A Resource-based Theory of Corporate Venture Capital[*]

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Abstract

Corporate investors (CIs) differ from venture capitalists (VCs) in a basic aspect: as incumbent producers in an industry, corporations possess unique resources that VCs lack. For young, startup firms seeking financing, this offers a double-edged sword: access to the corporation's unique resources vis-à-vis the risk of expropriation by the corporation. This paper studies this dilemma encountered by startup firms. Unlike the existing literature, we do not model any differences in the investment objectives of CIs and VCs. Instead, we focus on how the financier's unique resources influence the startup inventor's and the financier's incentives to specialize their resources, on the one hand, and to expropriate each other's resources, on the other hand. We show that while increased complementarity increases the likelihood of CI financing when the resources are difficult to expropriate, this result is *reversed* when the resources are easy to expropriate. We also predict that CI financing predominates when (i) intellectual property (IP) protection is stronger; (ii) product market competition is lower; and (iii) when the resources are difficult to expropriate. Further, the effects of IP protection and product market competition are disproportionately greater when resources are easy to expropriate.

Keywords: Complementary Assets, Corporate Venture Capital, Financing Choices, Resources, Startup Financing, Strategic Investing, Venture Capital

JEL Classifications: G24, G32, L22

1   Introduction

Innovative ideas are financed by venture capitalists as well as by corporate investors. However, corporate investors (CIs) differ from venture capitalists (VCs) in one basic aspect. As incumbent producers in an industry, corporations possess unique resources that VCs lack: research and development know-how, patent portfolios, customer management as well as sales and distribution expertise, etc. CIs let their portfolio companies access these unique resources. Anecdotal evidence of such support provided by CIs is abundant. The Economist (Feb 1999, p. 21) suggests that the high success rate of Xerox Technology Ventures' portfolio companies was "due to their proximity to an unusually high 'patent estate' – a concentration of Xerox' proprietary know-how." Similarly, Intel Capital's portfolio companies got the benefit of utilizing Intel labs' cutting-edge technology (Kanter et. al., 1990).[1] Startups also tap into the customer relationships of a corporation. For example, Envos Corporation, a startup supported by Xerox, inherited Xerox's customers in the area of Artificial Intelligence, apart from getting its continued research and development support (Chesbrough, 2002). Besides anecdotal evidence, empirical studies such as Katila et. al. (2008) and Dushnitsky and Shaver (2007) lend support to this claim; they hypothesize that CIs provide unique resources that VCs lack and find evidence consistent with the same.

For young, startup firms, the resources of CIs offer a double-edged sword. On the one hand, such unique resources offer startups substantial benefits at a stage when they are hungry for resources that can accelerate their growth. On the other hand, the presence of such unique, complementary resources raises concerns about expropriation. Gompers and Lerner (1998) document that CIs invest in startups to get a window into the startup's technology. Katila et. al. (2008) observe that investments by corporations involve severe concerns that the corporation may expropriate the startup's technology since "corporations are exchanging their own resources for access to promising new technologies." However, as Katila et. al. (2008) argue, startups can avoid this "shark's dilemma." Citing Sahlman (1990), they argue that startups "may be able to form ties with other types of partners (e.g., VCs) that may have less risk of misappropriation than do corporate partners. . . but also *have less critical resources.*"

In this paper, we study this dilemma faced by young, startup firms when choosing to finance their idea through a CI or a VC. However, unlike the existing literature (for example, see Hellman 2002), we do not model any differences in the investment objectives of the CI and the VC. Instead, we focus on how the *financier's unique resources* influence the startup inventor's and the financier's incentives to specialize the idea to the financier's resources, on the one hand, and to expropriate each other's assets, on the other hand. We show that the optimal financing choice serves to balance the benefits of specializing the idea to the financier's resources against the temptation for misappropriation that is induced by the presence of such complementary assets.

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[1]To illustrate this benefit using a specific example, examine this statement by the founder of Bipolar Integrated Technology, a portfolio company of Analog Devices' VC arm (Source: Kanter et. al., 1990): "Ours was such an advanced technology that it was unrealistic to go to venture capitalists and expect them to understand it. We were going to *need a company within the industry that would understand and support our technology*" (Emphasis added).

Consider a scientist who seeks financing from a financier to develop her idea. The financier possesses resources that complement the scientist's idea. In our model, the essential difference between CIs and VCs is the following: the CI possesses greater resources than the VC. We define a resource as an expropriable, knowledge asset. As Maskus (2000) asserts, knowledge assets share two features of public goods. First, they are *non-rivalrous*: one person's use does not diminish another's use. Second, knowledge assets are *non-excludable* through private means: it may not be possible to prevent others from using the knowledge without authorization. The model incorporates both these features of resources.

Since the scientist's idea and the financier's resources are complementary to each other, specialization by the scientist and the financier to each other's resource is mutually beneficial. Yet, because the resources are non-rivalrous, *both* the scientist and the financier can produce independently of each other by using the idea and the complementary resources. This non-rivalrous property of resources induces the temptation to expropriate each other's resource. To specialize as well as to expropriate, the scientist and the financier need to learn their partner's resource/ idea. Therefore, we model the investment that the scientist and the financier make to learn how to use each other's resource/ idea. Since learning enables specialization as well as expropriation, these investments affect the joint output as well as each agent's outside options. As in Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995), we assume that: (i) these investments are observable but not verifiable; and (ii) contracts are incomplete so that all outputs are unverifiable ex-ante but verifiable ex-post.

After investing, the scientist and the financier bargain over the total surplus generated by developing the idea. The bargaining outcomes depend upon the scientist's and financier's outside options, which are derived *endogenously* in the model. Since resources are non-excludable through private means, the scientist (financier) cannot prevent the financier (scientist) from employing her idea (his complementary resources) for production, except through legal recourse. Therefore, if the scientist and the financier decide to pursue production independently, they sue each other for infringing their respective resources. If the scientist (financier) wins but the financier (scientist) loses, then the scientist (financier) operates as a monopoly. If both win, neither can produce while if both lose, they both produce and compete with each other in an oligopoly. The scientist's (financier's) outside option equals the expected value of profits from each of these scenarios. In equilibrium, neither pursues his/ her outside options; they produce together and operate as a monopoly.

If contracts were complete, they would choose investment to maximize the marginal value of the joint profit net the cost of their investment; this first-best benchmark corresponds to learning only to specialize each other's resources. However, since contracts are incomplete and the investments are unverifiable, each agent chooses investment to maximize his/ her share of the joint profit net of the cost of investment. Therefore, the second-best investment corresponds to learning partly to specialize and partly to expropriate. We show that as a result, each agent *learns too much* compared to the first-best.

The optimal choice between financing by a CI and a VC is the one that maximizes the profits from developing the idea, which is equivalent in the model to maximizing the startup's financial returns. Thus, unlike Hellman (2002), we do not assume any differences in the investment objectives of the VC and the CI.

The trade-off between CI and VC financing is as follows. Since the CI possesses more resources, CI financing leads to more efficient specialization between the scientist and the financier. On the other hand, since the scientist's idea and the financier's resources are complementary to each other, greater resources makes expropriation more profitable for both the scientist and the financier. Therefore, the cost of CI financing is greater distortion (compared to the first-best) in the scientist's and financier's investments. The benefit of greater resources increases with the magnitude of resources as well as with the degree of complementarity between the scientist's idea and the financier's resources. In contrast, the cost of greater resources increases in a *convex* manner with the extent of distortion from the first-best; therefore, the cost increases with a (i) decrease in the strength of IP protection; (ii) increase in the intensity of product market competition; (iii) increase in the ease of expropriating the resources; and (iv) increase in the degree of complementarity between the scientist's idea and the financier's resources. In particular, the increase in the cost with the degree of complementarity is *disproportionately* more when resources are easily expropriable than when the resources are easy to expropriate.

A key result we obtain is that while increased complementarity increases the likelihood of CI financing when the resources are difficult to expropriate, this result is *reversed* when the resources are easy to expropriate. While the positive effect of complementarity is identical to Hellman (2002), the negative effect obtained here is novel. Therefore, in contrast to Hellman (2002), we assert that increased complementarity between the startup's idea and the corporation's existing business generates *both a cost and a benefit*. Whether increased complementarity is a boon or a bane with respect to the likelihood of CI financing depends upon whether the resources are easily expropriable or not.

The theory provides other empirical predictions. VC financing predominates CI financing if intellectual property (IP) protection is weaker, product market competition is more intense, and resources can be expropriated easily. Finally, IP protection and product market competition affect the choice disproportionately more when the resources are easy to expropriate.

Empirical evidence in Katila et. al. (2008) and Dushnitsky and Shaver (2008) support some of these predictions. Katila et. al. (2008) find that startups are more likely to pursue financing from a corporation than by a VC (i) if they have large complementary resource needs; and (ii) if they are better protected by defense mechanisms such as patents or secrecy. In particular, Katila et. al. (2008) examine the interaction of these two effects and find that the marginal effect of resources is greater when defense mechanisms are better and vice-versa. Dushnitsky and Shaver (2008) find that CI financing is less likely to materialize under a weak IP regime than a strong IP regime when the investment is in the same industry. Since investments in the same industry may be easier to expropriate, these pieces of evidence are consistent with the interactive effects predicted by our

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model.

This paper contributes to the literature on optimal financing choices. In particular, this study complements the work of Hellman (2002), who models corporations as strategic investors and analyzes when entrepreneurs would choose such strategic investors vis-à-vis purely financial investors such as independent VCs. As stated above, we model both the CI and the VC to maximize *purely* their return on investment in the startup. While CIs certainly have strategic objectives in many cases, they may focus purely on financial returns in many situations. For example, Xerox's corporate venture capital program, Xerox Technology Ventures was created "similar to independent venture organizations (but unlike many corporate venture programs) and had a clear goal: to maximize return on investment" (Gompers and Lerner 1998). In this paper, we argue that even if CIs resemble VCs in maximizing their return on investment, investment outcomes may differ across these classes of investors since *CIs and VCs differ along another key dimension*: CIs possess unique resources that VCs lack. Young, startup firms are often short on resources and are, therefore, eager to partner with corporations to utilize their vast resources. However, allying with corporations exposes these young startups to severe risk of expropriation. This paper models this shark's dilemma faced by young startups.

Ueda (2004) contrasts bank financing from venture capital finance and examines the effect of intellectual property protection on this choice. In Ueda (2004)'s model, the bank is an uninformed investor while the VC is informed. To ensure that it breaks-even in the presence of asymmetric information, the bank requires collateral. Therefore, while VC financing comes without the requirement of depositing collateral, the VC can expropriate the entrepreneur's idea. Since an increase in IP protection reduces the threat of expropriation, the effect of the information advantage enjoyed by the VC shrinks with an increase in IP protection; therefore an increase in IP protection leads to more VC financing than bank financing. Though our prediction that an increase in IP protection leads to more CI financing than VC financing is similar, the same cannot be obtained from a simple extension of Ueda (2004)'s model. This is because it is unlikely that CIs enjoy any information advantage when compared to VCs. Second, unlike banks, VCs do not require any collateral to provide financing. Therefore, the trade-off underlying the choice between CI and VC financing is different from that between VC and bank financing. Third, while in Ueda (2004) the VC can expropriate more than the bank due to its information advantage, in our model the greater risk of expropriation with CIs stems from the corporation possessing more complementary resources. Finally, in signalling models such as Ueda (2004), exploitation of knowledge is portrayed as an instantaneous and costless act rather than as a costly and proctracted process (Winter and Suzlanski 2000). In contrast, here we view learning of the knowledge as the essential precursor to both its specialized usage as well as its expropriation and model the incentive distortions in this learning process.

Anand and Galetovic (2004) examine holdup by the innovator in the context of financing of a startup's research and development stages by either an independent VC or a corporation. They argue that CIs cannot commit to cash-flow sharing with the entrepreneur while VCs can. In

contrast, we assume no differences in the menu of contracts available to VCs and CIs. Instead, we derive endogenously that the CI is able to expropriate more than the VC since it possesses the complementary resources that are required to develop the idea. Furthermore, while in Anand and Galetovic (2004) strong IP protection *enables* the CI to expropriate the scientist, strong IP protection *limits* expropriation by both the scientist and the financier here.

Mathews (2006) models the use of equity stakes in alliances between an established incumbent and an entrepreneurial firm. In his setting, the *transfer* of know-how from the entrepreneurial firm to the established firm enhances the efficiency of both firms; however, it also heightens the established firm's incentive to enter the entrepreneur's market. Equity ownership solves the incentive problems by internalizing the effect of the incumbent's entry on the entrepreneur's profits. While this paper resembles Mathews (2006) in examining efficiency and expropriation together, we examine the incentive effects of the sharing of knowledge resources (rather than knowledge transfer) between the corporation and the startup.

This paper is organized as follows. The next section describes the model while Section 3 presents the results from the model. Section 4 reviews other areas of the literature to which this paper is related. Section 5 shows that the results are robust to contracting on cash flow rights, control rights as well as ownership of intellectual property rights from developing the idea. Section 6 concludes the paper.

2   Model

Consider a Scientist (hereafter denoted S) who possesses knowledge in developing antibodies for curing diseases. The scientist comes up with a breakthrough idea (hereafter denoted I) for an AIDS antibody. The scientist seeks a financier (hereafter denoted F) who possesses resources that are complementary to those of the scientist's idea. These resources could include (a) technological expertise in research and development, patent portfolios, etc.; (b) business expertise; (c) customer and supplier relationships; and (d) abilities in team building, setting up human resource management policies, recruiting executives, etc. We collectively refer to these as complementary resources (hereafter denoted C). The financier owns β units of the resources. As stated in the Introduction, we view resources as expropriable, knowledge assets.

As argued in the Introduction, CIs possess more resources than VCs. We therefore assume that the resources possessed by CIs β_{CI} is greater than the resources possessed by VCs β_{VC},

$$\beta_{CI} > \beta_{VC} \tag{A1}$$

Some readers may argue that VCs possess more resources than CIs. For our purposes, however, all we need is that the CI possesses more expropriable, knowledge assets that matter for specialization, on the one hand, and expropriation, on the other.

As we describe shortly, unlike Hellman (2002), we *do not assume any differences in the investment objectives* between these two classes of investors. Furthermore, unlike Anand and Galetovic
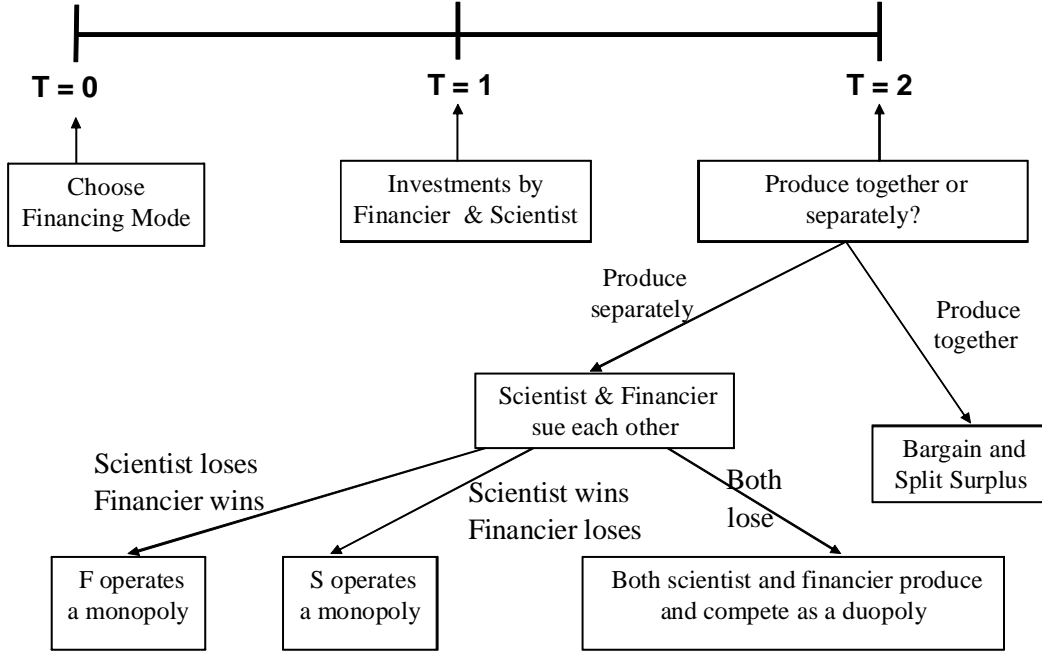
Figure 1: Timing and Sequence of Events

(2004), in our setup, there is no difference between CIs and VCs in either their ability to commit to the verifiability of project accounts or in their ability to exploit spillovers from the project/ idea. In fact, in our setup, the *only difference* between CIs and VCs lies in their nature of resources: as incumbent producers in their industry, CIs possess more unique resources than VCs.

We assume that both the scientist and the financier are risk-neutral; furthermore, the financier is not liquidity constrained but the scientist is. Figure 1 summarizes the time line and events in the model. There are three dates, $t = 0, 1$ and 2. The mode for financing the idea – VC or CI – is chosen at date 0. After deciding the financing mode, S and F make investments e_S and e_F respectively to learn how to use their partner's resource/ idea. As in Grossman and Hart (1986) and in Hellman (2002), we assume that these investments are *observable but not verifiable*.

Since knowledge is non-rivalrous and is non-excludable through private means, any investment to learn how to use the partner's resource/ idea can not only enable *specialization* to it but also allow *expropriation* of the same. For example, F learns about the scientist's idea for the antibody so that he can specialize his resources, which would enable them to generate an effective AIDS vaccine at date 2. However, F may use what he learns to expropriate S's idea and produce the AIDS vaccine all by himself at date 2. Similarly, S learns how to use the financier's complementary resources so that she can specialize her antibody to these resources. At the same time, S may use what she learns to expropriate the financier's resources, which would enable her to develop the AIDS vaccine without the financier's support at date 2.

2.1 Joint Profit and Outside Options

At date 2, the scientist and the financier decide whether they would produce together or separately. Denote the joint profit, i.e. the expected profit if S and F produce together, by R. Denote the scientist's and the financier's outside options, i.e. the expected profits if they were to produce individually, by r_S and r_F. If S and F decide to continue their relationship at date 2, they bargain over the split of the joint profit R using $50:50$ Nash bargaining.[2] Now, we derive the outside options endogenously by modeling the sub-game that results when S and F decide to go their separate ways at date 2.

2.1.1 Resources as expropriable, knowledge assets

As Maskus (2000) asserts, knowledge assets bear assets of a public good in two separate ways. First, they are *nonrivalrous*: one person's use does not diminish another's use. Second, knowledge assets are *non-excludable* through private means: it may not be possible to prevent others from using the knowledge without authorization. Since we view resources as expropriable, knowledge assets, resources share these two properties of public goods as well.

These two properties translate into our setup as follows. First, the nonrivalrous property of resources implies that *both* the scientist and the financier can produce using the idea and the complementary resources at date 2. Second, the non-excludable property implies that the scientist cannot prevent (using private means) the financier from employing her idea for production. Similarly, the financier cannot prevent (using private means) the scientist from employing his complementary resources for production. They both need to resort to the legal system to prevent unauthorized use of their respective resources. We incorporate these features into the following sub-game.

2.1.2 Product Market Characteristics and Profits

We assume that if S and F produce together, they have a monopoly over the product that they produce. Similarly, if $S(F)$ can produce, but $F(S)$ cannot, then $S(F)$ operates a monopoly. If both S and F can produce, then they compete with each other in an oligopoly.

If S and F produce together, their joint profit is R. The joint profit increases with (i) the assets that the agents can use to produce and (ii) the investments they make to learn about their partner's resource. Thus,

$$R = k + \phi\left(A, e_S\right) + \phi\left(A, e_F\right) \tag{1}$$

where $k > 0$ is a constant and A denotes the assets that the agents use for production. ϕ is given by the simple Cobb-Douglas production function

$$\phi\left(A, e_i\right) = A^{0.5} e_i^{0.5} \tag{2}$$

Since the scientist's idea I and the financier's resources C are complementary to each other, we

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[2] As we show in Appendix A, the results are robust to alternative bargaining solutions.

capture this complementarity in a simple manner by assuming that

$$A = (A_I)^\lambda (A_C)^\lambda, \qquad 0 < \lambda < 1 \tag{3}$$

where A_I and A_C denote respectively the units of the scientist's idea and the financier's complementary resources available for production. Since $\frac{\partial^2 A}{\partial A_I \partial A_C}$ is proportional to λ^2, λ captures the degree of complementarity between these resources.

We normalize the scientist's idea I to be 1 unit and the financier's resources to be $\beta > 1$ units. Thus, when the financier and the scientist produce together, $A_I = 1$ and $A_C = \beta$ so that

$$A_{SF} = 1^\lambda \cdot \beta^\lambda = \beta^\lambda \tag{4}$$

When S produces on her own, she has available for production her idea, equal to 1 unit, and the part of the financier's resource that she can potentially learn. Thus, in this case, $A_I = 1$ and $A_C = \beta \cdot \theta_S$, where $\theta_S \geq 0$ denotes the proportion of the financier's resource that S can learn. We view θ_S as primarily being determined by the technological characteristics of the financier's resource; if it is tacit and intricate and therefore very difficult to replicate, θ_S is close to zero while if it is codified and relatively simple, then θ_S is high. Thus, when S produces on her own

$$A_S = 1^\lambda \cdot (\beta \theta_S)^\lambda = \beta^\lambda \theta_S^\lambda \tag{5}$$

Similarly, when F produces on his own, $A_I = 1 \cdot \theta_F$ and $A_C = \beta$, where $\theta_F \geq 0$ denotes the proportion of the scientist's idea that F can potentially learn. Thus, when F produces on his own

$$A_F = (\theta_F)^\lambda \cdot \beta^\lambda = \beta^\lambda \theta_F^\lambda \tag{6}$$

When $S(F)$ has to produce without $C(I)$, then $A_C = 0 \, (A_I = 0)$, so that their profits are zero. When agent i operates as a monopoly, then the profit that i generates π_{iM} is given by

$$\pi_{iM} = k + \phi(A_i, e_i), \quad i = S, F \tag{7}$$

Comparing the above equation to (1), we note that when the scientist (financier) produces on her (his) own, the financier's (scientist's) learning does not contribute to profits.

If *both* S and F can produce separately, then they compete with each other in an oligopoly with *differentiated products*. Since both S and F learn from each other, they will compete with each other if they can both produce. However, $F(S)$ may not be able to learn and acquire all of $S(F)'$s knowledge. Therefore, their products will be differentiated from each other. We allow for strategic interactions between S and F when they compete in an oligopoly. We assume that in this

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case their profits, denoted by π_{SD} and π_{FD}, are given by

$$
\begin{aligned}
\pi_{SD} &= 0.5k + \phi\left(A_S, e_S\right) - \gamma\phi\left(A_F, e_F\right) \\
\pi_{FD} &= 0.5k + \phi\left(A_F, e_F\right) - \gamma\phi\left(A_S, e_S\right)
\end{aligned}
\tag{8}
$$

where $0 < \gamma < 1$ captures the degree to which F's product features dampen S's profits and vice-versa; thus, γ captures the intensity of product market competition S and F face when they produce independently and compete with each other.[3]

2.1.3 Intellectual Property Protection and Outside Options

If F and S decide to go their separate ways at date 2, S has the right to sue F for infringing on her Intellectual Property (IP) rights over the idea while F has the right to sue S for infringing on his IP rights over the complementary resources. With probability μ, the agent seeking legal recourse wins the IP infringement suit and loses with a probability $(1 - \mu)$; thus, μ captures the strength of IP protection, i.e. whether the legal system approves a broad scope of IP rights and whether it is efficient in prosecuting incidents of expropriation.[4] The product market outcome and the corresponding payoffs to the scientist and the financier are given by the following matrix

	S wins	S loses
F wins	Neither can produce $(0,0)$	F monopoly $(0, \pi_{FM})$
F loses	S Monopoly $(\pi_{SM}, 0)$	Both produce and compete in an oligopoly (π_{SD}, π_{FD})

Using $i = S, F$ and $j = \{S, F\} \setminus i$, agent i's outside option value r_i is given by

$$
r_i = \underbrace{\mu\left(1 - \mu\right) \cdot \pi_{iM}}_{\text{Monopoly for i}} + \underbrace{\left(1 - \mu\right)^2 \cdot \pi_{iD}}_{\text{Oligopoly}}
\tag{9}
$$

where π_{iM} is given by (7) and π_{iD} is given by (8). Simplifying, we get

$$
r_i = 0.5k\left(1 - \mu^2\right) + \underbrace{\left(1 - \mu\right)\beta^{0.5\lambda}\theta_i^{0.5\lambda}e_i^{0.5}}_{\text{Effect of own investment}} - \underbrace{\gamma\left(1 - \mu\right)^2\beta^{0.5\lambda}\theta_j^{0.5\lambda}e_j^{0.5}}_{\text{Effect of partner's investment}}
\tag{10}
$$

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[3]This profit function will be obtained for example if S and F compete (Cournot) Bertrand and face linear (inverse) demand functions, where the (quantity demanded) price that they charge decreases with not just their (own price) quantity that also that of the other firm.

[4]As Cohen, Nelson and Walsh (2000) find in the Carnegie Mellon University survey, strong patent protection is an exception rather than a norm. Therefore, even if the idea/ resource is patented at date 2, the owner may not be able to enforce ownership rights with certainty. Note that what matters is whether the idea/ resource is patented or not *at date* 2, or more generally whether intellectual property rights are delineated or not at date 2. Therefore, ideas/ resources that are not patented at date 0 but receive a patent by date 2 fall into the same category as ideas that are patented at date 0. If the idea is unpatentable or is not patented at date 2, then effectively $\mu = 0$.

The scientist's outside option, which equals the expected value of the profits from the monopoly and oligopoly scenarios, increases with her own investment in learning how to use F's resources but decreases with F's investment in learning; the decrease is *disproportionately* higher when product market competition is more intense, which highlights the externalities stemming from competition in an oligopolistic setting (similar for F).

The joint profit upon simplification becomes

$$R = k + \beta^{0.5\lambda}e_S^{0.5} + \beta^{0.5\lambda}e_F^{0.5} \tag{11}$$

Note that how easily the resources can be expropriated θ_i, the strength of IP protection μ, and the intensity of product market competition γ affect only the outside options but not the joint profit. This is because the joint profit is *only* affected by learning undertaken to specialize each other's resources. In contrast, the outside options are also affected by factors that influence the expected profits from expropriating the partner's resource/ idea.

To allow for learning to lead to both specialization as well as expropriation, we make the following parametric assumption:

$$\left(1 - \mu\right)\theta_i^{\lambda/2} > 1 \tag{A2}$$

This assumption involves two components. First, intellectual property (IP) protection is not *extremely* high (i.e. IP protection μ is below a threshold). Second, the financier's and the scientist's resources are not *extremely* difficult to replicate (i.e. ability to expropriate θ^i is above a threshold). The assumption can be motivated using the survey evidence of Cohen, Nelson and Walsh (2000). They document in their survey evidence on IP protection for over 140 4-digit SIC industries that firms primarily rely on secrecy and other informal mechanisms to guard their IP from being expropriated. Furthermore, they find that protection accorded to product and process patents are an exception rather than a norm: only in a few industries such as Chemicals and Drugs and Biotechnology, patents enable the owner to reasonably protect their IP assets. In most other industries, patenting is ineffective in protecting IP assets. This evidence suggests that neither are resources extraordinarily difficult to expropriate nor is patent protection strong enough to avoid expropriation altogether. Our assumption is similar to Anton and Yao (1994), who focus on situations where IP assets cannot be protected at all (i.e. $\mu = 0$ and θ_i is very high). Unlike them, however, we are only assuming that expropriation is possible, but the extent of expropriation may vary across industries and IP regimes.

2.2 Nature of contracts

As in Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995), contracts are assumed to be incomplete. Explicitly, two important assumptions characterize the incomplete contracts environment. First, the date 1 investments are observable but not verifiable. The inability to contract on investment can be motivated by the fact that the nature of activities required in developing an idea are quite subtle and therefore difficult to verify. Second, the payoffs R, r_S and

r_F are assumed to be non-contractible ex-ante, i.e. at date 0, though they are contractible ex-post, i.e. at date 2.[5]

Kaplan and Stromberg (2003) document that VCs write detailed contracts specifying the allocation of cash flows and control rights. Therefore, we show in an extension of the model in Section 5.2 that our results are robust even if we allow the scientist and the financier to contract on the division of cash flows and the allocation of control rights. We also show that the effects analyzed here are robust to contracting on (i) the level of access that the scientist and the financier provide to each other, as in Rajan and Zingales (1998); and (ii) to the intellectual property rights on innovations stemming from the idea.

2.3 Solving the model

The model is solved using backward induction. The following Lemma leads to the conclusion that the outside options are never exercised in equilibrium.

Lemma 1:

$$r_S + r_F < R \tag{12}$$

Thus, neither the financier nor the scientist exit the relationship to develop the idea on their own. Therefore, the outside options only affect the division of surplus in equilibrium.

The total surplus is given by

$$TS = R - e_S - e_F \tag{13}$$

Given 50:50 Nash bargaining at date 2, each agent's share of the surplus is given by

$$\Pi_i = 0.5\left(R + r_i - r_j\right) - e_i \tag{14}$$

The investments are chosen at date 1. The first-best investments $\left(e_S^{FB}, e_F^{FB}\right)$, which maximize TS, are given by the following first order condition

$$\frac{dTS\left(e_i^{FB}\right)}{de_i} = 0, i \in \{S, F\} \tag{15}$$

The second-best Nash equilibrium level of investments (e_S^*, e_F^*), which firm i chooses to maximize

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Π_i, are given by

$$\frac{d\Pi_i(e_i^*)}{de_i} = 0 \qquad (16)$$

It is easy to see that $\left(e_S^{FB}, e_F^{FB}\right)$ and (e_S^*, e_F^*) exist and are unique.

Given the equilibrium level of investments, define the equilibrium net surplus as

$$TS^* = R(e_S^*, e_F^*) - e_S^* - e_F^* \qquad (17)$$

Since the scientist comes up with the idea, she owns the idea.[6,7] We therefore assume the scientist has all the bargaining power at date 0. Since the financier is not financially constrained, ex-ante private transfers from the financier to the scientist are possible. Therefore the financing mode is chosen to maximize the joint surplus.

Note that we are assuming that *both the VC and the CI maximize the financial returns* from the developing the idea. This is in contrast to Hellman (2002), where the CI invests in the startup for strategic reasons and therefore has an objective function that differs from that of the VC.

3   Theoretical Results

We now describe the results from the model.

Using the functional forms for the outside options (10) in (14), we obtain the marginal value of each agent's investment on her share of the profits as

$$\frac{d\Pi_i}{de_i} = \underbrace{-1}_{\text{Cost of Investment}} + \underbrace{0.25\beta^{0.5\lambda}e_i^{-0.5}}_{\text{Marginal Value of the profit from Joint Production}} \qquad (18)$$

$$+ \underbrace{0.25(1-\mu)\beta^{0.5\lambda}\theta_i^{0.5\lambda}e_i^{-0.5}}_{\text{Marginal Value of expected rents from Monopoly for i}} + \underbrace{0.25\gamma(1-\mu)^2\beta^{0.5\lambda}\theta_i^{0.5\lambda}e_i^{-0.5}}_{\text{Marginal Value of expected rents from Oligopoly}}$$

Substituting (18) into (16), we get for the second-best investment e_i^*

$$e_i^* = \frac{1}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]^2 \beta^{\lambda} \qquad (19)$$

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[6] Even if the scientist were an employee of a corporation and got the idea while working for the firm, the employee would still own the idea. Gilson (1999) notes that: "Who owns an invention discovered by an employee depends on the stage of the inventive process at which the question is asked. The critical point in the process is "conception," defined as "the first occurrence of the complete invention in the mind of the inventor - as corroborated by objective evidence." Under the law of inventions, ideas remain the employee's property until conception. And because conception requires the employee to take the affirmative step of creating written corroboration, an employee can choose to delay this event until after he leaves the company."

[7] Since we focus on the financing choices of startup firms, we do not model the choice of ownership of the idea. However, in Section 5.3, we show that our results are robust to contracting on ownership of intellectual property rights from developing the idea.

where for notational brevity we denote

$$\Lambda = (1 - \mu)\{1 + \gamma(1 - \mu)\} \tag{20}$$

The first-best investment e_i^{FB} obtained using the first-order condition (15) is

$$e_i^{FB} = \frac{1}{4}\beta^\lambda \tag{21}$$

The first-best level of investment in learning e_i^{FB} corresponds to one which maximizes the joint profits from developing the idea. Since this learning maximizes the joint profits, we interpret the first-best level of investment as learning done by the scientist and the financier to specialize their resource/ idea to that of their partner. In contrast, the second-best level of investment e_i^* maximizes each agent's share of the joint profit, which is affected by the agent's outside option as well. Therefore, we interpret the second-best level of investment as learning done not only to specialize to the partner's resource/ idea but also to be able to expropriate the same.

Proposition 1 (Over-investment in learning): For $i = S, F$

$$e_i^* > e_i^{FB} \tag{22}$$

This result states that both the scientist and the financier learn *too much* compared to the economically optimal (first-best) levels. To understand this result intuitively, consider the following example of a resource provided by the financier – the technology to administer drugs to humans. If the scientist has to specialize her AIDS antibody to the financier's drug-delivery technology, she needs to learn only about those drug delivery mechanisms that would work with the AIDS antibody. However, in order to expropriate the drug delivery technology, she needs to understand it in totality. But by doing so, she duplicates what the financier already knows. Therefore, when the scientist learns both to specialize to the financier's resource and to expropriate it, she over-invests in learning compared to the situation where she only learns so as to specialize. A similar intuition applies for the financier's investment as well. This result is similar to that in Hart (1995), except that the focus here is on over-investment compared to the first-best while under-investment is the essential investment distortion analyzed in Hart (1995).

Proposition 2 (Marginal Effects on investment): For $i = S, F$

$$(a)\,(i)\,\frac{de_i^{FB}}{d\beta} > 0;\,(ii)\,\frac{de_i^{FB}}{d\lambda} > 0 \tag{23}$$

$$(b)\,(i)\frac{de_i^*}{d\beta} > 0;\,(ii)\,\frac{de_i^*}{d\lambda} > 0;\,(iii)\,\frac{de_i^*}{d\theta_i} > 0;\,(iv)\,\frac{de_i^*}{d\mu} < 0;\,(v)\,\frac{de_i^*}{d\gamma} > 0 \tag{24}$$

This proposition shows the differences in the determinants of the first-best and second-best levels of investment made by the scientist and the financier. Since the first-best level of investment

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in learning corresponds to that done for the purpose of specialization, it is affected only by the resources provided by the financier β, and the degree of complementarity between these resources and the scientist's idea λ. In contrast, the second-best level of investment in learning corresponds to that done for specialization and expropriation. Therefore, these investments are influenced both by those parameters that influence the joint profit as well as those parameters that affect *only the outside options* — the ease of expropriating the scientist's idea and the financier resources (θ_S, θ_F), the strength of IP protection μ, the intensity of product market competition γ.

Parts (i) and (ii) of (a) and (b) are quite intuitive. Irrespective of the purpose of learning, learning each other's resource is more efficient when greater resources are available and when they are more complementary to each other.

The intuition for part (iii) of (b) is as follows. If the financier's resources are easier to expropriate, then the scientist finds learning to expropriate the financier's resource more efficient. As a result, the scientist's expected rents from the monopoly and oligopoly scenarios are more sensitive to investment (see terms 2 and 3 in (18)), which translates into an increase in the effect of investment on the scientist's share of joint profit. Therefore, if the financier's resources are easier to expropriate, the scientist's investment increases. A similar intuition applies for the financier's investment.

The intuition for part (iv) of (b) is as follows. Since the scientist gets to operate as a monopoly when she wins the law suit against the financier, an increase in IP protection enhances the likelihood of a monopoly but decreases that of an oligopoly. Therefore, an increase in IP protection increases the marginal value of the expected rents that the scientist generates from a possible monopoly (see term 2 in (18)) but decreases that from a possible oligopoly (see term 3 in (18)). However, since the scientist's investment in expropriation has the dual effect of increasing her oligopoly profits as well as dampening the financier's oligopoly profits, the effect of the second term dominates that of the third term, i.e. the effect of the rents from a possible oligopoly dominates that from a possible monopoly. Therefore, an decrease in IP protection increases the scientist's investment. A similar intuition applies for the financier's investment as well.

Part (v) follows using a similar intuition. An increase in the intensity of product market competition, ceteris paribus, enhances the marginal rents from the scientist's (financier's) investment by dampening the financier's (scientist's) profits (see term 3 in (18)). Therefore, an decrease in product market competition reduces the scientist's and financier's investment.

Proposition 3 (Determinants of over-investment): For $i = S, F$,

$$\left(e_i^* - e_i^{FB}\right) \propto \left[(1-\mu)\{1 + \gamma(1-\mu)\}\theta_i^{\lambda/2} - 1\right] \tag{25}$$

Proposition 3 describes the factors that affect the extent of over-investment compared to the first-best. The Proposition describes that the extent of over-investment increases if (i) the resources are easier to expropriate (θ_i higher); (ii) the strength of IP protection (μ) decreases; and (iii) the intensity of product market competition (γ) increases. This is because the second-best level of

investments increase with these parameters but the first-best level of investment is unaffected by them (as seen in Proposition 2).

This proposition also describes the subtle effect of complementarity between the financier's resources and the scientist's idea (λ). If the scientist and the financier cannot expropriate each other's resources easily $(\theta_i < 1)$, then an increase in complementarity decreases their over-investment compared to the first best. However, this effect is reversed if the scientist and the financier can expropriate each other's resources easily $(\theta_i \geq 1)$. Thus, complementarity between the resources becomes a bane rather than a boon when the resources can be expropriated easily.

The intuition for this result is as follows. An increase in the complementarity between the scientist's idea and the financier's resources increases the benefits from learning and therefore increases both the first-best and second-best level of investments. However, when the scientist's and financier's resources are easier to expropriate, an increase in complementarity makes expropriation *disproportionately* more attractive than specialization, thereby increasing the second-best investment *disproportionately* more than the first-best investment. Therefore, when the resources are easier to expropriate, an increase in complementarity increases the over-investment while the effect is opposite when resources are difficult to expropriate.

3.1 Optimal Financing Choice

To serve as a benchmark, examine the financing mode that would be employed in a first-best scenario. If contracts were complete, then the financing mode would be chosen to maximize

$$TS^F = R\left(e_S^{FB}, e_F^{FB}\right) - e_S^{FB} - e_F^{FB} = k + \frac{1}{2}\beta^\lambda \tag{26}$$

$$\frac{dTS^F}{d\beta} = \frac{\lambda\beta^{\lambda-1}}{2} > 0 \because 0 < \lambda < 1 \tag{27}$$

Therefore, in the first-best world, $\frac{dTS^F}{d\beta} > 0$. Since $\beta_{CI} > \beta_{VC}$, financing by the CI is always optimal in the first-best scenario. If contracts could ensure the first-best level of investments by the scientist and the financier, then the CI's greater resources lead the scientist and the financier to learn more to specialize. Therefore, CI financing would be always optimal.

In contrast, when contracts are incomplete, the financing mode is chosen to maximize the joint surplus TS^* as given by (17), which upon simplification yields

$$TS^* = k + \frac{1}{16} \sum_{i\in S,F} \beta^\lambda \left[1 + \Lambda\theta_i^{\lambda/2}\right] \left[3 - \Lambda\theta_i^{\lambda/2}\right] \tag{28}$$

Therefore,

$$\frac{dTS^*}{d\beta} = \underbrace{\frac{\lambda\beta^{\lambda-1}}{4}}_{\text{Benefit of Financier's Resources}} - \underbrace{\frac{\lambda\beta^{\lambda-1}}{16} \sum_{i\in S,F} \left[1 - \Lambda\theta_i^{\lambda/2}\right]^2}_{\text{Cost of Financier's Resources}} \tag{29}$$

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where recall that

$$\Lambda = (1 - \mu)\{1 + \gamma(1 - \mu)\} \tag{30}$$

Thus, the trade-off stemming from having more resources available for production is as follows. On the one hand, since the financier's resources are complementary to the scientist's idea, greater resources enhances the benefits from learning to specialize these resources to the idea. Therefore, both the scientist and the financier learn more to specialize their resources to each other. This benefit increases with an increase in the magnitude of resources β and their complementarity to the scientist's idea λ.

On the other hand, greater resources generate the cost of *distorting the scientist's and the financier's investments* from economically optimal levels, i.e. generates incentives for the scientist and the financier to learn too much in order to expropriate their partner's resource/ idea. As Proposition 3 shows, the over-investment in learning is directly proportional to the difference $1 - \Lambda\theta_i^{\lambda/2}$. Equation (29) shows that the cost of having more resources is *convex* in the extent of over-investment in learning.

Intuitively, the cost of greater resources is as follows. Since the idea and the financier's resources are complementary, greater resources makes expropriation more attractive to both the scientist and the financier. To expropriate the financier's resource (scientist's idea), the scientist (financier) finds it attractive to learn those aspects that the financier (scientist) already knows. This duplication is economically costly and increases in a convex manner when (i) the strength of IP protection (μ) decreases; (ii) the intensity of product market competition (γ) increases; and (iii) their ability to expropriate each other's resources (θ_i) increases.

The increase in the cost due to an increase in the complementarity (λ) depends upon the nature of the resource/ idea. If the scientist's idea and the financier's resources are difficult to expropriate $(\theta_i < 1)$, then an increase in the complementarity decreases the cost. In contrast, if they can be expropriated easily $(\theta_i \geq 1)$, then an increase in the complementarity increases the cost. Thus, an increase in the *complementarity between the resources becomes a bane*, i.e. imposes additional costs, rather than a boon *when the resources can be expropriated easily*.

Proposition 4 (Optimal Financing Choice):

$$(1 - \mu)\{1 + \gamma(1 - \mu)\}\theta_i^{\lambda/2} \gtreqless 3 \Leftrightarrow TS^*(\beta_{VC}) \gtreqless TS^*(\beta_{CI}) \tag{31}$$

This result follows directly from the trade-off described by equation (29). Since the CI possesses greater resources than the VC $(\beta_{CI} > \beta_{VC})$, financing by the CI is optimal when the benefit of additional resources predominates the cost from the same. In contrast, financing by the VC is optimal when the cost of such additional resources dominates the benefits from the same.

Result 1 (Complementarity can be a Boon as well as a Bane):

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$$(i) \lambda \gtreqqless \widehat{\lambda} \Rightarrow TS^* (\beta_{CI}) \gtreqqless TS^* (\beta_{VC}) \text{ if } \theta_i \leq \widehat{\theta} \tag{32}$$

$$(ii) \lambda \gtreqqless \widehat{\lambda} \Leftrightarrow TS^* (\beta_{CI}) \lesseqqgtr TS^* (\beta_{VC}) \text{ if } \theta_i > \widehat{\theta}$$

This result shows that if the scientist's idea and the financier's resources are difficult to expropriate, then an increase in their complementarity leads to CI financing predominating VC financing. However, this effect of complementarity is *reversed* when the resources are easier to expropriate. While the positive effect of complementarity is identical to Hellman (2002), the negative effect obtained here is novel.

The intuition for this result is quite simple. As the trade-off described by equation (29) shows, an increase in the complementarity λ increases *both the costs and benefits* of CI financing when compared to independent VC financing. Increased complementarity makes learning in order to specialize more attractive. Yet, when these resources are more complementary to each other, each agent can also produce more on his/ her own by expropriating the partner's resource. Therefore, increased complementarity accentuates the temptation to expropriate the partner's resource and increases the over-investment in learning.

In contrast to the effect of complementarity, the scientist's and financier's abilities to expropriate (θ_i) affects the cost (in the form of over-investment in learning) but not the benefit. Therefore, when the scientist's idea and the financier's resources are difficult to expropriate $\left(\theta_i \leq \widehat{\theta} \right)$, an increase in complementarity increases the benefit of CI financing more than its cost. However, when these are easy to expropriate $\left(\theta_i > \widehat{\theta} \right)$, an increase in complementarity increases the cost more than the benefit. This explains why complementarity has a positive (negative) effect on the choice of CI versus VC financing when ability to expropriate is low (high).

It is informative to contrast this result to that in Hellman (2002). In Hellman (2002), both CIs and VCs provide support to the startup but under-invest compared to the first-best levels. However, since the CI cares about the impact of the startup's idea on its core business, he under-invests less (more) than the VC when the startup's idea complements (substitutes) its business. In other words, an increase in complementarity provides the benefit of lowering the financier's under-investment (compared to the first-best) in support to the startup, which explains the positive effect of complementarity on CI financing. In contrast to Hellman (2002), first, we assert here that increased complementarity between the startup's idea and the corporation's existing business generates both a cost and a benefit. In other words, complementarity between the scientist's idea and the financier's complementary resources can be both a bane as well as a boon, depending upon whether the agents can expropriate easily or not. Second, while the main incentive distortion in Hellman (2002) is under-investment in support to the startup, here the incentive distortion is over-investment in learning.

Result 2 (Intellectual Property Protection and Optimal Financing Choice):

$$\mu \gtreqqless \widehat{\mu} \Leftrightarrow TS^* (\beta_{CI}) \gtreqqless TS^* (\beta_{VC}) \tag{33}$$

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This result shows that an increase in the strength of intellectual property protection increases the likelihood of CI financing when compared to that of VC financing. The intuition for this result is as follows. Recall from Proposition 3 that, ceteris paribus, compared to an environment with strong IP protection, the scientist and the financier overinvest more in an environment with weak IP protection. As the cost of CI financing (compared to VC financing) increases with the extent of distortion in the investment, an increase in the distortion decreases the likelihood of CI financing. Therefore, an decrease in IP protection decreases the likelihood of CI financing. Anand and Galetovic (2004) obtain a result opposite to that above. This is because while in Anand and Galetovic (2004) strong IP protection *enables* the CI to expropriate the scientist, strong IP protection *limits* expropriation by both the scientist and the financier here.

Result 3 (Product Market Competition and Optimal Financing Choice):

$$\gamma \gtreqqless \widehat{\gamma} \Leftrightarrow \ TS^{*}\left(\beta_{CI}\right) \lesseqqgtr TS^{*}\left(\beta_{VC}\right) \tag{34}$$

This result shows that an increase in the intensity of product market competition decreases the likelihood of CI financing when compared to that of VC financing. The intuition for this result is similar to that in Result 2. Recall from Proposition 3 that, ceteris paribus, compared to an industry where product market competition is moderate, the scientist and the financier overinvest more in an industry where product market competition is intense. Therefore, an increase in product market competition decreases the likelihood of CI financing by increasing its cost relative to VC financing.

Result 4 (Expropriability and Optimal Financing Choice):

$$\theta_i \gtreqqless \widehat{\theta_i} \Leftrightarrow \ TS^{*}\left(\beta_{CI}\right) \lesseqqgtr TS^{*}\left(\beta_{VC}\right) \tag{35}$$

This proposition states that, ceteris paribus, CI financing becomes less likely compared to VC financing when the scientist's idea/ financier's resources become easier to expropriate. The intuition for this result is similar to that in Result 2. Recall from Proposition 3 that as the financier's resources (scientist's idea) become easier to expropriate, the scientist (financier) overinvests more in learning. Therefore, an increase in expropriability decreases the likelihood of CI financing by increasing its cost relative to VC financing.

Result 5 (Expropriability increases the marginal effect of IP Protection):

$$\frac{d\left[TS^{*}\left(\beta_{CI}\right) - TS^{*}\left(\beta_{VC}\right)\right]}{d\mu d\theta_i} > 0 \tag{36}$$

This result states that the strength of IP protection affects the choice between CI and VC financing *disproportionately* more when the scientist's idea and the financier's resources are easily expropriable than when they are difficult to expropriate. This interactive effect can be understood by

examining the cost of CI financing in (29). As the scientist's and financier's ability to expropriate each other's resources increases, any decrease in IP protection disproportionately increases the scientist's and financier's over-investment compared to the first-best benchmark, thereby disproportionately increasing the cost of CI financing. Therefore, as the scientist's idea and the financier's resources become easier to expropriate, the marginal effect of IP protection becomes greater.

Result 6 (Expropriability increases the marginal effect of Competition):

$$\frac{d\left[TS^*\left(\beta_{CI}\right) - TS^*\left(\beta_{VC}\right)\right]}{d\gamma d\theta_i} > 0 \tag{37}$$

This result states that the intensity of product market competition affects the choice between CI and VC financing *disproportionately* more when the scientist's idea and the financier's resources are easily expropriable than when these resources are difficult to expropriate. The intuition for this result is identical to that described above.

3.2 Discussion

Empirical evidence is consistent with some of the above predictions. Katila et. al. (2008) find that startups are more likely to pursue investment by a corporation than by an venture capitalist: (i) if they have large complementary resource needs, which is consistent with part (a) of Result 1; and (ii) if they are more strongly protected by defense mechanisms such as patents or secrecy, which is consistent with Result 2. In particular, Katila et. al. (2008) examine the *interaction* of these two effects and find that the marginal effect of complementary resources is greater when defense mechanisms are better and vice-versa. Since lower ability to expropriate is correlated with defense mechanisms being stronger, this result is fully consistent with Result 1. Dushnitsky and Shaver (2008) find that CI financing is less likely to materialize under a weak IP regime than a strong IP regime when the investment is in the same industry. Since investments in the same industry may be easier to expropriate, this evidence is also consistent with the interactive effects predicted by Result 5.

Other studies find evidence consistent with Result 2. Gans, Hsu and Stern (2002) find using a novel dataset of 118 start-up companies that startup firms with greater intellectual property protection (those having at least one patent associated with their technology) are 23% more likely to pursue a cooperative strategy with incumbent corporations than firms that have no patents associated with their technology. Finally, Lerner and Merges (1998) document the widespread use of research alliances between pharmaceutical firms and biotech startups while Bhide (2000) finds the salience of VC financing in Internet, Software and Semiconductors. This is consistent with the above prediction since Cohen, Nelson and Walsh (2000) find that patent protection is stronger in Drugs and Biotechnology than in Internet, Software and Semiconductors.

While the above empirical evidence is consistent with some of the predictions, many of the results above are novel and are yet to be empirically tested. To test the new predictions, data on

venture capital and corporate venture investments can be combined with proxies for IP protection μ, product market competition γ, the degree of complementarity in the assets λ and measures for expropriability of resources θ. Cohen, Nelson and Walsh (2000) generate survey measures for the level of IP protection and the importance of complementarity assets in over 140 industries at the 4-digit SIC level, which can be used to proxy μ and λ respectively.

Laws that change Intellectual Property protection can also be employed as natural experiments to test the predicted *causal* effect of IP protection. For example, the Cooperative Research and Technology Enhancement (CREATE) Act, which was enacted as a law by US Congress in March 2004, allows a patent application to be approved even if it involves collaborators from more than one organization (Meagher and Copeland, 2006). In the past, prior work by one of the partners in a joint research program could be used as prior art to deny a patent for discoveries made under the joint research program. The CREATE act removes such obstacles for collaborative research. In the framework of this paper, the CREATE act enhances protection to intellectual property generated through collaborative research by allowing them to be patented. Similarly, the World Trade Organization (WTO)'s agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) requires, starting January 2005, that developing countries must implement product patents on drugs. Thus, the CREATE act and TRIPS agreement provide time-series proxies where μ increased due to the enactment of these laws.

Herfindahl index based measures can be used to construct proxies for the degree of product market competition γ. Proxies for the ability to expropriate resources, θ_S and θ_F, can be constructed using self-citations as in Trajtenberg, Jaffe and Henderson (1992). Since citations to patents track the trail of spillovers from existing knowledge, they are useful to construct proxies for expropriability of knowledge. In particular, citations made to a firm's own patents measure the extent to which the originating innovation represents appropriation of benefits to its predecessors housed in the same firm.

4   Other Related Literature

Apart from the literature on optimal financing choices, which was discussed in the Introduction, this paper is related to the literature on innovation and stealing of ideas/ knowledge. Anton and Yao (1994) and Baccara and Razin (2006) analyze disclosure of ideas in situations where IP protection is non-existent. Rajan and Zingales (2001) examine how vertical versus horizontal hierarchies can be employed to prevent stealing of ideas by employees. Biais and Perotti (2004) show that an unpatentable idea may be safely shared in a partnership with experts who have expertise which complements their idea. Hellman (2006) considers how the trade-off between requiring employees to focus on core tasks versus allowing them to explore new ideas affects the process of idea generation in firms and their development inside/ outside firms. Hellman and Perotti (2007) model ideas as incomplete concepts requiring feedback from agents with complementary abilities for completion and analyze circulation of ideas in firms and in markets.

This paper is also related to the strategy literature crystallized in the Resource-Based View of the firm, which postulates that the core of an organization consists of unique capabilities and resources (Penrose 1959; Wernerfelt 1984; Wernerfelt and Montgomery 1988; Hamel and Prahalad 1990; Barney 1991). We view resources as expropriable, knowledge assets. While the Resource-Based View admits to a broader definition of resources, unlike the model here, it does not indicate how these resources influence investment incentives and distortions. Furthermore, to our knowledge, this study is the first to bring the resource-based view to formally analyze the financing choices available to young, startup firms.

5   Robustness

We conclude by examining the robustness of our results to changes in the set of variables that are contracted upon. In the Appendix, we show that the results do not show if the bargaining model for deciding the split of surplus at date 2 is changed.

Here, we show that the results remain unchanged if we allow for contracting on (i) the level of access provided to the resources; (ii) control rights over important actions that need to be taken to develop the idea; (iii) division of the verifiable portion of cash flows; and (iv) ownership of the intellectual property rights from the innovation.

5.1   Access

Rajan and Zingales (2001) examine the level of access than an entrepreneur provides to his/ her subordinates and analyze how the organizational hierarchy helps to regulate this access. We show here that the incentive distortions we are analyzing do not disappear if we allow the scientist and the financier to contract on the level of access that they provide each other. Say that the access that the scientist and the financier provide each other is α. To allow for the level of access received to affect the investments, we assume that access is received at date 0.5, i.e., before the investments are made (at date 1) but after the contracting on the financing choice. To capture the effect of access on investment, we modify the function ϕ in equation (2) as follows

$$\phi\left(A, e_i, \alpha_i\right) = A^{0.5} e_i^{0.5} \alpha^{0.25} \tag{38}$$

which captures the effect in Rajan and Zingales (1998, 2001) that a higher level of access enhances the efficiency of the investments ($\phi_{e\alpha} > 0$).

Given the financing choice and the level of access, the equilibrium first-best and second-best level of investments are given by

$$e_i^{FB} = \frac{1}{4} \beta^\lambda \alpha^{0.5} \tag{39}$$

$$e_i^* = \frac{1}{16} \left[1 + \Lambda \theta_i^{\lambda/2}\right]^2 \beta^\lambda \alpha^{0.5} \tag{40}$$

while the equilibrium level of the joint surplus TS^* is given by

$$TS^* = R\left(e_S^*, e_F^*, \alpha\right) - \sum_{i \in S,F} e_i^*\left(\alpha\right) = k + \frac{\beta^\lambda \alpha^{0.5}}{16} \sum_{i \in S,F} \left[1 + \Lambda \theta_i^{\lambda/2}\right] \left[3 - \Lambda \theta_i^{\lambda/2}\right] \qquad (41)$$

$$\frac{dTS^*}{d\beta} = \frac{\lambda \beta^{\lambda-1} \alpha^{0.5}}{16} \sum_{i \in S,F} \left[1 + \Lambda \theta_i^{\lambda/2}\right] \left[3 - \Lambda \theta_i^{\lambda/2}\right] \qquad (42)$$

Therefore, for any $\alpha > 0$, the incentive distortions that we analyzed will not disappear (in the extreme case where $\alpha = 0$, i.e. no access is provided, there is no benefit from specialization).

Proposition 5 (Optimal Financing Choice allowing for contracting on access): Given α,

$$(1 - \mu)\left\{1 + \gamma\left(1 - \mu\right)\right\} \theta_i^{\lambda/2} \gtreqqless 3 \Leftrightarrow TS^*\left(\beta_{VC}\right) \gtreqqless TS^*\left(\beta_{CI}\right) \qquad (43)$$

Therefore, all our results remain unchanged even when the scientist and financier contract on the level of access to provide each other.

5.2 Incomplete Contracts

Kaplan and Stromberg (2003) document that VCs write detailed contracts specifying the allocation of cash flows and control rights. Therefore, in this section, we show in an extension of the basic model that our results are robust even if we allow the scientist and the financier to contract on the division of cash flows and the allocation of control.

5.2.1 Control rights

Following Aghion and Bolton (1992), to model the allocation of control rights, we allow for an action ω that can be taken either by the scientist or the financier. For example, the action could be recruitment of employees, in which case ω denotes the number of employees that are decided to be recruited. To allow for the action to affect the investments, we assume that the action is taken at date 0.5, i.e., before the investments are made (at date 1) but after the contracting on the financing choice and the right to take this action (at date 0). To capture the effect of the action on profits, we modify the function ϕ in equation (2) as follows

$$\phi\left(A, e_i, \omega\right) = A^{0.5} e_i^{0.5} \omega^{0.25} \qquad (44)$$

which reflects the fact that a higher level of the action enhances the efficiency of the investments ($\phi_{e\omega} > 0$). We also assume that implementing the action involves a private cost, which equals ω. For example, recruiting more employees involves conducting more interviews which is costly for the agent undertaking the action.

As in Aghion and Bolton (1992), we assume that the action is *observable but not verifiable*. However, we assume the right to implement this action to be contractible at date 0. Say $\Omega = 0$

($\Omega = 1$) denotes the scientist (financier) having the right to implement this action. Given Ω, ω and the financing choice, the equilibrium first-best and second-best level of investments are given by

$$e_i^{FB} = \frac{1}{4} \beta^\lambda \omega^{0.5} \tag{45}$$

$$e_i^* = \frac{1}{16} \left[1 + \Lambda \theta_i^{\lambda/2}\right]^2 \beta^\lambda \omega^{0.5} \tag{46}$$

while the equilibrium level of the joint surplus TS^* and each agent's share Π_i^* are given by

$$TS^* = R(e_S^*, e_F^*, \omega) - \sum_{i \in S, F} e_i^*(\omega(\Omega)) - \omega(\Omega) \tag{47}$$

$$= k - \omega + \frac{\beta^\lambda \omega^{0.5}}{16} \sum_{i \in S, F} \left[1 + \Lambda \theta_i^{\lambda/2}\right] \left[3 - \Lambda \theta_i^{\lambda/2}\right] \tag{48}$$

$$\Pi_i^* = 0.5 \left[R(e_S^*, e_F^*, \omega) + r_S(e_S^*, e_F^*, \omega) - r_F(e_S^*, e_F^*, \omega)\right] - e_i^*(\omega(\Omega)) - \omega(\Omega) \tag{49}$$

$$= k - \omega + \frac{\beta^\lambda \omega^{0.5}}{16} \sum_{i \in S, F} \left[1 + \Lambda \theta_i^{\lambda/2}\right]^2 \tag{50}$$

Given this modified setup, at date 0, the scientist and the financier choose the optimal allocation of control rights Ω apart from the financing choice itself. Say, ω^{FB} denotes the first-best choice of action that maximizes the joint surplus. The second-best actions are chosen by the scientist and the scientist to maximize their respective shares of the joint surplus. Say that $\omega_S(\omega_F)$ denotes the optimal action implemented by the scientist (scientist). Thus,

$$\omega^{FB} \equiv \underset{\omega}{\arg\max} \ TS^*(\omega) = \left\{ \frac{\beta^\lambda}{32} \sum_{i \in S, F} \left[1 + \Lambda \theta_i^{\lambda/2}\right] \left[3 - \Lambda \theta_i^{\lambda/2}\right] \right\}^2 \tag{51}$$

$$\omega_i \equiv \underset{\omega}{\arg\max} \ \Pi_i^*(\omega) = \left\{ \frac{\beta^\lambda}{32} \sum_{i \in S, F} \left[1 + \Lambda \theta_i^{\lambda/2}\right]^2 \right\}^2 \tag{52}$$

Lemma 2 (Choice of Action):

$$\Omega = 0 \Rightarrow \omega = \omega^{FB} \tag{53}$$

$$\Omega = 1 \Rightarrow \omega = \omega_F$$

If the scientist has the control right, i.e. $\Omega = 0$, then $\omega = \omega^{FB}$. This is because the financier can make a private transfer to incentivize the scientist to choose ω^{FB}. However, since the scientist is financially constrained, the financier having the control right, i.e. $\Omega = 1$, implies that the financier will choose ω_F. Thus, as argued by Aghion and Bolton (1992), the scientist and the financier would

differ in their choice of actions.

Proposition 6 (Conflict of Interests in implementing the Action):

$$\omega_S \neq \omega_F \neq \omega^{FB} \tag{54}$$

The scientist's choice action differs from the financier's choice of action. Furthermore, both the scientist's and the financier's choice of actions differ from the benchmark first-best choice of action. By showing that there exists a conflict of interest between the actions taken by the scientist and the financier, we have shown that the allocation of control rights matters in our setting.

Given any allocation of control rights Ω and therefore given any action ω_S, ω_F or ω^{FB}, it follows that

$$\frac{dTS^*}{d\beta} = \frac{\lambda \beta^{\lambda-1} \omega^{0.5}}{16} \sum_{i \in S,F} \left[1 + \Lambda \theta_i^{\lambda/2} \right] \left[3 - \Lambda \theta_i^{\lambda/2} \right] \tag{55}$$

Proposition 7 (Optimal Financing Choice allowing for contracting on Control Rights):
Given Ω and the resulting ω,

$$(1 - \mu) \{ 1 + \gamma (1 - \mu) \} \theta_i^{\lambda/2} \gtreqqless 3 \Leftrightarrow TS^* (\beta_{VC}) \gtreqqless TS^* (\beta_{CI}) \tag{56}$$

Thus, all our results above remain unaltered.

5.2.2 Cashflow and Control rights

In order to allow for the allocation of cashflow rights at date 0, we have to allow for a portion of the joint profits to be verifiable at date 0. Since we have assumed the joint profit R to be completely unverifiable at date 0, say that of the joint profit S, a proportion $s = \xi S$ is verifiable and the remaining $R = (1 - \xi) S$ is non-verifiable at date 0 (but verifiable at date 2). Now, let us say that the financier offers the scientist an optimal compensation contract $q^*(s)$ at date 0, where s is the contractible portion of the joint profits. Given this modification, the scientist's and the financier's share of the non-verifiable portion of the joint surplus are Π_S^* and Π_F^* respectively.

The optimal financing choice, which in this section we denote by $\varphi^* \in \{CI, VC\}$, together with the optimal allocation of control rights Ω^* and the scientist's compensation contract $q^*(s)$ therefore solve the following optimization problem:

$$(\varphi^*, \Omega^*, q^*(s)) \equiv \underset{(\varphi, \Omega, q(s))}{\arg \max} \ [\Pi_F^* + s - q^*(s)] \tag{57}$$

subject to the scientist's participation constraint,

$$\Pi_S^* + q^*(s) \geq U \tag{58}$$

and the incentive compatibility constraint,

$$(\varphi^*, \Omega^*) = \arg \max_{(\varphi, \Omega)} \left[\Pi_S^* + \Pi_F^* + s \right] \tag{59}$$

In constraint (58), the variable U denotes the scientist's reservation payoff. Constraint (59) is the constraint that the optimal financing choice together with the optimal allocation of control rights maximizes the net surplus (which now comprises both the verifiable and non-verifiable cashflows). Since the financier is not liquidity constrained and the scientist has the bargaining power at date 0, the following result follows.

Proposition 8 (Financing Choice allowing for contracting on Cashflow and Control Rights): The maximization problems (57) and (59) are equivalent.

Thus, if we allow for a portion of cash flows to be verifiable and provide for its contractual allocation between the scientist and the financier apart from allocating control rights between them, the maximization problem with and without the cashflow contract are equivalent. We have already shown that our results are robust when we allow for contracting on control rights. Therefore, we can conclude that our results remain robust to the allocation of both cashflow and control rights between the scientist and the financier.

5.3 Ownership of intellectual property rights

We now consider contracting over an action which *directly* affects *only* the outside options and not the joint profits – the act of producing alone at date 2. Specifically, if the scientist (financier) has the right to take this action, then only the scientist (financier) can withdraw from the relationship and pursue his outside opportunities at date 2; the financier (scientist) cannot do so. Following Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995), such control rights essentially stem from ownership of the intellectual property rights (IPR) over innovations that stem from developing the idea. However, as Crampes and Langinier (2002) assert, ownership of an intangible asset merely grants the owner the right to sue intruders. Therefore, the owner of the resource can enforce his IPR *only* through legal recourse.

Suppose δ_i be a dummy variable which equals 1 if i owns the IPR over the innovations stemming from the idea ($i = S, F$). Since either the scientist or the financier can own the IPR, $\delta_S + \delta_F = 1$. As discussed above, if the scientist owns the IPR, then only the scientist (financier) has the right to pursue her (his) outside options at date 2. However, to enforce her (his) ownership rights, the scientist (financier) has to seek legal recourse; as before, the strength of IP protection determines the ease with which the owner can enforce ownership rights. Thus with probability μ the owner wins the infringement law suit against the erstwhile partner. If the owner wins the law suit, then only the owner can produce, which leads to a monopoly by the owner. In contrast, if the owner loses the law suit, then an oligopoly results.

In other words, when the scientist and the financier contract over ownership of the IPR over innovations from the idea, only the owner of the IPR has the legal right to produce on his own and

therefore the right to sue if the non-owner pursues production on his own. In contrast, in our basic setup, both the scientist and the financier could sue their erstwhile partner for infringing on their ownership of the idea and the complementary resources respectively.

Contracting on ownership of IPR changes the outside options as follows:

$$r_i = \delta_i r_i \left(\delta_i = 1\right) + \left(1 - \delta_i\right) r_i \left(\delta_i = 0\right) \tag{60}$$

$$r_i \left(\delta_i = 1\right) = \underbrace{\mu \cdot \pi_{iM}}_{\text{Monopoly for } i} + \underbrace{\left(1 - \mu\right) \cdot \pi_{iD}}_{\text{Oligopoly}}$$

$$r_i \left(\delta_i = 0\right) = \underbrace{\mu \cdot 0}_{\text{Monopoly for } j \neq i} + \underbrace{\left(1 - \mu\right) \cdot \pi_{iD}}_{\text{Oligopoly}}$$

Therefore, the outside options change to

$$r_i = 0.5k \left(1 - \mu + 2\mu\delta_i\right) + \left(1 - \mu + \mu\delta_i\right) \phi\left(A_i, e_i\right) - \gamma \left(1 - \mu\right) \phi\left(A^j, e^j\right) \tag{61}$$

Solving the model, we get the equilibrium investment to be

$$e_i^* = \frac{1}{16} \left[1 + \Lambda_i \theta_i^{\lambda/2}\right]^2 \beta^\lambda \tag{62}$$

where

$$\Lambda_i = \left(1 - \mu\right)\left(1 + \gamma\right) + \mu\delta_i \tag{63}$$

Using these equilibrium level of investments, we get

$$\frac{dTS^*}{d\beta} = \frac{\lambda\beta^{\lambda-1}}{16} \sum_{i \in S, F} \left[1 + \Lambda_i \theta_i^{\lambda/2}\right] \left[3 - \Lambda_i \theta_i^{\lambda/2}\right] \tag{64}$$

Proposition 9 (Optimal Financing Choice allowing for contracting on Intellectual Property Rights): Given Ω and the resulting ω,

$$\left\{\left(1 - \mu\right)\left(1 + \gamma\right) + \mu\delta_i\right\} \theta_i^{\lambda/2} \gtreqless 3 \Leftrightarrow TS^* \left(\beta_{VC}\right) \gtreqless TS^* \left(\beta_{CI}\right)$$

All our subsequent results about the effects of the various parameters on the optimal financing choice remain unaltered.

6   Conclusion

Corporate investors differ from venture capitalists in a basic aspect: as incumbent producers in an industry, corporations possess unique resources that VCs lack. For young, startup firms seeking financing, this offers a double-edged sword: access to the corporation's unique resources vis-à-vis the risk of expropriation by the corporation. This paper studies this dilemma encountered by young, startup firms. We examine how the financier's unique resources influence the startup inventor's

and the financier's incentives to specialize their resources, on the one hand, and to expropriate each other's resources, on the other hand. We show that the optimal financing choice serves to balance the benefits from complementary resources against the temptation for misappropriation that is induced by the presence of such complementary resources. A novel result we obtain is that while increased complementarity increases the likelihood of CI financing when the resources are difficult to expropriate, this result is *reversed* when the resources are easy to expropriate. Therefore, we assert that increased complementarity between the startup's idea and the corporation's existing business generates *both a cost and a benefit*. Whether increased complementarity is a boon or a bane with respect to the likelihood of CI financing depends upon whether the resources are easily expropriable or not.

Though we examined the robustness of our results by allowing for allocation of control rights in Section 5.2, this was not the focus of the study. The framework employed here can be extended to study the optimal allocation of control rights in CI financing vis-à-vis that in VC financing. More generally, the interaction between the nature of control rights and the financing choice is a potential area for future research.

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Appendix A – Changing the Bargaining Model

In this Appendix, we show that the distortions in the investment by the Scientist and the Financier would exist even if the Bargaining model for deciding the split of surplus at date 2 is changed. Then, we proceed to argue that the analysis in the paper would remain unaltered in this case.

As an alternative model of bargaining, let us use the alternating-offers protocol of Rubinstein (1982) that is employed by De Meza and Lockwood (1998) to question the generality of the Grossman-Hart-Moore results on ownership. As specified in Section 2.1, the bargaining for the surplus R occurs at date 2 after the contract has been signed at date 0 and after the investments are already sunk by both the scientist and the financier.

Bargaining occurs over multiple rounds $k = 1, 2, \ldots$. At the beginning of the first round, either the Scientist(S) or the Financier (F) is selected to be the proposer with probability 0.5. If the proposer is agent i, he proposes a split x_i so that S gets x_i, while F gets $R - x_i$. After agent i proposes, the responder $j \neq i$ has three choices. First, j can accept the proposal in which case the bargaining game ends. Second, j can reject the proposal in which case both agents get zero over that round and bargaining proceeds to the next round where j gets to make a proposal. Third, j could choose to terminate the bargaining process, in which case both S and F are obliged to pursue their own opportunities individually. In this case, S and F get their outside options r_S and r_F respectively. We allow only the responders to terminate the bargaining process since this ensures uniqueness of the solution to this bargaining game. Finally, the discount factor for both agents is $\tau < 1$.

The realized payoffs to S and F in equilibrium depend upon whether their outside options bind or they are slack. The realized payoffs to S and F, v^S and v^F, respectively are as follows:

$$
\left(v^S, v^F\right) = \begin{cases} (0.5R, 0.5R) & \text{if} \quad r_S \leq 0.5R \text{ and } r_F \leq 0.5R \\ (R - r_F, r_F) & \text{if} \quad r_S > 0.5R \text{ and } r_F \leq 0.5R \\ (r_S, R - r_S) & \text{if} \quad r_S \leq 0.5R \text{ and } r_F > 0.5R \end{cases} \tag{65}
$$

Given ex-ante uncertainty about the returns from investment and the respective outside options, the expected payoff for each agent is the expectation of the payoff over the above three scenarios. To account for this uncertainty, say that the ex-ante probability (i.e. probability at date 0) that the outside option of the scientist is binding (i.e. $r_S > 0.5R$) is p^S. Similarly, say that the ex-ante probability that the outside option of the financier is binding (i.e. $r_F > 0.5R$) is p^F. Then, the probability that neither agent's outside option is binding is $1 - p^S - p^F$. Therefore the expected payoff of the scientist is

$$
\begin{aligned}
TS^S &= \left(1 - p^S - p^F\right) \cdot \frac{R}{2} + p^S \left(R - r_F\right) + p^F r_S \\
&= \left(1 + p^S - p^F\right) \cdot \frac{R}{2} - p^S r_F + p^F r_S
\end{aligned} \tag{66}
$$

where the expectation is taken at date 1 when the scientist decides the level of investment to make.

Similarly, the expected payoff to the financier is

$$TS^F = \left(1 - p^S + p^F\right) \cdot \frac{R}{2} + p^S r_F - p^F r_S \tag{67}$$

Given these payoffs, the second-best investment levels e_S^* and e_F^* are given by the following first order conditions

$$\frac{1 + p^S - p^F}{2} \cdot \frac{dR}{de_S}\left(e_S^*, e_F^*\right) + p^F \cdot \frac{dr_S}{de_S}\left(e_S^*, e_F^*\right) - p^S \cdot \frac{dr_F}{de_S}\left(e_S^*, e_F^*\right) = 1 \tag{68}$$

$$\frac{1 - p^S + p^F}{2} \cdot \frac{dR}{de_F}\left(e_S^*, e_F^*\right) + p^S \cdot \frac{dr_F}{de_F}\left(e_S^*, e_F^*\right) - p^F \cdot \frac{dr_S}{de_F}\left(e_S^*, e_F^*\right) = 1$$

Comparing the above first order conditions to the those for the first-best level of investments, we can see that

$$p^F \cdot \frac{dr_S\left(e_S^*, e_F^*\right)}{de_S} - p^S \cdot \frac{dr_F\left(e_S^*, e_F^*\right)}{de_S} \underset{>}{\overset{\leq}{\lessgtr}} \frac{\left(1 + p^S - p^F\right)}{2} \cdot \frac{dR\left(e_S^*, e_F^*\right)}{de_S} \Leftrightarrow e_S^* \underset{>}{\overset{\leq}{\lessgtr}} e_S^{FB}$$

. Similarly,

$$p^S \cdot \frac{dr_F\left(e_S^*, e_F^*\right)}{de_F} - p^F \cdot \frac{dr_S\left(e_S^*, e_F^*\right)}{de_F} \underset{>}{\overset{\leq}{\lessgtr}} \frac{1 - p^S + p^F}{2} \cdot \frac{dR}{de_F}\left(e_S^*, e_F^*\right) \Leftrightarrow e_F^* \underset{>}{\overset{\leq}{\lessgtr}} e_F^{FB}$$

. Therefore, we get the problem of over-investment and under-investment as in the case of the 50:50 Nash bargaining solution.

The intuition for the generality of the results is the following. The over-investment and the under-investment result from the difference in the marginal values of the outside option and that of the surplus produced in the relationship. For the bargaining game used here, the no trade payoffs r^S and r^F do not affect the equilibrium payoffs over a certain range of the levels of the outside options. However, what is important for the analysis here is that the no-trade payoffs sometimes matter, not that they always matter. Therefore, with some amount of ex-ante uncertainty about the investment returns (i.e. surplus R and the no-trade payoffs), the no-trade payoffs will affect the equilibrium division of surplus with positive probabilities. Therefore, the analysis under alternative-offers bargaining is similar to the axiomatic 50:50 Nash bargaining.

Appendix B – Proofs of Propositions

Proof of Lemma 1:

$$r_i = 0.5k\left(1 - \mu^2\right) + (1 - \mu)\beta^{\lambda/2}\theta_i^{\lambda/2}e_i^{1/2} - \gamma(1 - \mu)^2\beta^{\lambda/2}\theta_j^{\lambda/2}e_j^{1/2}$$

$$r_S + r_F = k\left(1 - \mu^2\right) + \left[\theta_S^{\lambda/2}e_S^{1/2} + \theta_F^{\lambda/2}e_F^{1/2}\right]\beta^{\lambda/2}(1 - \mu)\left[1 - \gamma(1 - \mu)\right]$$

$$< k + \left[e_S^{1/2} + \theta_F^{\lambda/2}e_F^{1/2}\right]\beta^{\lambda/2} \because \mu, \gamma, \theta_S, \theta_F \in [0, 1]$$

$$= R$$

Therefore

$$r_S + r_F < R \ \forall e_S, e_F, \theta_S, \theta_F,, \delta \tag{69}$$

◇

Proof of Proposition 1: The first-best and second-best investments are given by

$$\frac{dTS\left(e_i^{FB}\right)}{de_i} = 0 \tag{70}$$

$$\frac{d\Pi_i\left(e_i^*\right)}{de_i} = 0 \tag{71}$$

Now

$$TS = k + \beta^{\lambda/2}e_S^{1/2} + \beta^{\lambda/2}e_F^{1/2} - e_S - e_F$$

$$\frac{d^2TS}{de_i^2} = -\frac{1}{2}\beta^{\lambda/2}e_i^{-3/2} < 0$$

Therefore, a maximum exists. We reproduce equations (19) and (21) here

$$e_i^* = \frac{1}{4}\beta^\lambda \left[\frac{1 + \Lambda\theta_i^{\lambda/2}}{2}\right]^2 \tag{72}$$

$$e_i^{FB} = \frac{1}{4}\beta^\lambda \tag{73}$$

Using A2 we get since $\gamma > 0$ and $\Lambda = (1-\mu)\{1 + \gamma(1-\mu)\}$

$$(1-\mu)\theta_i^{\lambda/2} > 1 \Rightarrow \Lambda\theta_i^{\lambda/2} > 1$$

Therefore $e_i^* > e_i^{FB}$. ◇

Proof of Proposition 2: Reproducing equation (19) we get

$$e_i^* = \frac{1}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]^2 \beta^\lambda \tag{74}$$

$$\frac{de_i^*}{d\mu} = -\frac{1}{8}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\theta_i^{\lambda/2}[1 + 2\gamma(1-\mu)]\beta^\lambda < 0 \tag{75}$$

$$\frac{de_i^*}{d\gamma} = \frac{1}{8}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\theta_i^{\lambda/2}(1-\mu)^2\beta^\lambda > 0 \tag{76}$$

$$\frac{de_i^*}{d\theta_i} = \frac{1}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\Lambda\lambda\theta_i^{0.5\lambda-1}\beta^\lambda > 0 \tag{77}$$

$$\frac{de_i^*}{d\beta} = \frac{\lambda}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]^2\beta^{\lambda-1} > 0 \tag{78}$$

$$\frac{de_i^*}{d\lambda} = \frac{1}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]^2\beta^\lambda\ln\beta + \frac{1}{16}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\Lambda\theta_i^{\lambda/2}\ln\theta_i \tag{79}$$

$$\theta_i > 1 \Rightarrow \frac{de_i^*}{d\lambda} > 0$$

◇

Proof of Proposition 3: Using (19) and (21) we get

$$e_i^* - e_i^{FB} = \frac{\beta^\lambda}{16}\left[3 + \Lambda\theta_i^{\lambda/2}\right]\left[\Lambda\theta_i^{\lambda/2} - 1\right] \tag{80}$$

Therefore $e_i^* - e_i^{FB}$ is proportional to $\Lambda\theta_i^{\lambda/2} - 1 = (1 - \mu)\{1 + \gamma(1 - \mu)\}\theta_i^{\lambda/2} - 1.$ $\diamondsuit$

Proof of Proposition 4: Reproducing (29), we get

$$TS^*(\beta_{CI}) - TS^*(\beta_{VC}) = (\beta_{CI} - \beta_{VC})\frac{dTS^*}{d\beta} \tag{81}$$

$$= \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16}\sum_{i \in S,F}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\left[3 - \Lambda\theta_i^{\lambda/2}\right] \tag{82}$$

Since $\beta_{CI} > \beta_{VC}$,

$$\Lambda\theta_i^{\lambda/2} \gtreqqless 3 \Rightarrow TS^*(\beta_{VC}) \gtreqqless TS^*(\beta_{CI})$$

$\diamondsuit$

Proof of Result 1:

$$\frac{d\Psi}{d\lambda} = \frac{(\beta_{CI} - \beta_{VC})\beta^{\lambda-2}}{16}[\beta + \lambda(\lambda - 1)]\sum_{i \in S,F}\left[1 + \Lambda\theta_i^{\lambda/2}\right]\left[3 - \Lambda\theta_i^{\lambda/2}\right] \tag{83}$$

$$+\frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16}\sum_{i \in S,F}\left[1 - \Lambda\theta_i^{\lambda/2}\right]\theta_i^{\lambda/2}\ln\theta_i$$

$$\frac{d^2\Psi}{d\lambda d\theta_i} = \frac{(\beta_{CI} - \beta_{VC})\beta^{\lambda-2}}{16}[\beta + \lambda(\lambda - 1)]\sum_{i \in S,F}\lambda\left[1 - \Lambda\theta_i^{\lambda/2}\right]\theta_i^{0.5\lambda-1} \tag{84}$$

$$+\frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16}\sum_{i \in S,F}\theta_i^{0.5\lambda-1}\left\{\left[1 - \Lambda\theta_i^{\lambda/2}\right] + \lambda\left[0.5 - \Lambda\theta_i^{0.5\lambda}\right]\ln\theta_i\right\}$$

Using $(A2)$, it follows that $0.5 < 1 < \Lambda\theta_i^{\lambda/2}$. Also since $\beta > 1, \beta + \lambda(\lambda - 1) > 0$. Clearly, the first term above is negative. The second term is negative if $\theta_i > 1$. In fact, as long as θ_i is not a very small fraction, the second term is negative as well. Therefore,

$$\frac{d^2\Psi}{d\lambda d\theta_i} < 0$$

It is easy to check by setting $\lambda = 0$ that $\frac{d\Psi}{d\lambda}$ can take both negative and positive values depending upon whether $\Lambda\theta_i^{\lambda/2} < 3$ or $\Lambda\theta_i^{\lambda/2} > 3$. Since $\frac{d\Psi}{d\lambda}$ can take both positive and negative values, there exists a unique $\widehat{\theta}$ such that if

$$\theta \leq \widehat{\theta} \Rightarrow \frac{d\Psi}{d\lambda} \geq 0$$

$$\theta > \widehat{\theta} \Rightarrow \frac{d\Psi}{d\lambda} < 0$$

Since Ψ takes on both positive and negative values (as seen from Proposition 3), it follows that there exists a unique root $\widehat{\lambda}$ such that $\Psi\left(\lambda = \widehat{\lambda}\right) = 0$. Using the monotonicity of Ψ w.r.t. λ above, the result follows. $\diamondsuit$

Proof of Result 2:

$$\frac{d\Psi}{d\mu} = \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \sum_{i \in S,F} 2\theta_i^{\lambda/2} \left[1 - \Lambda\theta_i^{\lambda/2}\right] \frac{d\Lambda}{d\mu} \tag{85}$$

$$= -\frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \left[1 + 2\gamma(1-\mu)\right] \sum_{i \in S,F} 2\theta_i^{\lambda/2} \left[1 - \Lambda\theta_i^{\lambda/2}\right] \because \Lambda = (1-\mu)\{1 + \gamma(1-\mu)\}$$

$$> 0 \because \Lambda\theta_i^{\lambda/2} > 1 \text{ using (A2) and } \gamma > 0$$

Again, using the fact that Ψ takes on both positive and negative values, the result follows. $\lozenge$
Proof of Result 3:

$$\frac{d\Psi}{d\gamma} = \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \sum_{i \in S,F} 2\theta_i^{\lambda/2} \left[1 - \Lambda\theta_i^{\lambda/2}\right] \frac{d\Lambda}{d\gamma} \tag{86}$$

$$= \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} (1-\mu)^2 \sum_{i \in S,F} 2\theta_i^{\lambda/2} \left[1 - \Lambda\theta_i^{\lambda/2}\right] \because \Lambda = (1-\mu)\{1 + \gamma(1-\mu)\}$$

$$< 0 \because \Lambda\theta_i^{\lambda/2} > 1 \text{ using (A2) and } \gamma > 0$$

Again, using the fact that Ψ takes on both positive and negative values, the result follows. $\lozenge$
Proof of Result 4:

$$\frac{d\Psi}{d\theta_i} = \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \sum_{i \in S,F} \Lambda\lambda\theta_i^{0.5\lambda-1} \left[1 - \Lambda\theta_i^{\lambda/2}\right] \tag{87}$$

$$< 0 \because \Lambda\theta_i^{\lambda/2} > 1 \text{ using (A2) and } \gamma > 0$$

Again, using the fact that Ψ takes on both positive and negative values, the result follows. $\lozenge$
Proof of Result 5:

$$\frac{d^2\Psi}{d\theta_i d\gamma} = \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \sum_{i \in S,F} \frac{d\Lambda}{d\gamma}\lambda\theta_i^{0.5\lambda-1} \left[1 - 2\Lambda\theta_i^{\lambda/2}\right] \tag{88}$$

$$< 0 \because \frac{d\Lambda}{d\gamma} = (1-\mu)^2 > 0 \text{ and } 1 < \Lambda\theta_i^{\lambda/2} < 2\Lambda\theta_i^{\lambda/2}$$

$\lozenge$
Proof of Result 6:

$$\frac{d^2\Psi}{d\theta_i d\mu} = \frac{\lambda\beta^{\lambda-1}(\beta_{CI} - \beta_{VC})}{16} \sum_{i \in S,F} \frac{d\Lambda}{d\mu}\lambda\theta_i^{0.5\lambda-1} \left[1 - 2\Lambda\theta_i^{\lambda/2}\right] \tag{89}$$

$$> 0 \because \frac{d\Lambda}{d\mu} = -\left[1 + 2\gamma(1-\mu)\right] \text{ and } 1 < \Lambda\theta_i^{\lambda/2} < 2\Lambda\theta_i^{\lambda/2}$$

$\lozenge$
Proof of Proposition 5: is identical to that for Proposition 4 except using (42).$\lozenge$

Proof of Proposition 6: Reproducing the expressions for ω^{FB} and ω_i from (51),

$$\omega^{FB} \equiv \arg\max_{\omega} \ TS^*(\omega) = \left\{ \frac{\beta^\lambda}{32} \sum_{i \in S,F} \left[1 + \Lambda\theta_i^{\lambda/2}\right]\left[3 - \Lambda\theta_i^{\lambda/2}\right] \right\}^2 \tag{90}$$

$$\omega_i \equiv \arg\max_{\omega} \ \Pi_i^*(\omega) = \left\{ \frac{\beta^\lambda}{32} \sum_{i \in S,F} \left[1 + \Lambda\theta_i^{\lambda/2}\right]^2 \right\}^2$$

we can see that since $\theta_S \neq \theta_F \Rightarrow \omega_S \neq \omega_F$. Also from the above expressions, it is clear that $\omega_i \neq \omega^{FB}.\diamondsuit$

Proof of Proposition 7: is identical to that for Proposition 4 except using (55).$\diamondsuit$

Proof of Proposition 8: Note that, because the scientist has all the bargaining power at date 0 and the financier is not liquidity constrained, the participation constraint (58) must be binding in the optimal contract, which implies that

$$q^*(s) = U - \Pi_S^* \tag{91}$$

so that

$$\Pi_F^* + s - q^*(s) = \Pi_F^* + \Pi_S^* + s - U \tag{92}$$

$$\arg\max_{(\varphi,\Omega,q(s))} \ [\Pi_F^* + s - q^*(s)] \equiv \arg\max_{(\varphi,\Omega)} [\Pi_S^* + \Pi_F^* + s] \tag{93}$$

which completes the proof.$\diamondsuit$

Proof of Proposition 9: is identical to that for Proposition 4 except using (64).$\diamondsuit$