v}^2, \sigma_u^2 \right\} \).

\(^8\)This type of mean variance preference representation is widely used in the financial economics literature.
are represented by the following utility function:

\[ U^i(q, e) = \Pi^{i.o.} - be - \sigma^2, \]

where \( \Pi^{i.o.} \) is the expected profit of his venture, and \( \sigma^2 \) is the variance of this income and \( b \) is the (constant) marginal disutility of effort. The superscript \( i \) will stand for the case of the lab or the start-up, that is, \( i = l, s \), respectively. It is important to point out that, whenever the \( i.o. \) chooses his effort level, he does so after observing the quality of the project \( q \).

The corporate venture capitalist is assumed to be a risk neutral profit maximizer. His utility level corresponds to the profit level of his business, \( \Pi^{c.v.c.} \).

Ownership Structure

The ownership structure can take one of two basic forms. The corporate venture capitalist may contract the idea owner as a researcher in the c.v.c.’s own lab, or he may finance a start-up. Actually, the first structure will be equivalent to the c.v.c. buying the idea and developing it in its own lab, be it with the \( i.o. \) working as a scientist or using other scientists for the job. If the idea is developed inside the firm, the c.v.c. can impose the level of effort he wants.

In our model, if the firm hires the \( i.o. \) as a lab scientist, it is also including a new project (which the \( i.o. \) brings with him) into its activities. Incorporating the project into the firm’s production line-up allows the c.v.c. to set the level of effort he desires the \( i.o. \) to exercise. In order to do so, the c.v.c. has some administrative costs (for example, the firm may have an internal hierarchy and audit mechanism for any project undertaken). We will adopt a simple monitoring technology function: \( ke \), where \( e \) is the effort mentioned above and \( k \) is a constant (the marginal cost of monitoring). It is important to be clear on the following point. The c.v.c. has the possibility, but is not obliged, to set the effort level. If he finds it profitable to determine the effort level, the c.v.c. has to use the monitoring technology; alternatively, he will not incur in monitoring costs, but would have to provide incentives to the \( i.o. \) to exercise a positive level of effort.

In addition, when the c.v.c. develops the idea inside the firm (by hiring the \( i.o. \) and/or using his own scientific team), the c.v.c. is not able to observe the actual value of the project. In other words, the c.v.c. may notice an increase in the total value of his company, but this may be happening because of different reasons. The success may certainly be due to the particular quality of the new project or because the marketing and brand name of the company have made the project a success; or, some other division of the company got exceptional results that overflow to the whole company. Therefore, we postulate, that in the lab case, the c.v.c. observes
\( R(q, e) + u + v \), which is the total revenue stemming from his core business plus the revenue generated by the new project.\(^9\)

If the c.v.c. finances a start-up, then he is not able to control effort (because the start-up company is out of reach of the c.v.c.’s auditing mechanism), but he receives a clear signal from the market on the value of the project. He observes both \( v \) and \( R(q, e) + u \) separately.

**Compensation**

The compensation of the idea owner takes different forms depending on whether the i.o. works in a corporate lab or a start-up firm. As mentioned in the introduction, lab scientists get most of their compensation as a salary. Therefore, to be true to this fact, \( w \) denotes the wage paid by the c.v.c. to the idea owner. Furthermore, to allow for some part of the compensation to be a profit-sharing agreement, call \( \alpha \) the idea owner’s share of the revenue of the business (hence, the c.v.c. keeps \( 1 - \alpha \)).

If the c.v.c. decides to finance a start-up, the agreement with the i.o. takes the form of a transfer \( y \) (funds to initiate operations) and a share of the revenue kept by the i.o. of \( \gamma \).

Since the c.v.c. is risk neutral and the i.o. is risk averse, the socially optimal solution is that the first give full insurance to the latter (as we shall see in the lab case). In the case of a start-up this is not possible, because the c.v.c. has to give the idea owner incentives to apply effort. This is done by giving the i.o. the share \( \gamma \), so that the risk is shared.

**Game sequence**

In summary, the game sequence is as follows: first, nature chooses the quality of the project, which is only observed by the idea owner. Second, the c.v.c. makes a start-up or internal lab offer. Third, the i.o. exercises effort according to the lab contract or to his will. Fourth, nature draws \( u \) and \( v \). In the start-up case the c.v.c. observes \( R(q, e) + u \) separately from \( v \), in the lab case the c.v.c. observes \( R(q, e) + u + v \) and payoffs are made according to \((\gamma, y)\) for the start up or \((\alpha, w)\) for the internal lab case.

### 3 Institutional Arrangements

The idea owner knows the quality of the project, but the corporate venture capitalist does not. The capitalist only knows that the quality level \( q \) has support on the interval \([\underline{q}, \overline{q}]\) where \( \underline{q} \)

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\(^9\)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—from \( u \) when the new project is developed in the lab.
is the lowest level of quality allowed. On this support, quality $q$ has a probability distribution function $p(q)$ and cumulative distribution function $P(q)$. As is common in the literature, we define $H(q) = \frac{p(q)}{1-P(q)}$ to be the hazard function, which is non-decreasing in $q$.

### 3.1 The Start-up Problem

We begin by examining the start-up arrangement. As mentioned in the description of the model, in this case, the idea owner gets a share $\gamma$ of the profits of the projects and an amount $y$ to start operations. Since in this case the idea owner is not part of the internal hierarchy of the firm, the c.v.c. cannot monitor the effort level. In consequence, the i.o. will choose independently his effort $e$ to maximize his own payoff:

$$\max_e 2\gamma q\sqrt{e} + y - be - \gamma^2 \sigma_u^2$$

Thus $e(q, \gamma) = \frac{\gamma^2}{b} q^2$. This defines an effort rule; note that $\frac{\partial e}{\partial \gamma} > 0$, so that effort level rises the more the i.o. shares in the revenue.

The c.v.c.’s objective function becomes:

$$\max_{\{\gamma, y\}} E_v(v) + E_{w,q} \{ (1 - \gamma) [R(q,e) + u] - y(q) \} - I$$

$$= \max_{\{\gamma, y\}} \int_q [2(1 - \gamma)q\sqrt{e} - y(q)] p(q) dq - I.$$

Notice that in this case, as mentioned in the previous section, we separate the “core business” of the capitalist (which we summarize in the variable $v$) from the expected profit of the start up that he finances. Let $U^*(q, \gamma, y)$ be the utility of the idea owner in the start-up case, where $U^*(q, \gamma, y) = \frac{\gamma^2}{b} q^2 + y - \gamma^2 \sigma_u^2$. The objective function is maximized subject to the following constraints regarding the idea owner:

$$U^*(q, \gamma, y) \geq 0$$

$$U^*(q, \gamma(q), y(q)) \geq U^*(x, \alpha(x), y(x)) \quad \forall x \in [q, \bar{q}]$$

The first expression is the participation constraint of the i.o. We normalize his reservation utility to zero; thus, the contract the capitalist offers has to meet at least that level of reservation.
utility. The second constraint is the incentive compatibility constraint for the idea owner to be truthful about the quality of the project.

To solve the c.v.c.'s problem, we make use of the following lemma:

**Lemma 1** Two sufficient conditions for the idea owner to tell the truth are:

i) that the idea owner's share in profits $\gamma$ is non-decreasing in $q$; and,

ii) that the transfer $y$ that the idea owner gets from the capitalist has the form:

$$y(q) = \int_0^q \frac{\gamma^2}{b} x dx - \frac{\gamma^2}{b} q^2 + \gamma^2 \sigma_u^2$$

Since $\frac{\partial U_s}{\partial q} > 0$, it is enough to check the participation constraint for the lowest type.

Following standard procedure in the literature (see, for example, Salanié (2004)), we check if the solution of the c.v.c.'s unconstrained problem satisfies the condition of the previous lemma.

From Lemma 1 the transfers can be eliminated from the c.v.c. objective function:

$$\int_q^\gamma \left[ 2(1 - \gamma) \frac{\gamma^2}{b} q^2 - 2 \frac{\gamma^2}{b} q^2 \int_q^\gamma \gamma^2 x dx + \frac{\gamma^2}{b} q^2 - \gamma^2 \sigma_u^2\right] p(q) dq - I.$$

After integrating by parts and some algebra\(^{10}\), the c.v.c. problem can be rewritten as:

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

s.t.

$$\gamma(q) \text{ non decreasing.}$$

Ignoring for the moment the monotonicity constraint and solving the unconstrained problem, we obtain, from the first order conditions, the following expression for the share the idea owner gets from the profits (as a function of quality $q$):

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

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.

\(^{10}\)This is standard procedure in the asymmetric information literature with a continuum of types.
The total expected payoff to the c.v.c. is now:

\[ \Pi_{c.v.c.}^{st.up} = \int_{q}^{\bar{q}} \frac{1}{b} \gamma(q) q^2 p(q) dq - I \]

### 3.2 The Lab Problem

#### 3.2.1 Lab with monitoring technology

The c.v.c. may choose to develop the idea inside the firm. If so, the compensation will be a wage \( w \) and a share \( \alpha \) of the revenue of the whole business. We start assuming that the c.v.c. chooses to control the effort level by incurring a monitoring cost \( ke \), if he wants to impose an effort level \( e \). The corporate venture capitalist offers a contract such that the idea owner tells the truth on the quality of the idea, and applies the correct effort \( e \). To maximize his profits, the c.v.c. chooses the optimal share \( \alpha \), the wage \( w \) and effort level \( e \). Formally, we write the capitalist’s problem as:

\[
\max_{\{\alpha, w, e\}} E_{u, v, q} \left\{ (1 - \alpha) \left[ R(q, e) + u + v \right] - w - ke \right\} - I
\]

\[
= \max_{\{\alpha, w, e\}} \int_{q}^{\bar{q}} \left[ 2(1 - \alpha) q \sqrt{e} - w - ke \right] p(q) dq - I.
\]

Note that \((1 - \alpha)\) is the share the capitalist keeps of the whole revenue \(2q \sqrt{e} + u + v\), after paying the wage \( w \), the monitoring cost \( ke \) and the fixed cost of the investment \( I \). The objective function is maximized subject to participation and incentive constraints of the idea owner:

\[
U^l(q, \alpha(q), w(q), e(q)) \geq U^l(x, x, w(x), e(x)) \quad \forall x \in [q, \bar{q}]
\]

As in the start up case, we need the following lemma to solve the c.v.c.’s problem:

**Lemma 2** Two sufficient conditions for the idea owner to tell the truth are:

i) the idea owner’s share \( \alpha \) and effort \( e \) be non-decreasing in quality \( q \); and,

ii) that the wage \( w \) be a function of the quality \( q \), with the form:
\[ w(q) = \int_q^\pi 2\alpha \sqrt{e}dx - 2\alpha q \sqrt{e} + be + \alpha^2 \sigma^2_{(u+v)} \]

Since the payoff of the idea owner is increasing in quality \( q \left( \frac{\partial U}{\partial q} > 0 \right) \), it is enough to check the participation constraint for the lowest type.

Replacing the wage in the capitalist’s objective function we obtain:

\[
\int_q^\pi \left[ 2(1 - \alpha) q \sqrt{e} - \int_q^\pi \alpha \sqrt{e}dx + \alpha q \sqrt{e} - be - \alpha^2 \sigma^2_{(u+v)} - ke \right] p(q) dq - I
\]

After integrating by parts, and eliminating the integral inside the last expression\(^{11}\), the relaxed problem can be written as:

\[
\max_{\{\alpha, e\}} \int_q^\pi \left[ 2q \sqrt{e} - 2\alpha \sqrt{e} \frac{[1 - P(q)]}{p(q)} - be - \alpha^2 \sigma^2_{(u+v)} - ke \right] p(q) dq - I
\]

Notice that the objective function is strictly decreasing in \( \alpha \). At any solution to this problem, it must be that \( \alpha(q) = 0 \) for all \( q \). Therefore, the i.o. will not share in the profits of the c.v.c.\(^{12}\)

With the above calculations, the unconstrained problem of the corporate venture capitalist becomes:

\[
\max_{\{e(q)\}} \int_q^\pi \left[ 2q \sqrt{e} - be - ke \right] p(q) dq - I
\]

The optimal effort level as a function of quality \( q \) is given by the following expression:

\[
e(q) = \frac{1}{(b + k)^2} q^2
\]

It is straightforward to notice that effort \( e \) is increasing in quality. Since both \( \alpha \) and \( e \) are (at least) non-decreasing in \( q \), the solution to the relaxed problem is the solution to the problem of the c.v.c. This yields the following wage schedule (contingent on \( q \)):

\[
w(q) = e(q),
\]

\(^{11}\)The procedure is very similar as in the case of the start-up case.

\(^{12}\)This is not far from what happens in practice, as mentioned in the introduction.
and the total expected profit of the venture capitalist is:

$$\Pi_{\text{c.v.c. lab}} = \int_q^T \frac{1}{(b + k)} q^2 p(q) dq - I$$

### 3.2.2 Lab without controlling effort

Alternatively, the c.v.c. may choose to develop the idea inside the firm, but does not make use of the monitoring technology available. He allows the i.o. to set the effort level he desires as in the start-up case. The compensation is still a wage $w$ and a share $\alpha$ of the revenue of the whole business. Given moral hazard on the part of the i.o., the c.v.c. has to provide incentives to the i.o. to exercise positive effort. This problem is equivalent to the problem of the start-up, the only difference being that it is not possible to separate $u$ from $v$.

Thus, by symmetry with the start up problem, the i.o.’s effort level will be $e(q, \alpha) = \frac{\alpha^2}{b} q^2$ with

$$\alpha(q) = \frac{q^2}{q^2 + 2qH(q)^{-1} + b\sigma_{u+v}^2}$$

and

$$w(q) = \int_q^q \frac{2 \alpha^2}{b} xdx - \frac{\alpha^2}{b} q^2 + \alpha^2 \sigma_{u+v}^2$$

This implies that the c.v.c. profit level in the lab case with an start up like contract would be:

$$\Pi_{\text{lab - start up}}^{\text{c.v.c.}} = \int_q^T \frac{1}{b} \alpha(q) q^2 p(q) dq - I$$

### 3.3 Characterization

The c.v.c.’s objective has been characterized under both ownership arrangements. In case of in-house development and effort monitoring, the profits for the corporation are:

$$\Pi_{\text{lab}}^{\text{c.v.c.}} = \int_q^T \frac{1}{(b + k)} q^2 p(q) dq - I$$

Second, in the case of in-house development, but with a “start up like” contract, the corporation profits are:
Finally, in the case of financing a start-up venture, the profits are:

\[ \Pi_{c.v.c.}^{st.up} = \int_{q}^{q_1} \frac{1}{b} \gamma(q) q^2 p(q) dq - I. \]

### 3.3.1 Start-up contract inside the lab

**Proposition 1** When the shock affecting the main line of business of the c.v.c. is positively (negatively) correlated with the shock of the new project, the c.v.c. does not (does) find it profitable to reproduce a start-up - type of arrangement internally.

In the introduction of the paper we stressed that endeavors from corporate venture capitalists tend to be focused on a few high tech industries, and that c.v.c.s assign most of their funding to areas related to the corporation’s main line of business. This means that \( u \) and \( v \) are positively correlated, so that \( \sigma_{u+v}^2 > \sigma_u^2 \) and, thus, in general, a start up like contract will not be implemented in the internal lab.\(^{13}\)

### 3.3.2 In-house production or start-up

Following the argument at the end of the last subsection, the rest of the paper assumes that in the internal lab the c.v.c. makes use of the monitoring technology and sets the effort level.

For the start-up to be preferred we must have:

\[ \int_{q}^{q_1} \frac{1}{(b + k)} q^2 p(q) dq \leq \int_{q}^{q_1} \frac{1}{b} \gamma(q) q^2 p(q) dq, \quad (1) \]

or

\[ \int_{q}^{q_1} \left[ \frac{1}{(b + k)} - \frac{\gamma}{b} \right] q^2 p(q) dq \leq 0. \quad (2) \]

\(^{13}\)We thank a referee for pointing out the importance of differentiating a pure lab case from a lab with a start up like contract.
A sufficient condition for this to hold is $\gamma(q) \geq \frac{b}{k}$. In other words, this condition sets a minimum amount of shares that the corporate venture capitalist has to yield to the entrepreneur, so that the start-up is preferred.

### 3.3.3 Better projects

There are different ways to compare projects and say that one is “better” than the other. In the following proposition it is shown that a good project is developed as a start-up, and this is done under two different definitions of what a “good” project is.

**Proposition 2** Better projects are developed as a start-up, worse projects are developed in the lab. This happens when:

i) the lower $q$, so that the more likely it is that the project is developed in the lab.

ii) the higher both $\bar{q}$ and $q$, so that the more likely it is that the project is developed as a start-up.

Consider one extreme case where the highest quality level of $q$ is small enough. Then, the c.v.c. prefers to develop the project in his 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 $\Pi_{lab}^{c.v.c.} > \Pi_{st.up}^{c.v.c.}$. Consider now the other extreme case: when $q$ is big enough (i.e. if the support is all contained in a “high quality” range), then the c.v.c. prefers to finance a start-up. Note that $\lim_{q \to \infty} \gamma(q) = 1$; therefore, in the “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 $\Pi_{st.up}^{c.v.c.} > \Pi_{lab}^{c.v.c.}$.

Next, we look at changes in risk and monitoring, to have an idea of what to expect in industries with different risk or monitoring characteristics.

### 3.3.4 Risk

We start by looking at the riskiness of the venture. From the point of view of the c.v.c., there are two types of risks associated with developing an idea. One type of risk is the realization of the shock $u$, which is unknown to both the c.v.c. and the i.o. Another source of risk is intrinsic to the quality or “quality risk”. An increase in either type of risk associated with an idea has different effects according to the type considered.
A higher shock risk simply means higher $\sigma^2_u$. In this case, the realization of the random external shock is unknown to both the corporate venture capitalist and the idea owner. A good quality idea may end up as a failure, if the realization of the shock is bad enough.

However, we need to define more carefully what is meant by an increase in “quality risk”. Consider two ideas drawn from distributions $P_A$ and $P_B$ with finite means. $P_B$ is riskier than $P_A$ if $P_A$ second order stochastically dominates $P_B$. Specifically, $P_A$ 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 $q$. To see how we can work with this concept, it is convenient to use 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 $\lambda$, the riskier the project.14

**REMARK.** Before we show our next proposition, we would like to point out the following. Note that in the exponential distribution, as $\lambda$ changes, this also changes the mean of the distribution (and not only the variance). For our purposes, this is not a problem, because we want to examine stochastic dominance per se, not a mean-preserving spread. In other words, a mean-preserving spread is equivalent to second order stochastic dominance of one distribution over another if the means are the same, but in our case we do not necessarily need equal means.

The next proposition states the effects of quality and shock risk on the arrangement decision.

**Proposition 3** Assume $q \sim \exp(\lambda)$ and suppose that $\lambda > \frac{1}{q}$. Then:

i) The higher the quality risk, and the higher the expected return (driven by a higher expected quality), the more likely it is to develop the project in a start-up.

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

Interestingly both types of risks have different effects over the arrangement. With more risk, risk-sharing arrangements have more value. Thus the firm can relax the idea owner’s participation constraint in the internal lab and so extract more profit. As described in the introduction, new ventures are extremely risky, but usually associated with very high returns; therefore, the statement for the quality risk effect is in line with the empirical evidence. 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 below the first best. Therefore, 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 level is farther away from the first best.

---

14Graphically, it is clear that with exponential distributions this holds if $\lambda_B > \lambda_A$. 15
Therefore, the increase in the shock risk has no effect in the lab case but increases the distortion in the effort decision in the start-up.

An increase in the shock risk increases the a priori uncertainty of both the \textit{i.o.} and the \textit{c.v.c.} about the project. On the other hand, an increase in the quality risk does not affect the \textit{i.o.} uncertainty, since he perfectly observes the quality of the project. In that sense industries where there is a high quality risk are industries where there are larger adverse selection problems.

### 3.3.5 Monitoring and effort

We now consider the effects of the costs of the monitoring technology and costs of effort. The results in the next claim are intuitively appealing. Basically, they assert that in industries where monitoring costs are low (for instance, due to the fact that they have been around for a long time) their projects will be developed in their own R&D laboratories, while in newer industries those are more likely to be developed as start-ups. The converse hold true for the costs of effort.

**Proposition 4** \textit{The better the monitoring technology, or the higher the marginal disutility of effort, i.e.,}

- \textit{the lower} $k$, or,
- \textit{the higher} $b$, then:

  more projects are developed in the lab.

### 4 Conclusion

We develop a model that helps us understand the decision of a corporation to develop a project in their own lab or to finance a new venture. This model is able to replicate some of the qualitative features of the real world.

If our model is correct that lower quality projects are developed in-house, it may explain why Jensen (1993) finds the internal R&D expenditures are on average less succesful than the venture capital industry.

Having expertise in a particular area may help a corporation to monitor effort. Therefore, it may be easier for the \textit{c.v.c.} to impose the right amount of effort in areas where the \textit{c.v.c.} has some knowledge. Thus, the \textit{c.v.c.} may prefer to develop projects in their area of expertise (what we called the main line of business or “strategic focus” or also “core competence”) as is consistent with business practice.
Newer industries are the ones where there is more uncertainty about the quality of an idea and it is probably more difficult (costly) to monitor effort. Agents involved in new industries do not yet have the ability to fully evaluate projects like established industries 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 (as Gompers (1995) points out).

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.

Our model can be extended in several ways. One possible extension is to include several possible corporate investors, who compete for the idea owner’s project. Each c.v.c. could offer possible contracts to develop the project in-house or as a start-up company. Competition for funding may not only come from other corporations; banks are another obvious option for funds, if the idea owner wants to set up his own firm. Another possible extension relates to the question on how the lab contract may evolve once the idea owner joins the firm to develop the project in-house. Over time the scientist may shirk, and blame failure to develop new ideas on “bad luck” or “nature”. Lastly, over time, the corporation may want to prevent the scientist to leave the firm to work for a competitor (Pakes and Nitzan (1983)).

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References


15See Bergemann and Hege (1997) for a model along related lines.


Proof of Lemma 1. The utility of the idea owner in the case of the start-up is $U^s(q, \gamma, y) = \frac{\gamma^2}{b} q^2 + y - \gamma^2 \sigma_u^2$. Given quasi-linear preferences, using Theorem 7.1 in Fudenberg and Tirole.
(1991, p. 258), to prove part i) it is enough to check the single crossing condition for each instrument, which in case of this Lemma is the idea owner’s share in the start-up $\gamma$. To check the single crossing condition we need to differentiate $U^s$ with respect to the instrument, and that derivative with respect to the private information variable $q$. In other words, we compute:

$$\frac{\partial U^s}{\partial \gamma} = 2\frac{\gamma}{b}q^2 - 2\gamma \sigma_u^2 \geq 2\frac{\gamma}{b}q^2 - 2\sigma_u^2 = 2q\sqrt{e} - 2\sigma_u^2 \geq 0$$

The last inequality follows by the assumption in footnote 7 (that is, for technical reasons we require $R(q, e) \geq 2 \max \{\sigma_{(u+v)}^2, \sigma_u^2\}$). Then:

$$\frac{\partial U^s}{\partial \gamma q} = 4\frac{\gamma}{b}q > 0$$

To satisfy the single crossing condition, it must be that $\frac{d\gamma}{dq} \geq 0$.

By the Envelope Theorem, $\frac{\partial U^s}{\partial q} = 2\gamma q$. Integrating back and using the boundary condition $U^s(q, \gamma, y) = 0$ we obtain $y(q)$ and part ii) of Lemma 1 follows.

**Proof of Lemma 2.** The utility of the idea owner in the case of the lab is: $U^l(q, \alpha, w, e) = 2\alpha q\sqrt{e} + w - b\alpha - \alpha^2 \sigma_{(u+v)}^2$.

Given quasi-linear preferences, as in Lemma 1, we appeal again to Fudenberg and Tirole (1991). To prove part i) it is enough to check the single crossing condition for each instrument, share $\alpha$ and effort level $e$. That is:

$$\frac{\partial U^l}{\partial \alpha} = 2q\sqrt{e} - 2\alpha \sigma_{(u+v)}^2 \geq 2q\sqrt{e} - 2\sigma_{(u+v)}^2 \geq 0$$

The first inequality follows from $0 \leq \alpha(q) \leq 1$, and the second by assumption stated in footnote 7. Then:

$$\frac{\partial U^l}{\partial \alpha q} = 2\sqrt{e} > 0$$

Thus, the first single crossing condition holds. Now we check for the second instrument:

$$\frac{\partial U^l}{\partial e} = \alpha q - b$$

Then:

$$\frac{\partial U^l}{\partial e q} = \alpha \frac{1}{\sqrt{e}} > 0$$
Hence, the second single crossing condition holds, and part i) of the lemma is proven.

To show part ii) of the lemma, we differentiate \( U^l(q, \alpha, w, e) \) with respect to \( q \),
\[
\frac{\partial U^l}{\partial q} = 2\alpha \sqrt{e}.
\]

Then, we integrate back:
\[
U^l(q) = \int_q^q 2\alpha \sqrt{e} dx
\]
and we use this expression in lieu of \( U^l \):
\[
\int_q^q 2\alpha \sqrt{e} dx = 2\alpha q \sqrt{e} + w(q) - be - \alpha^2 \sigma^2_{u+v}.
\]

Using the boundary condition \( U^l(q, \alpha, w, e) = 0 \) we solve for \( w(q) \) and part ii) of the lemma follows.

Proof of Proposition 1. Note that the profits in the start-up case and in the lab with a start up like contract are increasing in the i.o. share of the total profits. Thus, the c.v.c. does not find it profitable to reproduce a start-up type of arrangement internally when:
\[
\frac{q^2}{q^2 + 2qH(q)^{-1} + b\sigma^2_{u+v}} < \frac{q^2}{q^2 + 2qH(q)^{-1} + b\sigma^2_{u}}
\]

If \( u \) and \( v \) are positively correlated, then \( \sigma^2_{u+v} > \sigma^2_{u} \) and the c.v.c. strictly prefers to open a real start up. On the contrary, if \( u \) and \( v \) are negatively correlated, \( \sigma^2_{u+v} < \sigma^2_{u} \), then the c.v.c. prefers to reproduce a start-up type of arrangements internally.

Proof of Proposition 2.

i) Recall that the condition for the start-up to be preferred is:
\[
\int_q^q \frac{1}{b+k} q^2 p(q) dq \leq \int_q^q \frac{1}{b} \gamma(q) q^2 p(q) dq
\]
We can re-write this condition as:
\[
G(q) = \frac{\int_q^q q^2 p(q) dq}{\int_q^q \gamma(q) q^2 p(q) dq} \leq \frac{b + k}{b}
\]
When the lower boundary of the quality range, \( q \), increases, the lefthand side of the equality is negative, but the right hand side is not affected; in other words, \( \frac{\partial L.H.S.}{\partial q} < 0 \), \( \frac{\partial R.H.S.}{\partial q} = 0 \). We can calculate:

\[
\frac{\partial L.H.S.}{\partial q} = \frac{\partial G}{\partial q} = \frac{[\text{Numerator}] \gamma(q)q^2 p(q) - [\text{Denominator}]q^2 p(q)}{[\text{Denominator}]^2} = \frac{q^2 p(q) [[\text{Numerator}] \gamma(q) - [\text{Denominator}]]}{[\text{Denominator}]^2}
\]

The expression in brackets in the last fraction is negative. Thus, \( \frac{\partial L.H.S.}{\partial q} < 0 \). Or, to the contrary, if there is a decrease in \( q \), the c.v.c. strictly prefers the lab over the start-up.

ii) Take again the condition for the start-up to be preferred. If \( q \) and \( \pi \) increase, and given that \( \lim_{q \to \infty} \gamma(q) = 1 \), if \( q \) increases enough, \( \gamma(q) \) can be made arbitrarily close to 1, there is a level of quality \( q \) where the start-up is strictly preferred over the in-house development. In other words, if the whole support of the project moves sufficiently to the right, the start-up is strictly preferred.

Proof of Proposition 3.

i) Consider again the condition for the start-up to be preferred:

\[
\int_2^\pi \frac{1}{(b + k)} q^2 p(q) dq \leq \int_2^\pi \frac{1}{b} \gamma(q)q^2 p(q) dq
\]

This we can re-write as

\[
\int_2^\pi \left[ \frac{1}{(b + k)} - \frac{\gamma}{b} \right] q^2 p(q) dq \leq 0
\]

Using the exponential distribution, we can write this as:

\[
\int_2^\pi \left[ \frac{1}{(b + k)} - \frac{\gamma}{b} \right] q^2 e^{-\lambda q} dq \leq 0
\]

The right hand side does not depend on the parameter \( \lambda \). An increase in quality associated
risk implies an increase in $\lambda$. We calculate the following expression:

$$
\frac{\partial LHS}{\partial \lambda} = \int q \left[ -\frac{1}{b} \frac{\partial \gamma}{\partial \lambda} q^2 e^{-\lambda q} + \left[ \frac{1}{(b+k)} - \frac{\gamma}{b} \right] q^2 e^{-\lambda q} - \left[ \frac{1}{(b+k)} - \frac{\gamma}{b} \right] q^3 e^{-\lambda q} \right] dq = 
$$

The first term in the integral in the last expression is negative (straightforward calculation shows that $\frac{\partial \gamma}{\partial \lambda} > 0$). The second term is also negative, under the condition for the proposition. Thus, the left hand side of the inequality is decreasing in $\lambda$. 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 i.e. $\Pi_{lab}^{c.v.c.} = \Pi_{st.up}^{c.v.c.}$. Since all the effects of the shock risk are through the share, and $\frac{\partial \gamma}{\partial \sigma} < 0$, an increase in the risk reduces $\Pi_{st.up}^{c.v.c.}$ while $\Pi_{lab}^{c.v.c.}$ remains constant. Therefore, the higher shock-risk projects are developed in the lab.

**Proof of Proposition 4.**

Consider the condition for $\gamma$ for which the start-up is preferred to the in-house development:

$$
\gamma(q) \geq \frac{b}{b+k}
$$

It is easy to see that if $k$ increases (monitoring costs increase), the condition is easier to fulfill. Or, if $k$ decreases, it becomes harder to fulfill.

On the other hand, if the effort costs $b$ increase, the right hand side of the condition increases. Thus, it becomes harder to fulfill the condition for the start-up to be preferred.