Weak Property Rights and Holdup in R&D

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We study how the sequence of financing of R&D varies according to the ease with which property rights over knowledge can be defined. There are two financiers: a venture capitalist (VC) *and a corporation. The knowledge acquired in costly research becomes embodied in the researcher's human capital, and she may hold up the financier and walk away with the project to develop it elsewhere. The main results are: (1) When property rights are strong, research is always funded by the* VC*, development is performed efficiently, and breakaways from the* VC *to the corporation are observed in equilibrium. (2) When property rights are weak, projects may be financed by the* VC *or the corporation, or may remain unfunded. (3) When property rights are weak, no breakaways occur in equilibrium; local spillovers and strong product market competition increase the likelihood that research projects will get funding. (4) The equilibrium sequence of R&D finance need not be first-best efficient. (5) In equilibrium, and controlling for the strength of property rights,* VC*s finance projects that are more profitable on average.*

1. Introduction

When looking at the financing of entrepreneurial ventures in the United States one confronts a few outstanding puzzles. First, despite the prevalent view that venture capital is a better mode of governance, considerable R&D activity occurs within corporations. Second, there is some evidence that venture-capital financing has, on average, generated superior returns and accounted for a disproportionate share of

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mega-successes. Nevertheless, persistent differences in performance are surprising, particularly since the robust venture-capital activity over the past two decades has attracted so much attention and the nature of venture-capital finance been dissected so thoroughly (see, for example, Gompers and Lerner, 1999). Indeed, there is some evidence that when corporations mimic venture capitalists (VCs), they do rather well (see Gompers and Lerner, 1998), further amplifying the question why more corporate intrapreneurship is not organized similarly. Third, while the study of IPOs as an exit mechanism for venture capitalists has attracted considerable attention, more than one-third of all VC exits are in the form of corporate acquisitions or trade sales. This raises the question: when should one or the other form of exit be observed? Then, a fourth question arises: why is VC-backed research followed by corporate acquisitions so common while the reverse—corporate-financed research followed by independent development—is not? Asset sales by corporations are certainly common, so what is different about R&D projects? This paper uses an equilibrium approach to study the sequence of financing of R&D, and analyzes these puzzles within a unified framework.

To explain these facts, one must determine what is special about R&D. We focus on two appropriability problems that are endemic to R&D.[1] First, it is often the case that the knowledge acquired through costly research becomes embodied in the human capital of the researcher, not necessarily in the firm for which the research is performed.[2] In many cases property rights over this knowledge are weak because it is nonverifiable. Weak property rights enable the researcher to hold up the financier by threatening to walk away with the project.[3]

1. Theoretical papers that focus on appropriability problems include Anton and Yao (1994, 1995) and Bhattacharya and Ritter (1983). Empirical papers include Cohen et al. (1996), Levin et al. (1987), and Anand and Khanna (2000).

2. As the *The Economist* notes, "... the term 'technology transfer' is something of an oxymoron. Real innovations do not move from laboratory to shopfloor as patents, research reports, or even working prototypes. To stand any chance of success, they have to be transferred as concepts embedded in people's heads. The one time an innovation (laser imaging) made it successfully out of (Xerox) PARC to become a multi-billion dollar business for Xerox, it was because the person who championed it in the laboratory, Robert Adams, moved with it and drove the innovation hard through engineering, manufacturing, marketing, and sales." ("Adopting Orphans," February 20, 1999.)

3. The importance of the threat of holdup can be inferred from the examples of entrepreneurial breakaway. For example, "[Xerox] PARC is famous for having pioneered ideas (including a superior personal computer, the facsimile machine, the Ethernet, and the laser printer) that made fortunes for many of its Silicon Valley neighbours, but little for itself" ("Adopting Orphans," *The Economist*, February 20, 1999); see also Lerner (1995a) and "Xerox Won't Duplicate Past Errors," *Business Week*, September 29, 1997). Elsewhere, *The Economist* notes that "... people at Bell Labs have still not forgotten how, half a century ago, William Shockley took the transistor idea, which he and his colleagues had invented at Murray Hill, to Palo Alto in California and started

Moreover, the usual solution of allocating property rights over the output of research may not be feasible, since knowledge itself is nonverifiable and is embodied in the researcher.

Second, corporations and VCs are different financiers: specifically, a corporation cannot replicate the control rights and cash-flow allocations granted by a VC, because many of their activities are joint or nonseparable. Joint activities enable the corporation to inflate costs and shift revenues across activities, making surpluses nonverifiable. This limits the ability of a corporation to commit *ex ante* to share profits with the researcher.[4] By contrast, VCs finance standalone projects and therefore can commit to share profits.

Starting from these two premises, we construct a model with two phases, research and development. The output of the research phase is *knowledge*, which becomes embodied in a researcher and is necessary to develop the the idea into a marketable innovation. Each phase can be financed by either a VC or a corporation, and the researcher can switch financiers after research. Both financiers are equally able to screen, monitor, and add value to a project in the research phase. Nevertheless, they differ on three accounts: first, the VC can commit *ex ante* to any arbitrary surplus-sharing rule, but the corporation cannot; second, the corporation can take advantage of local spillovers to learn about the project and develop the innovation without the researcher's participation, but the VC cannot; third, development may be more efficient with one or the other financier. We parametrize the strength of property rights over knowledge as the probability that the financier can establish its rights over the innovation's cash flow should the researcher switch financiers after the research phase. We then study how the sequence of financing of R&D endogenously depends on the strength of property rights over the knowledge created in research.

We obtain the following results. First, when property rights are strong, research is always funded by the VC and development is performed efficiently. Second, when property rights are weak, either the corporation or the VC finances both research and development, or the project gets no funding. Thus, researchers never break away when property rights are weak; breakaways from the VC to the corporation are observed in equilibrium, but only when property rights are strong. Third, when property rights are weak, the equilibrium sequence of

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a company (Fairchild Semiconductor) that eventually became Intel. As president of Bell Labs' New Ventures Group, Thomas Uhlman is out to see that no more Intels are allowed to escape." (*The Economist*, ibid., February 20, 1999.)

4. Pakes and Nitzan (1983) also analyze the consequences of researcher mobility. Nevertheless, they assume that contracts are complete so that the corporation can commit *ex ante* to share the project's surplus.

financing of R&D need not be first-best efficient. Fourth, when property rights are weak, local spillovers (i.e., knowledge that spills over to the corporation) and strong product-market competition by the corporation in case of a spinoff increase the likelihood that research projects will get funding. This second-best result suggests that different appropriability problems may neutralize each other instead of adding up. Last, we show that in equilibrium and controlling for the strength of property rights, VCs finance projects that are, on average, more profitable.

Several recent studies examine, on the one hand, the range and difficulties of internal corporate venturing activities (see, for example, Kanter, 1989; Block and Macmillan, 1995; Lerner, 1995b). On the other hand, others have analyzed the structure and role of venture-capital financing (see, for example, Admati and Pfleiderer, 1994; Amit et al., 1990; Barry, 1990; Gompers, 1995; Gompers and Lerner, 1996; Lerner, 1994; Neher, 1995; Sahlman, 1990). We explicitly model the choice of financier and study it in an equilibrium framework.

Several recent papers study the financing of innovation theoretically. In an incomplete-contracts framework, Aghion and Tirole (1994) assume that the output of research cannot be described *ex ante*. They show that incentives to make nonverifiable investments and exert effort can be provided by choosing the allocation of property rights over the final innovation. Like them, we assume that financing contracts are incomplete and that knowledge becomes embodied in the researcher. Nevertheless, in our model, the strength of property rights over knowledge is an attribute of the project and cannot be altered.[5] Since inefficiencies cannot be mitigated by optimally choosing the allocation of property rights, the question of whether the project will then be financed remains. In addition, we go beyond Aghion and Tirole by allowing for an additional financier (a VC) and explicitly distinguishing between research and development. This enables the researcher to switch financiers after acquiring knowledge and introduces a holdup problem, forcing us to examine how the incentive of the researcher not to cheat *ex post* is preserved. The distinction between research and development phases allows us to characterize the equilibrium sequence of financing of R&D.

Our paper is also related to Hellmann (1997), who examines the choice between VC and corporate financing of new ventures. In his

5. Intellectual-property rights may be weak when it is difficult to clearly specify the boundaries of the knowledge being contracted upon. Indeed, there is evidence that trailer clauses and other contractual devices aimed at preventing entrepreneurial holdup are remarkably weak in many situations. Anand and Khanna (2000) discuss why it may be useful to think of the strength of property rights as exogenous.

model, the corporation helps projects that complement existing operations, but hinders projects that are substitutes (e.g., a project that would cannibalize existing products). Hence, the larger are the benefits to existing operations, the greater are the advantages of corporate finance. Conversely, VC financing dominates when the project hurts the corporation's current activities. We depart from Hellmann by assuming that the corporation cannot commit to share the surplus created by the innovation, because it can manipulate the accounts of the new venture; moreover, this is independent of whether the project is a complement or a substitute to existing operations. Thus, in our model, the researcher may prefer VC financing even when the corporation can exploit complementarities. Furthermore, since Hellmann considers neither appropriability issues nor the possibility of switching between financiers, both our results on the influence of weak property rights and those concerning the finance cycle of R&D are novel.

Finally, Anton and Yao (1994, 1995) have also studied the consequences of weak property rights. In their 1995 paper, they consider the case of an employee-researcher who already has an idea that can be efficiently developed with the help of her corporate employer. While the researcher may be expropriated after revealing the idea to her employer, they show that, in equilibrium, she will not break away and will appropriate part of the project's surplus. Like Anton and Yao, we assume that the researcher's bargaining power stems from the possibility of leaving to develop the innovation elsewhere.[6] However, we add a research stage and study how the possibility of an *ex post* breakaway by the researcher will affect the *ex ante* incentives of the corporation to finance research.[7] We show that the possibility of walking away with knowledge creates a *reverse* holdup problem (i.e., the researcher holds up the corporation), but need not prevent financing. Indeed, we find conditions under which breakaway will not occur in equilibrium even when property rights are weak and corporate development is inefficient. We also study the case when property rights are strong and the financier can establish property rights over knowledge. Strong property rights reduce the value of the researcher's outside option and increase the corporation's willingness to finance, but, on the other hand, they make the researcher vulnerable to an *ex post* holdup by the corporation. We show that in this case the researcher obtains funds from an outside financier.

6. Similarly, Anton and Yao (1994) show that the inventor can prevent the financier from stealing the innovation by threatening to reveal the idea to a competitor and increasing product-market competition.

7. Indeed, this is the main (efficiency) argument against limiting the scope of noncompete contracts for employees.

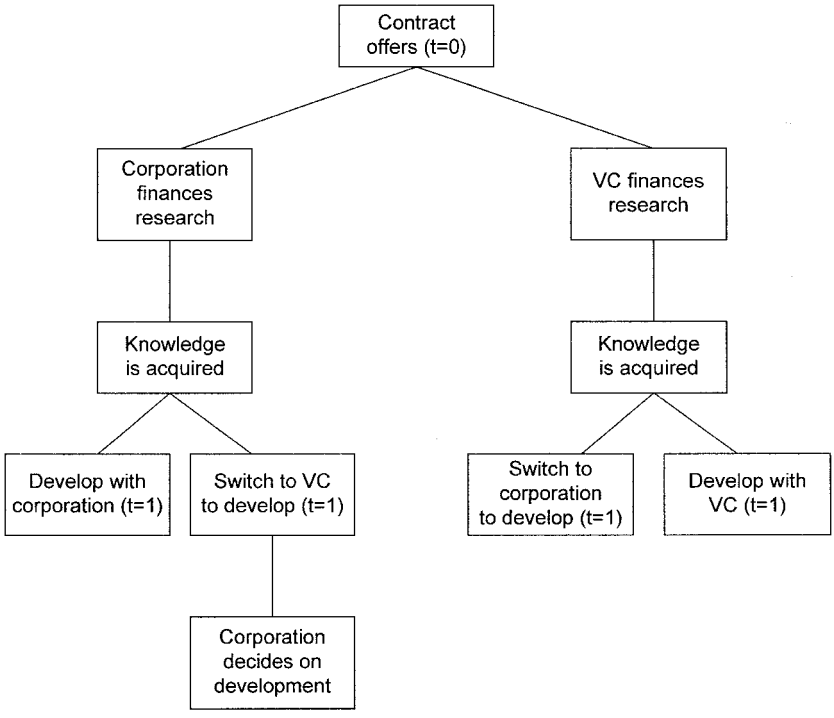

FIGURE 1. TIMELINE

The rest of the paper proceeds as follows. Section 2 presents the model and discusses why corporations and VCs are different financiers. Section 3 solves the model and studies the sequence of financing of R&D. Section 4 presents four applications of the model. Section 5 concludes.

2. The Model

2.1 The Setup and the Main Questions

There are two periods: a research phase and a development phase; and three dates: date 0, before research; date 1, in between research and development; and date 2, after development (see Fig. 1 for the timeline of the game). The output of the research phase is *knowledge*. This knowledge is necessary in the development phase, which yields a marketable innovation.

There is a measure c of cash-constrained researchers and two financiers: a corporation and a VC. All are risk-neutral. One and only one researcher has the ability to turn an idea into useful knowledge at cost R, and, as in Hellmann (1997), there is asymmetric information: while each researcher knows her ability at date 0, financiers do not. All uncertainty about researcher ability is revealed after the research

TABLE I.

NOTATION

R	Cost of research
D^r, D^c	Cost of development
S	Value of innovation (monopoly)
S^r, S^c	Value of innovation (duopoly)
$v \in [0, 1]$	Verifiability of research
$b \in [0, 1]$	Strength of local spillovers
$\phi_{r\&d}$, ϕ_r	VC R&D contract
ϕ_d	VC development contract
$\psi_{r\&d}$	Corporate R&D contract
ψ_d	Corporate development contract

phase at date 1, but ability is nonverifiable and cannot be contracted upon.[8] Researchers cannot divert any funds during the research phase and derive no intrinsic utility from being financed in research. Nevertheless, a financier will not make any cash payments beyond R at date 0, because that would attract a lemon with probability one.

In both the research and the development phase, the researcher can obtain funding from either the VC or the corporation, and she can switch financiers at date 1. The development cost is D^r if the researcher partners with the VC (call this *independent development*), and D^c if the researcher partners with the corporation (call this *joint development*), with $D^r \lesseqgtr D^c$.[9] (The notation is summarized in Table I.) The assets required for development cannot be rented from the more efficient party. For example, if $D^c < D^r$, the only way of exploiting this cost advantage is to develop jointly. Once brought to market, the innovation yields a surplus worth S in present value if exploited monopolistically. We further assume that $S - R - \max\{D^r, D^c\} > 0$: net surpluses are positive.

8. This rules out a contract specifying "I will pay you $\$X$ upon its being revealed that you are a good researcher."

9. The case of $D^r > D^c$ may result from a corporation being able to provide easier access to markets, supplies, and finance because of existing operations or because it can leverage existing assets (for example, its patent base) cheaply. For example, Kids R Us, founded by Toys R Us, was a new product line (children's clothes) but in a familiar market, so it could use its industry-specific skills to select styles and manufacturers, buy, display, and sell products, process information, and control inventories; see Block and Macmillan (1995) for other examples and Teece (1992) for a discussion of complementary assets. On the other hand, there may be reasons why $D^r < D^c$: a VC, by virtue of serving on multiple boards of portfolio companies and receiving and financing a large array of deals, is probably more familiar with the common mistakes and sources of failure in a business than is a corporation, which essentially has experience with a single business model or process. In addition, venture capitalists are usually successful former entrepreneurs with industry-specific expertise and a unique network of personal relationships. For example, at Kleiner Perkins each partner is required to have previous experience running a company or working near the top. According to *Fortune* ("Silicon Valley Machine," October 26, 1998), "Kleiner Perkins' pals ... include the founders of Netscape, Cisco, AOL, Intuit, Intel, TCI, Sun, Lotus, and Comcast."

In the spirit of Grossman and Hart (1986) and like Aghion and Tirole (1994), we assume that neither knowledge nor the innovation can be described at date 0. Thus, at date 0, parties cannot write a contract that fixes a payment upon delivery of either knowledge at date 1 or the innovation at date 2. In addition, knowledge becomes embodied in the researcher, and parties can define property rights over it only imperfectly. We model this assuming that if the researcher switches at date 1 after the research phase to pursue development elsewhere, the financier can establish its rights over the innovation's cash flow as specified in the contract signed at date 0 with probability v; with probability $1 - v$ the financier is unable to establish its rights. Weak property rights give rise to the holdup problem: the researcher has an incentive to switch financiers at date 1, right after the research phase. The question is whether the holdup problem can be solved, since the usual solution of allocating property rights over knowledge is not feasible.

The second question of interest concerns the sequence of financing of R&D. Assuming that the holdup problem can be solved, it would seem that the financier with the cost advantage in development should always be able to assure the researcher of getting at least as much as she could by partnering with another financier. Consequently, will breakaway ever be observed in equilibrium? To study this we must first discuss the differences between the VC and the corporation.

2.2 What Is Different about Corporations?

Since neither knowledge nor the innovation can be described at date 0, contracts can at most specify how the project's surplus S will be shared. As we discuss in this subsection, however, the next two assumptions imply that only the VC can commit to a sharing rule.

Assumption 1 (Account Manipulation): Any costs incurred by the corporation in the financing of research or development and any revenues generated in the subsequent marketing of the innovation are nonverifiable. By contrast, the VC cannot manipulate the project's accounts.

Assumption 2 (Local Spillovers): If the corporation finances research, it learns the knowledge with probability b; then it can develop the innovation after date 1 even if the researcher leaves. Local spillovers are nonverifiable. By contrast, the VC cannot exploit local spillovers.

These assumptions follow from the jointness or nonseparability of activities within corporations (Alchian and Demsetz, 1972), which may become manifest in a variety of ways. Assets or resources—

e.g., lab facilities, centralized purchasing facilities, and managerial time—are often shared across activities and projects; the transfer of know-how or best practices across projects may be common; or the communication of information may be essential, even inevitable (see Chandler, 1966). Similarly, processes and outputs may need to be compatible in order to function together,[10] products may be cross-sold or bundled,[11] and new products may cannibalize existing ones.

Of course, a corporation should be able in principle to mimic the organization of a stand alone project, in which case the organization of R&D within and outside corporations should look the same. Nevertheless, the key point is that it may not be *optimal* for the corporation to do so, since complementarities on both the cost side (arising from shared ideas, assets, and time) and on the revenue side (arising from cross-selling, bundling, etc.) would be lost.[12, 13]

The consequence of joint activities is that the proper accounting of costs and revenues for each project may be difficult within the corporation because isolating the components of costs or the sources of revenue generation may be a genuinely hard task. Moreover, it may be in the interest of the corporation to misrepresent costs and revenues to reduce payouts to the researcher. In either case, the net effect is that costs and revenues from projects are at least partially nonverifiable.[14] Holmstrom (1989) rationalizes similar assumptions, arguing that either "the best intentioned firm does not know capital costs," or, even if it does, it "has control of many levers to make accounting measures less reliable." Consequently, "the allocation of costs poses a

10. See, for example, Baldwin and Clark's (1999) study of evolution of the architecture of the PC.

11. Shapiro and Varian (1998) give many examples to illustrate the benefits of bundling, including its role in exploiting scale or scope economies, and in reducing dispersion in consumers' willingness to pay for products.

12. Clearly, the problem of cost and revenue accounting may be more or less severe for different projects. Thus, Assumption 1 is extreme because we do not allow for partial verifiability, which would mitigate accounting problems. We do this because we want to focus on the interaction between nonverifiability and weak property rights. In another paper (Anand and Galetovic, 1999) we assume that the corporation can choose among a continuum of delegation levels and study the trade-off between complementarities and stronger incentives due to delegation.

13. Companies often try to organize ventures to exploit existing corporate know-how, relationships, and operating processes most effectively. For example, Block and Macmillan (1995) argue that "... by far the most important factor to consider in venture organization is the relatedness between the venture's business and the established business."

14. Several recent studies make a similar argument. For example, Feinstein (1995) examines how entrepreneurs can manipulate accounts because of superior information. Aghion and Tirole (1994, p. 1189) also assume that the value of the innovation to the corporation (customer in their paper) is noncontractible because the benefit is shared across many activities within its domain (although the revenue from the particular innovation is verifiable in their model).

dilemma" for firms trying to charge fees for using its assets. Indeed, he argues:

> Difficulties in identifying relevant costs and benefits, so as to make the innovator bear his marginal share, are central. Of course, even as an individual entrepreneur, measurement problems are substantial. The entrepreneur does not know all the relevant figures either. But the knowledge that the money will flow into his own pockets, that nothing will be taken away, still provides appropriate incentives. It is when financial accounts are integrated that the difficulties of measurement become consequential and severe . . . . The key point is that verifiability is an endogenous variable, which depends on the incentives of those who collect the information.[15]

The first implication of Assumption 1 is that the corporation cannot commit to a surplus-sharing rule at any date. Moreover, even though it can make a cash payment to the researcher at any date, it will not do so until date 1; otherwise, it induces adverse selection. Consequently, the most that the researcher can get from the corporation is its outside option after research, viz. what it would get should it leave to pursue independent development with a VC; any other division of surplus agreed to at date 0 would be renegotiated. However, the VC can commit to any surplus-sharing rule at date 0, because it cannot manipulate accounts.[16]

The second implication of Assumption 1 regards the payments the researcher makes in the event of switching financiers. Since research costs are nonverifiable, the corporation might claim they are arbitrarily high if the researcher leaves at date 1. This claim is bounded above by the project surplus S only because of limited liability of the researcher, so that the corporation cannot commit not to

15. The problem of nonverifiability of costs and revenues is not restricted to R&D and may be endemic to corporations. For example, the revenue-accounting problem faced by television networks is severe because lead-in effects and cross-promotions are important determinants of viewing behavior and hence show ratings (see Shachar and Anand, 1998). Similarly, investment banks face a difficult problem when allocating the costs of their research divisions across other groups because many deals involve a number of departments. Nevertheless, Eccles and Crane (1998) report that investment banks rarely resort to complicated fee-splitting algorithms, since they believe that in "fee splitting, as in transfer pricing and cost allocations, there are no right answers." Moreover, "to attempt to do otherwise would ultimately be futile, given the high levels of interdependence created by the economic characteristics and production process of the industry" (p. 156).

16. It may be argued that the researcher could manipulate accounts to avoid sharing surplus with the VC. Nevertheless, this is less likely, because VCs typically finance stand-alone projects.

appropriate the entire gross surplus from the project if the researcher switches financiers.[17] This implies that with probability $1 - v$ the researcher-VC partnership gets nothing; thus, this event can be interpreted as the corporation having effectively blocked the development of the project. In contrast, since the VC cannot manipulate accounts, he can commit at date 0 to limit his payoff in the event of a corporate acquisition.

Finally, Assumption 2 also stems from the fact that the internal organization of the corporation is designed to exploit the complementarities that exist across projects or activities. This will make it more likely that the corporation learns the knowledge and is able to develop the innovation even without the researcher's participation.[18] As Hellmann (1997) points out, the fact that a corporation will generally have a *strategic*, in addition to a purely financial, motive to invest is in fact "central to the identity of a corporation." This feature is also central in Aghion and Tirole (1994), who assume that the corporation has a distinctive position relative to an outside financier (e.g., a bank) because it is also a potential customer of the innovation. Note that if both the corporation and the researcher develop the innovation, they will compete in the product market. We assume that in that case they earn, respectively, surpluses S^c and S^r, with $S^c + S^r \leq S$.

2.3 Timeline

We now describe the timing of actions, also summarized in Figure 1.

1. *Contract offers and research*. At date 0 the corporation and the VC simultaneously offer contracts to the researcher.[19]

   - The VC offers a financing contract $\{\phi_{r\&d}, \phi_r\}$ at date 0. Here $\phi_{r\&d}$ is the amount to be paid to the researcher at date 2 after the innovation is brought to market if the VC financed both

17. Even if the corporation writes a contract claiming that it contributes only R to the research project, it can claim later that the project used assets and employee or managerial time from other projects. This is consistent with the broad claims made by corporations filing for breach of noncompetes (e.g., Hertz vs. Avis, and Wal*Mart vs. Amazon) and the attempts of courts to severely restrict these (e.g., Augat Inc. vs. Aegis Inc.)

18. An example is the recent attempt by Microsoft to develop technology for transmitting video and audio over the Internet to reduce the value of this technology to its breakaway inventor Rob Glaser, who left in 1993 to start RealNetworks Inc. (see "A Former Ally Joins the War On Microsoft," *Wall Street Journal*, July 24, 1998).

19. We can restrict attention to high-quality researchers without loss of generality. Since researchers get paid from project surplus when financed by a VC, and low-quality researchers generate projects with no surplus, the latter would not approach a VC in the first place, since they derive no intrinsic utility from being financed and cannot divert research funds. Although the corporation can make a cash payment right after research, by then all uncertainty about researcher quality is revealed, so a corporation can refuse to pay a low-quality researcher.

research and development (then, the VC gets $S-R-D^r-\phi_{r\&d}$), and ϕ_r is the amount to be paid to the VC if the researcher obtains development financing from the corporation at date 1 and the VC can prove that he seed-financed the project. Limited liability implies that $\phi_r \leq S$.

- The corporation offers a financing contract $\{\psi_{r\&d}\}$. Here $\psi_{r\&d}$ is the amount to be paid to the researcher at date 1 if joint development occurs.[20,21]

2. *Research financed by the VC.* If the researcher accepts VC finance, then:

   - The VC pays R. Then knowledge is acquired by the researcher.
   - At date 1 (after the research phase), either of the following happens:

     1. *VC finances development.* The VC pays the development cost D^r.[22] Surplus S is then shared according to the financing contract $\{\phi_{r\&d}, \phi_r\}$, and the game ends.
     2. *Corporate acquisition or trade sale.* The researcher accepts a take-it-or-leave-it offer from the corporation to pursue development financing: the contract specifies a payment ψ_d to the researcher, with residual profits going to the corporation. Anytime after development costs have been incurred, the VC is paid ϕ_r according to its initial financing contract with the researcher.[23] If no payment is made to the VC, the VC sues and with probability v successfully proves that he seed-financed the project, thereby establishing (senior) claims in the amount

20. Exactly like a VC, the corporation can also offer a financing contract to the researcher that specifies a sharing rule over project surplus. However, as discussed above, because costs and surplus are nonverifiable, the corporation cannot credibly commit to share any surplus from the innovation with the researcher; therefore $\psi_{r\&d}$ cannot be greater than the researcher's *ex post* outside option.

21. Again, recall that since costs are nonverifiable, the corporation cannot commit to limit damages in the event of contract breach. Hence, without loss of generality, we can restrict attention to cases where the corporation does not specify such damages in the financing contract.

22. In our model, neither the VC nor the entrepreneur can commit upfront to continuing with the other party after the research phase: the former because of uncertain researcher quality, the latter because of weak property rights over knowledge. The effects of entrepreneurial holdup on the optimal VC financing contract (timing of payments and staging of financing, respectively) have been studied by Hart and Moore (1994) and Neher (1995).

23. The reason for this restriction is that sinking development costs is the only verifiable action that indicates that the researcher has partnered with another agent.

ϕ_r on the project's surplus.[24] With probability $1-v$, the VC is unsuccessful, and gets nothing. Surplus S is then shared at date 2 between the researcher and corporation according to the acquisition contract, and the game ends.

3. *Research with the corporation.* If the researcher accepts the corporation's offer, then:

   - The corporation pays R. Then knowledge is acquired by the researcher.
   - At date 1 (after the research phase), one of the following happens:

     1. *Corporate development.* The researcher continues with the corporation, who pays D^c to develop the innovation and bring it to market. At date 2 the corporation pays $\psi_{r\&d}$ and appropriates surplus S, and the game ends.
     2. *Spinoff.* The researcher accepts a take-it-or-leave-it offer from the VC to pursue development financing: the contract specifies a payment ϕ_d to the researcher, with the remaining share of the surplus going to the VC. After the researcher leaves, the corporation proves with probability v that it seed-financed the project, in which case development is blocked.[25] With probability $1-v$ the corporation is unsuccessful, the innovation is brought to market, surpluses are shared at date 2, and the game ends.
     3. The corporation decides whether to pursue development on its own; if it does, it spends D^c and is successful in development with probability b.

3. The Sequence of R&D Finance

In this section we study the determination of the equilibrium financing of R&D. We first look at variation in the strength of property rights, ignoring local spillovers (Sections 3.1 and 3.2). We then examine the consequences of local spillovers.

24. This is a simplifying assumption; the effects of other forms of damage payments are qualitatively similar.

25. Equivalently, one can assume that the project goes ahead and with probability v the corporation receives damages up to the entire project surplus S; in either case, the researcher and VC get nothing. This assumption follows from the fact that, since research costs are nonverifiable when financed by the corporation, the latter cannot commit to limiting damages in the event of contract breach.

3.1 Strong Property Rights

What does the sequence of financing of R&D look like when property rights are strong? Proposition 3.1 shows that the VC *always* finances research, but that the innovation is developed efficiently.

Proposition 3.1 (R&D Financing When Property Rights Are Strong): *Let $v \geq R/S$. Then* (i) *the VC always finances research;* (ii) *if $D^r < D^c$, the VC finances development;* (iii) *if $D^r \geq D^c$, the innovation is developed by the corporation.*

Proof. To prove part (i) we show first that the VC is always willing to finance research. If the researcher breaks away at date 1, the VC will get paid with probability v. Since $v \geq R/S$, it follows that the project's gross surplus, S, is at least as large as R/v, the amount required for the VC to recoup R in expected value. Next we show that the corporation cannot offer a research contract that lures the researcher. At date 1 all the bargaining power of the researcher stems from the possibility of leaving to develop independently. In that case, with probability v the corporation successfully prevents development; with probability $1-v$ the corporation cannot prevent development and the researcher gets at most $S - D^r$ (or even less if $bS^c \geq D^c$ and the corporation develops independently). Hence, if the researcher partners with the corporation at date 0, she gets at most

$$\max\{(1-v)S - D^r, 0\}. \tag{3.1}$$

Since by assumption $1 - v \leq (S-R)/S$, this is at most equal to the surplus that is created if the VC finances both research and development, $S - R - D^r$, and generally less. Thus the VC can offer a contract that matches and improves anything that the corporation may offer.

(ii): Suppose that $D^r < D^c$. Then the surplus from staying with the VC at date 1 is greater than the surplus when leaving, and the VC can offer a contract that makes the researcher stay.

(iii): Let $D^r \geq D^c$. Then the surplus created if the researcher leaves to develop with the corporation, $S - R - D^c$, is always at least as large as the surplus that is created if the researcher stays with the VC, $S - R - D^r$. Thus, whatever the share of the surplus the VC would appropriate if the researcher stays, it can get at least as much in expected value from the breakaway fee. Thus, the VC and the researcher will always sign a contract that allows efficient breakaway. □

Figure 2 summarizes the sequence of financing of R&D. When property rights are strong (i.e., to the right of $v = R/S$), the VC always

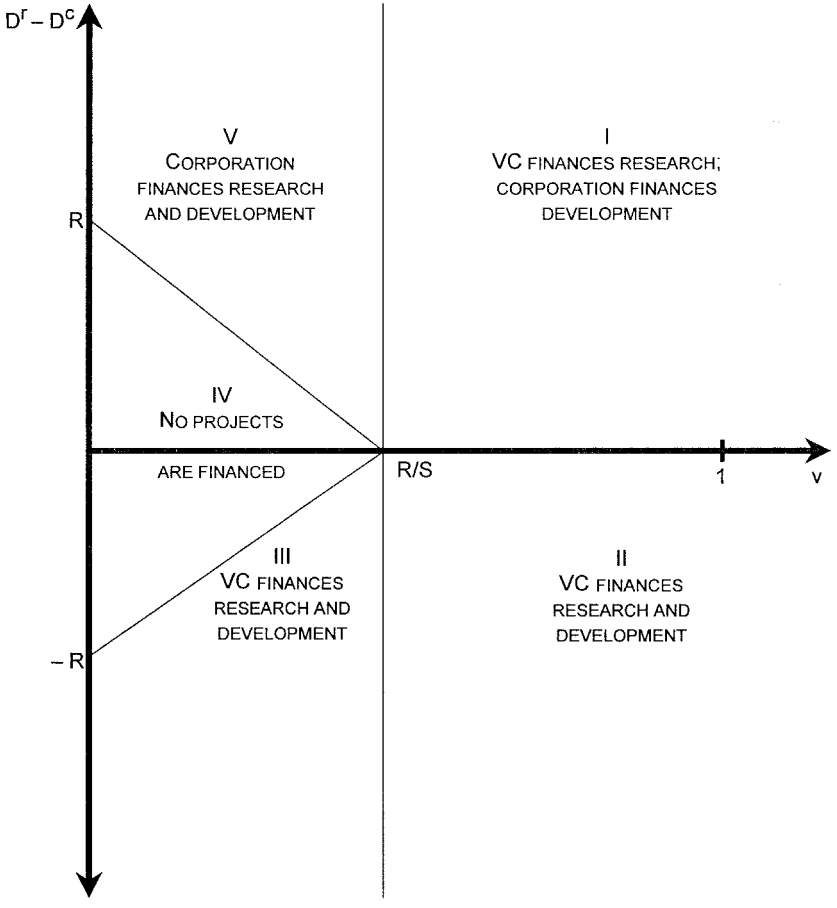

FIGURE 2. THE SEQUENCE OF R&D FINANCE (NO LOCAL SPILLOVERS)

finances research. Nevertheless, when $D^r > D^c$ the corporation develops the innovation (area I); examples of these include *ex post* licenses, manufacturing joint ventures, and acquisitions by the corporation. By contrast, when $D^c > D^r$ both research and development are financed by the VC (area II). Thus, the VC always finances research. In fact, one can obtain an even stronger result, namely, that when property rights are strong, the VC will finance research even when corporate *research* is more efficient. To see this, assume for a moment that research costs differ with financiers, and let R^r be the cost of independent research. Note that condition (3.1) implies that the VC can always match the corporation when $v \geq R^r/S$, since

$$\max\{(1-v)S - D^r, 0\} \leq S - R^r - D^r. \tag{3.2}$$

Now condition (3.2) is independent of R^c, the cost of corporate research, because that is already sunk when the holdup occurs. Hence, we have established the following result:

RESULT 3.2: *Let $v \geq R^r/S$. Then the VC will finance research even when the corporation is more efficient in both research and development.*

The unattractiveness of corporate-financed research is fundamental and stems from the interaction of the corporation's inability to commit to a sharing rule and strong property rights (which enables the corporation to expropriate the researcher). The corporation's inability to commit implies that it can only pay the researcher's outside option, which, as seen from condition (3.1), is of little value when property rights are strong. By contrast, the VC can commit to any sharing rule to match the corporation.

Result 3.2 contrasts with Aghion and Tirole (1994). In their model, the corporation (or "customer" in their terminology) will own the research project whenever it is (second-best) efficient.[26] However, if contractible outside financing were available with no capital constraints, then the first best would always be attained.[27] In our model, while allocating ownership to the corporation may give the right investment incentives, it also transfers to it most of the bargaining power. Thus, the researcher may prefer to get funding from an outside financier to appropriate part of the project's surplus, even if that is inefficient.[28] Result 3.2 also contrasts with Hellmann (1997), who finds that the corporation will finance research whenever it can take advantage of complementarities. His result hinges on the assumption that surplus is verifiable, so the corporation can commit to match whatever the researcher would get by partnering with a VC.

A key characteristic of the financing of R&D when property rights are strong is:

RESULT 3.3: *In equilibrium efficient breakaway from the VC is observed.*

Strong property rights imply that the researcher can credibly commit to compensate the VC in the event of a breakaway, despite the fact that knowledge is embodied in her. Thus, a prediction of the model is that corporate acquisitions should be common when property rights are strong, and that when they occur they are efficient. Note

26. In their model, corporate ownership of the research project is (second-best) efficient when returns are very sensitive to the corporation's investment.

27. Corporate ownership blunts the researcher's effort incentives in Aghion and Tirole (1994). Contractible outside financing would allow the corporation to choose the optimal investment level *and* transfer ownership to the researcher, thus achieving the first best.

28. Of course, this depends on the fact that the researcher cannot sell the project to the corporation at date 0.

that at date 1 the adverse-selection problem is no longer relevant, so that the corporation will be willing to pay cash for the invention.

3.2 Weak Property Rights

When property rights are weak, the VC will not recoup R in expected value if the researcher breaks away, since $v < R/S$. This reduces the scope of VC financing. Proposition 3.4 characterizes the sequence of financing when local spillovers do not matter (that is, $bS^c < D^c$).

Proposition 3.4 (R&D Financing When Property Rights Are Weak): *Let $v < R/S$ and $bS^c < D^c$. Then* (i) *the corporation will finance research if and only if*

$$D^r - D^c \geq R - vS; \tag{3.3}$$

(ii) *the VC will finance research if and only if*

$$D^c - D^r \geq R - vS; \tag{3.4}$$

(iii) *a project will not be financed if and only if*

$$R - vS > D^r - D^c > -(R - vS). \tag{3.5}$$

Proof. (i): Note first that since $bS^c < D^c$, the corporation will never develop independently. Thus, if the researcher breaks away from the corporation at date 1, she gets $(1 - v)S - D^r > 0$, since $v < R/S$ and $S - R - D^r > 0$ by assumption. Hence, the corporation will be willing to finance research if and only if $S - R - D^c \geq (1 - v)S - D^r$, which leads to the incentive-compatibility condition (3.3).

(ii): When $v < R/S$, the project's gross surplus S is not sufficient to compensate the VC in expected value, since $vS < R$. Thus, when property rights are weak, the VC finances research only if a holdup is not profitable. Assuming that $\phi_r = S$, the surplus to be shared with the corporation in the event of a breakaway is $(1-v)S-D^c > 0$. Hence the VC will finance the project if and only if $S-R-D^r \geq (1-v)S-D^c$, which leads to the incentive-compatibility condition (3.4).

(iii): Note that inequalities (3.3) and (3.4) imply (3.5). □

Figure 2 summarizes Proposition 3.4. To the left of $v = R/S$ the corporation finances research *and* development, but only if its cost advantage in development is sufficiently large (area V); examples of this case include research joint ventures, *ex ante* licenses, or the hiring of the researcher as an employee of the corporation. Moreover, no

breakaways are observed in equilibrium. *Mutatis mutandis* exactly the same holds for the VC (area III). Thus, a striking feature of Proposition 3.4, which is apparent from Figure 2, is the symmetry of corporate and VC finance. Thus:

RESULT 3.5: *When property rights are weak, the corporation's inability to commit to a sharing rule does not affect the sequence of financing of R&D.*

When property rights are strong, the inability of the corporation to commit to a sharing rule is key to determining the financing of R&D. Weak property rights change two things. First, the VC's ability to contractually fix the value of its compensation when a breakaway occurs, ϕ_r, is no longer relevant to its financing decision, because it can never recover its research costs in the event of breakaway ($v < R/S$, so that $v\phi_r < R$). Thus the VC's decision to finance depends solely on whether he can match the value of the researcher's outside option—just as is always the case with the corporation. Second, while the compensation that the corporation can credibly offer is still limited by the researcher's outside option, the condition $D^r - D^c = R - vS$ identifies points where the researcher gets all the project's net surplus. Thus, the corporation's inability to commit is no longer relevant. Both facts explain symmetry. Next, it is also apparent from Figure 2 and Proposition 3.4 that weak property rights may prevent the financing of research altogether (area IV):

RESULT 3.6: *When development costs are similar across the different financiers, profitable projects may not be financed.*

To see the intuition behind this result, consider the case of corporate-financed research. The VC will be willing to finance independent development as long as $(1 - v)S - D^r \geq 0$. The key thing to note is that, by breaking away, the researcher can avoid paying the research cost R. Since v is small when property rights are weak, $(1 - v)S - D^r \simeq S - D^r$. To prevent a breakaway, the corporation would need to have a significant advantage in development, since it should not only match this outside option, but also cover the research cost (recall that the researcher appropriates all surplus of marginal projects). Hence, the incentives for a breakaway exist even when independent development is more costly. By symmetry, exactly the same argument explains why the VC may not be willing to finance. In these cases, projects will be executed only if the researcher can finance the research cost on her own.[29] Result 3.6 also shows how the requirement

29. Note that there is no a priori reason to think that the government will be more able than private financiers to solve the holdup problem and thus finance the area IV projects.

that *ex ante* financing be feasible imposes restrictions on the conditions under which *ex post* development can occur.

The preceding discussion suggests that financiers will anticipate breakaways and then will not finance. Therefore

RESULT 3.7: *When property rights are weak, no breakaways occur in equilibrium.*

Putting together Results 3.3 and 3.7 leads to the conclusion that breakaways occur only when property rights are *strong*. The explanation for this somewhat surprising result is that strong property rights enable the financier to recoup research costs with high probability. By contrast, when property rights are weak, financiers cannot recoup research costs in the event of a breakaway, and they will lend only if they have a large cost advantage in development. This result also contrasts with Anton and Yao (1995), who find conditions under which breakaways from a corporation occur when property rights are weak. The reason for this difference is that in their model the corporation does not incur any costs prior to the breakaway; hence, the question of what preserves *ex ante* incentives to finance research is moot.

Note that, since only the VC finances when property rights are strong, it follows that:

RESULT 3.8: *The researcher may break away from the VC, but not from the corporation.*

A final observation is appropriate. Note that knowing the exact division of surplus between the researcher and the financier was not necessary to determine the equilibrium sequence of financing of R&D. This is so because, along the boundaries defined by the incentive compatibility conditions (3.3) and (3.4), the researcher's outside option equals project surplus; thus, whether the financier can commit to a sharing rule is irrelevant. Nevertheless, the ability to commit matters *within* each of the regions I, II, III, and V, and determines surplus sharing.

3.3 Local Spillovers

Local spillovers in research may give the corporation enough information to attempt independent development and become a product-market competitor. In turn, competition from the corporation in the product market reduces S^r and the value of the researcher's outside option. The next proposition studies the effects of local spillovers on the sequence of financing of R&D.

PROPOSITION 3.9 (The Effect of Local Spillovers). *Let* $v < R/S$, $bS^c \geq D^c$, *and* $b^* \equiv b(1 - S^r/S)$. *Then:* (i) *if* $v > 1 - (D^r/S)/(1 - b^*)$, *the*

corporation will always finance research; (ii) *if* $v \leq 1-(D^r/S)/(1-b^*)$, *the corporation will finance research if and only if*

$$D^r - D^c \geq R - [v + (1-v)b^*]S. \tag{3.6}$$

Proof. Since $bS^c \geq D^c$ at date 2, the corporation will compete in the product market with probability b. If the researcher breaks away from the corporation at date 1, the expected surplus (gross of development costs) is equal to $(1-v)[(1-b)S + bS^r] \equiv (1-v)(1-b^*)S$. To prove part (i), note that if this does not cover the development cost D^r, then no VC will be willing to finance independent development. Thus, the researcher will be unable to break away if $(1-v)(1-b^*)S < D^r$, which yields $v > 1-(D^r/S)/(1-b^*)$ after straightforward manipulation.

To prove part (ii) note that if $(1-v)(1-b^*)S \geq D^r$, then independent development is feasible; hence, the corporation will be willing to finance research only if it can match the outside option, that is, if $S-R-D^c \geq (1-v)(1-b^*)S - D^r$, or $D^r - D^c \geq R - [v+(1-v)b^*]S$. □

Figure 3 shows that local spillovers enlarge area V [we assume that $1-(D^r/S)/(1-b^*) < R/S$]; case (i) obtains to the right of the kink in the line separating areas IV and V, case (ii) to the left.[30] Thus

Result 3.10: *When property rights are weak, local spillovers enlarge the scope for corporate research, because appropriability problems cancel out instead of adding up.*

When $v \leq 1-(D^r/S)/(1-b^*)$, an additional term appears in the corporation's individual rationality constraint (3.6), namely $(1-v)b^* \equiv (1-v)b(1-S^r/S)$. The stronger are local spillovers (the larger is b) or the tougher is competition from the corporation in the product market (the smaller is S^r), the less profitable independent development becomes, and, consequently, the more attractive is corporate R&D. In the extreme, when $v > 1-(D^r/S)/(1-b^*)$, competition from the corporation in the product market becomes so strong that the VC is no longer willing to finance independent research. The result that product-market competition can help the victim of holdup to appropriate part of the project's surplus has also been recognized by Anton and Yao (1994). Our result shows that such competition also may give incentives to finance research and overcome the holdup problem.

The second part of Result 3.10 is a standard application of the second-best principle. Local spillovers and weak property rights over

30. Note that $1-(D^r/S)/(1-b^*) < R/S$ simplifies to the condition $(S-R)(1-b^*) - D^r < 0$. it can be easily shown that the kink must occur in the region where $D^r - D^c < 0$.

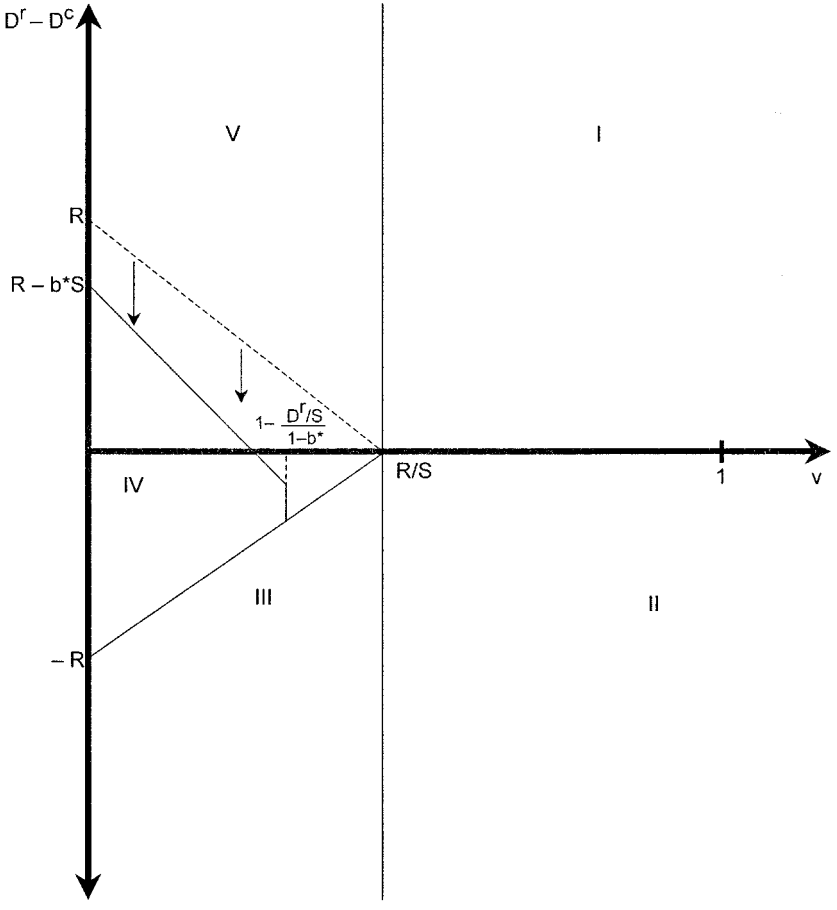

FIGURE 3. THE EFFECT OF LOCAL SPILLOVERS

knowledge are usually thought to reduce the incentives for innovation, but here they work to increase the scope of financing. The reason is that weak property rights create a preexisting distortion that is neutralized by local spillovers. Since different sorts of appropriability problems are common in R&D markets, this hints at a more general implication, namely that imperfections in R&D markets should not be analyzed separately; rather, their interactions must be carefully assessed. The next result is also apparent from Figure 3:

RESULT 3.11: *When property rights are weak, the corporation may finance R&D even when independent development is more efficient.*

Even when corporate development is not efficient (that is, $D^c > D^r$), the corporation may still provide research funding in equilibrium. On the one hand, although it is efficient for the VC to finance research

and development, this is not feasible, because the researcher would break the VC contract at date 1. The corporation, on the other hand, is protected from a holdup by its ability to exploit local spillovers and become a product-market competitor.

What is the effect of local spillovers when property rights are strong? The last result indicates that, under such conditions, local spillovers do not affect the financing of R&D.

RESULT 3.12: *When property rights are strong, local spillovers may affect the division of surplus between the researcher and the financier, but not the sequence of financing of R&D.*

We know from the proof of Proposition 3.1 that local spillovers make corporate research even less attractive for the researcher. However, this means that the VC can offer her less and still get the contract. Thus when property rights are strong, local spillovers may reduce the payoff to the researcher, but affect neither the feasibility nor the location of R&D.

4. APPLICATIONS

4.1 SOME PERFORMANCE IMPLICATIONS

There is some evidence that VC-financed projects obtain higher returns on average. It is often concluded that VCs are inherently better at selecting projects, and corporations should imitate their governance structure. Our model, however, suggests caution in interpreting this evidence.

Consider the consequences of a smaller research cost $R' < R$, keeping all else equal (i.e., the project has a higher return). Figure 4 shows that high-return projects are more likely to obtain research financing when property rights are weak, either by the corporation or by the VC (local spillovers are assumed irrelevant in the figure). When property rights are strong, however, the predominant effect is that VC financing substitutes for corporate financing (a given gross surplus S is more useful for compensating the VC in the event of a breakaway, thus enlarging the region where knowledge is verifiable). Therefore, the average return of a VC-financed project will be higher than that of a corporate-financed project, *ceteris paribus*. It can be easily shown that a similar result obtains when S, S^r, and S^c increase proportionately. This suggests that VCs may obtain higher returns because researchers with better projects self-select due to the inability of corporations to commit to a sharing rule. Thus, project quality may drive financier selection, not the other way round.

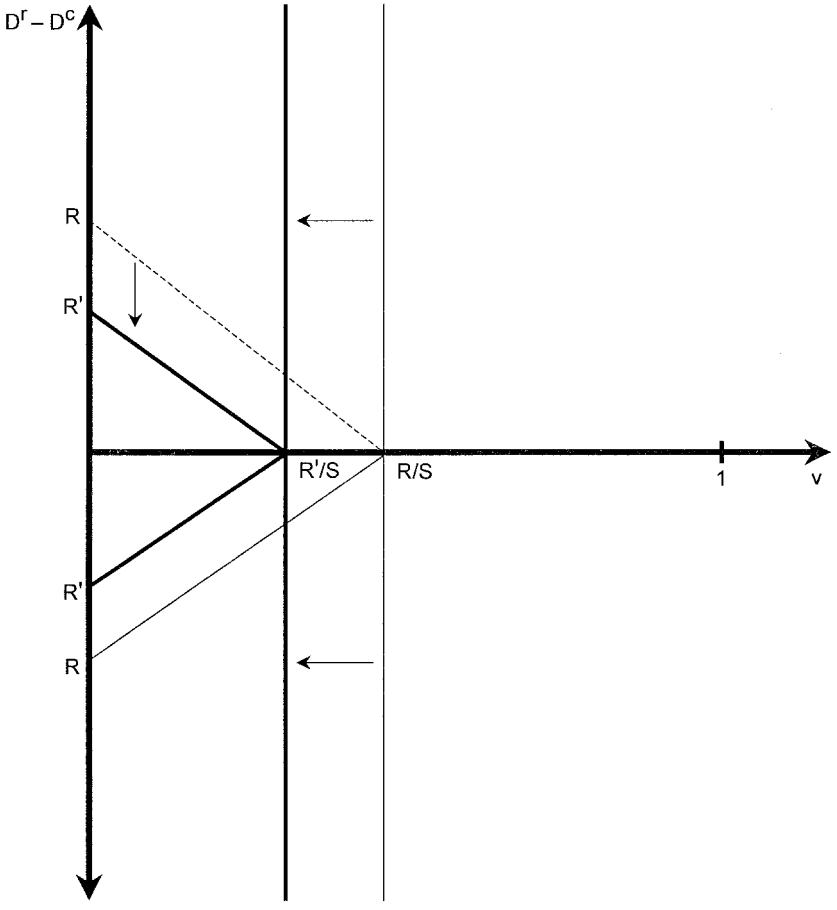

FIGURE 4. A DECREASE IN RESEARCH COSTS

4.2 Strategic Local Spillovers

In the model we treat local spillovers as a primitive. This is sensible when little unique knowledge is revealed to others no matter how much interaction or communication is facilitated between key researchers and other employees. In other cases, however, local spillovers may be endogenously affected by the internal organization of research activities. For example, requiring frequent updates and reports, organizing researchers in teams, and conducting research in common labs may all enhance local spillovers. In such cases, how should research be organized internally? A common line of reasoning suggests that corporations would do well to structure research activities as close to a VC model as possible, to provide the sharpest incentives to researchers [see, for example, Sahlman (1990)]. Nevertheless, there may be an important benefit to doing the opposite. Integrating

the researcher into the rest of the firm's activities is likely to enhance local spillovers and, by making the corporation a likely competitor, deter holdup. Again, this is an application of the second-best Result 3.10.

The model also has an empirical prediction. When the corporation has a large cost advantage in development, local spillovers will not be important for preventing a holdup. Thus, corporate research facilities that are separated from each other or from the rest of the firm are more likely when these cost advantages are large. By contrast, when these cost advantages are small, local spillovers will become important, and the locus of innovation within firms is likely to be more concentrated.

4.3 Alliances or Venture Capital?

A vast literature studying interfirm alliances has focused on two areas: the tradeoff between complementarities between partners (in R&D, production, or marketing), which enhance the scope for cooperation; and mutual learning (and other local spillovers), which enhances the scope for conflict. While there are clearly gains to such learning (for example, learning to manage alliances, to deal with conflict resolution, etc.), learning or acquiring knowledge from an alliance partner may also increase the incentive to break away from the partner and pursue the project on one's own.[31] Our approach may help to explain how these forces interact. First, contrary to common belief, holdup problems that arise in research activities may not be solved by contractual provisions that attempt to optimally allocate control and cash-flow rights over the resulting output of the partnership, because ownership rights over the output of the partnership (knowledge) may not be well defined. Second, enhanced local spillovers or learning between the partners can serve as credible commitments not to cheat on each other; so the usual conflict thought to arise from such local spillovers may also conceal a benefit that serves to increase alliance stability. Finally, Result 3.6 states that holdup is likely to be more severe for more generic capabilities of the partner; a corollary to this is that partnerships that create greater total surplus may not be pursued if the cost differences between competing partners in development is small.

4.4 The Changing Structure of the Pharmaceutical Industry

Up until 25 years ago, pharmaceutical research was based largely on brute-force trial-and-error methods performed in large-scale facilities where researchers would synthesize an immense array of chemical

31. Adarkar et al. (1997) provide numerous examples that highlight this possibility.

entities to find a useful one.[32] Most research was done by big firms that also developed and marketed them. In recent years, the industry has changed significantly. First, fundamental advances in molecular biology and genetic engineering have led to *discovery by design*.[33] Thus brute-force trial-and-error-methods are less common today. Second, now researchers can better describe innovations, not only after useful chemical compounds have been found, but also *ex ante*, before they are discovered. Third, advances in experimentation techniques (e.g. computer simulations) have reduced the scale of experimentation. Fourth, while advances in science have had a notable influence on the discovery process, they have not changed the type of assets needed for drug development and marketing. Last, the industry has seen a large increase in the division of labor: a significant part of pharmaceutical research is performed nowadays by small or medium-size research-intensive biotechnology companies that specialize in research; a large fraction of those companies' revenues comes from research contracts with larger companies.

Our model offers a simple explanation for the changes in the finance cycle of R&D in the pharmaceutical industry. Both discovery by design and advances in experimentation techniques lead to a smaller research cost R per discovered drug, *ceteris paribus*. Furthermore, the fact that innovations can be better described *ex ante* (not *ex post*; see the discussion below) should lead to a larger verifiability parameter v. As our model predicts, both a smaller R and a larger v lead to independent research financed by the VC. Moreover, since the assets needed for development and commercialization have not changed, it is not surprising that large companies still dominate that stage. Transfers of knowledge are feasible because patents can be clearly defined.

It could be argued that the only driving force behind these changes is reduced economies of scale (a smaller R), which have shifted research to smaller firms. This illustrates the importance of distinguishing between the ability to describe innovations *ex ante* (before they are made) and *ex post*. Pharmaceutical firms have always relied on patents to establish property rights *ex post* over their discoveries (see Levin et al., 1987). Nevertheless, patents help only *after* discovery. By contrast, when the corporation has a large advantage in

32. Particular features of the market described in this section have received careful treatment in Henderson and Cockburn (1996), Pisano and Mang (1993), and Zucker et al. (1998). A broader overview of the industry is provided in Gambardella (1995).

33. As Gambardella (1995, pp. 23–24) points out: "With discovery by design, scientists use knowledge about the causes of human disorders, the properties of drug compounds, and their action in the human organism, to conceptualize the structure of an ideal molecule that is expected to restore the altered equilibrium. The ideal molecule is then given to the laboratory chemists, which search for substances whose molecular structures match as closely as possible the theoretical model."

development, a VC's priority is whether it is possible to describe the product of research *ex ante*. With brute-force methods of discovery, VC financing was very difficult because it was not possible to specify *ex ante* what would be discovered, much less its characteristics and uses; thus it would have been far easier for a researcher to switch financiers after learning which compound in a million was the right one. Thus, despite the fact that drugs have always been patentable, v was very small. (In fact, note that patents made VC financing even more difficult: once the discovery has been made, patents make it easier to sell the knowledge and reduce the chances of holdup by the *acquiring* corporation.[34]) Corporations, in contrast, took advantage of their huge cost advantages in development, to prevent holdups.

5. Concluding Remarks

This paper has examined how the strength or weakness of property rights affects the sequence of financing of R&D. We conclude by pointing out some directions for further research.

While we assumed that VC- and corporate-financed research were equally efficient, our results suggest that self-selection of researchers may lead VCs to finance higher-quality projects. In our model, more profitable projects attract VCs because they can commit to a surplus-sharing rule, while the corporation cannot. The literature has repeatedly pointed out a second reason why VCs show better performance: they are able to provide stronger incentives. One may argue that stronger incentives can be traced to the same factor that makes researchers self-select: the ability of VCs to commit to a surplus-sharing rule. Thus, joint activities limit not only a corporation's ability to transfer surplus to the researcher but also the power of its incentive schemes. Examining the link between the internal organization of R&D, incentives, and the mode of financing is a fruitful area for research.

Despite stronger performance, VCs still account for a small fraction of all R&D finance, and most corporations do not try to mimic the VC mode of governance. Consequently, it is unlikely that corporate R&D is simply an off-equilibrium phenomenon bound to disappear. We have shown here that joint activities may also facilitate corporate R&D finance. For example, local spillovers and strong product-market competition from the corporation enlarge the scope of corporate R&D finance when property rights are weak. More generally, corporations exist because doing many activities facilitates the exploitation of economies of scope and complementarities, which are absent in standalone

34. Lamoreaux and Sokoloff (1999) have shown that large corporations have regularly bought patents since the second half of the nineteenth century.

projects. This suggests that corporations may *optimally* sacrifice incentives to exploit complementarities.

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