THE JOURNAL OF INDUSTRIAL ECONOMICS 0022-1821
Volume XLVI June 1998 No. 2

THE CONTROL OF TECHNOLOGY ALLIANCES: AN EMPIRICAL ANALYSIS OF THE BIOTECHNOLOGY INDUSTRY*

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We examine the determinants of control rights in biotechnology alliances through three case studies and a quantitative analysis. Aghion and Tirole [1994] argue that control rights will be assigned so as to maximize the value of the final output, as long as the R&D firm has sufficient financial resources. Consistent with this framework, the allocation of control rights to the R&D firm increases with the firm's financial resources. The empirical evidence regarding the relationship between control rights and the stage of the project at the time the alliance is signed is more ambiguous.

I. INTRODUCTION

AN IMPORTANT insight of the recent literature on the theory of the firm (reviewed in Hart, [1995]) is the need to allocate carefully the right to make decisions about issues that cannot be contractually specified (henceforth termed *control rights*). The proper allocation of control rights is particularly critical in alliances between firms seeking to develop new technologies. Young firms with novel technologies frequently lack the financial resources to effectively introduce a new product and may find it difficult to raise equity or debt due to the informational asymmetries

*Mark Edwards made this project possible by allowing very generous access to Recombinant Capital's databases. Supplemental data were provided by Venture Economics and VentureOne, for which we thank Jesse Reyes and Rolf Selvig. We thank seminar participants at Columbia University, Harvard University, the Massachusetts Institute of Technology, the NBER Productivity and Output Measurement Group, the NBER Universities Research Conference on Technology and Competition in Technology-Intensive Industries, Stanford University, and the State University of New York at Stony Brook for helpful comments, as well as David Audretsch, Joseph Farrell, Martin Feldstein, Alfonso Gambardella, Rebecca Henderson, Glenn Hubbard, Adam Jaffe, Julio Rotemberg, three anonymous referees, and a number of practitioners. Support was provided by the Consortium on Competitiveness and Cooperation; the NBER Project on Industrial Technology and Productivity, with support from the Alfred P. Sloan Foundation; and Harvard Business School's Division of Research. Research assistance was provided by Tiffany Lin, John Seeg, Evan Wamsley, and especially Elizabeth Whitburn. Melanie Patrick provided editorial assistance. All errors and omissions are our own.

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surrounding the project. In many cases, young firms lack complementary assets such as sales forces and manufacturing know-how, which may take many years to develop. As a result, small, research-intensive firms frequently rely on alliances with larger corporations. But the research outcomes of the alliances and the effort that the research and development (R&D) firm will devote to the project are often difficult to specify in an enforceable contract. As a result, ensuring that control rights are allocated properly is essential.

The challenges posed by the allocation of control rights in alliances between small research firms and larger corporations are analyzed theoretically by Aghion and Tirole [1994]. They show that two factors should determine how control rights are allocated:

- the extent to which underinvestment by either or both of the parties jeopardizes the success of the project, and
- the relative bargaining power of the two parties.

The first of these findings echoes the more general literature on incomplete contracts. Property rights should be allocated to the R&D firm when the marginal impact of its research effort on the value of the final output is greater than the marginal impact of the financing partner's financial investment. This allocation is likely to occur for projects in their earliest stages of development, where the ability to specify the contribution of the R&D firm and the desired outcomes in an enforceable contract is likely to be very poor.

Aghion and Tirole's second prediction is motivated by the limited ability of many small high-technology firms to obtain outside financing. Young research-intensive firms frequently do not generate positive cash flow from operations, and consequently must rely on outside investors, yet the uncertainty and information asymmetries surrounding these firms often discourage investors.

This paper empirically examines how control rights are assigned in one particular environment: alliances to research and develop new products and processes between biotechnology firms and either pharmaceutical or larger biotechnology companies. This is an appropriate arena in which to examine theoretical predictions for several reasons:

- Biotechnology research closely resembles the setting depicted in the theoretical literature. Biotechnology projects—particularly early-stage efforts—are highly complex and uncertain, making it very difficult to specify the features of the product to be developed (see Sherbloom, [1991, pp. 220–221] for a discussion). Similarly, the complexity and unpredictability of the research presents challenges in drafting an enforceable agreement that specifies the contributions of the R&D firm. In particular, firms that contract to perform R&D in alliances

frequently have ongoing research projects of their own, in addition to the contracted efforts. In case of a dispute, it may be very difficult for the financing firm to prove that the R&D firm has employed alliance resources to advance projects which are not part of the alliance.

- The firms entering into these alliances exhibit considerable heterogeneity, facilitating an empirical analysis. In some cases, the technologies covered by the alliances are well along the way to regulatory approval. In other cases, they are in the very earliest stages of research exploration. The value-maximizing allocation of control rights is likely to be affected by the stage of the project's development at the time the alliance is signed. In early-stage alliances, the end-points of the project and efforts of the R&D firm are much more difficult to specify in an enforceable contract, and the research contribution of the R&D firm is likely to be particularly critical. In these settings, more of the control rights should be assigned to the biotechnology firm. The availability of equity from public investors for new biotechnology firms has also been particularly variable. The financing activities of biotechnology firms between 1978 and 1995 are summarized in Table I.[1] During periods with little financing activity, young firms suffer tremendous financial stresses and the bargaining power in alliance negotiations is likely to shift in favor of their potential strategic partners. These periods are frequently termed 'buyer's markets'. The theoretical literature suggests that financing constraints may drive R&D firms to cede control rights in a buyer's market.
- The allocation of control rights has considerable practical importance. Case studies and practitioner discussions suggest that the allocation of control rights is a central issue in the negotiation of alliances. The prerogatives of the parties in every stage of the project, from the allocation of research dollars, to decisions about patent litigation against third parties, to marketing strategy, are painstakingly negotiated and carefully delineated in alliance agreements.
- The economic importance of technology alliances has been increasing. As Panel A of Table II suggests, the number of such alliances has been growing in a variety of industries. Nowhere is this trend clearer than in the biotechnology industry, where alliances with pharmaceutical firms have become in recent years the single largest source of financing for biotechnology firms, accounting for several billion dollars of funds

[1] It may be wondered what the changing financing patterns indicate. Since young biotechnology firms face enormous costs while developing new products, they are typically very aggressive in raising capital. Practitioner accounts suggest that during the periods when there are few public equity issues, the markets are essentially 'closed' to biotechnology firms. Thus, it is not unreasonable to infer that periods with little financing activity are ones where accessing capital is very difficult.

TABLE I

External financing of the US biotechnology industry. The table summarizes the total raised (in millions of 1995 dollars) by US new biotechnology firms through several major sources: venture capital investments in private firms, initial public offerings (IPOs), follow-on public equity offerings, private placements by financial investors in public firms, debt and convertible security issues, the issuance of shares in R&D financing organizations (RDFOs), and the sum of these offerings. Alliance-related financings are excluded. The table also indicates the year-end level of an inflation-adjusted index based on the valuation of publicly traded biotechnology firms in this period, normalized to be equal to one on January 1, 1978.

	Amount (millions of 1995 dollars) raised through . . .							
Year	*Venture capital*	*IPOs*	*Follow-on offerings*	*Private placements*	*Debt and convertibles*	*RDFOs*	*Total*	*Biotech equity index*
1978	23	0	0	0	0	0	23	1.16
1979	71	0	0	0	0	0	71	1.39
1980	161	87	0	0	0	0	248	2.26
1981	185	263	0	13	0	0	461	1.99
1982	247	98	57	0	0	147	549	2.29
1983	292	423	182	0	0	172	1070	1.87
1984	179	55	0	0	0	251	485	1.20
1985	190	10	118	10	0	57	384	1.75
1986	342	538	581	0	148	174	1782	1.60
1987	481	306	309	0	442	113	1651	0.89
1988	467	52	44	35	0	74	671	1.06
1989	469	73	259	24	350	210	1386	1.09
1990	514	152	340	29	130	118	1282	1.14
1991	467	1482	2734	220	301	182	5385	2.48
1992	768	1432	788	12	55	118	3172	2.27
1993	763	716	1092	313	197	11	3091	1.48
1994	737	451	608	184	0	0	1980	1.02
1995	716	670	1605	100	0	0	3091	1.62

Source: The methodology for the construction of the venture financing and biotechnology index series are described in Lerner [1994]. The IPO and follow-on offering series are from www.recap.com and Recombinant Capital's unpublished databases. The private placement, debt and convertible, and RDFO compilations are based on the compilations of Shane [1994], extended in time and comprehensiveness through searches of a wide variety of sources by the authors.

TABLE II

Inter-firm alliances in three research-intensive industries, and by biotechnology firms. Panel A presents the number of publicized alliances by US firms in information technology, biotechnology, and advanced materials between 1980 and 1994. Panel B presents only alliances involving US biotechnology companies between 1981 and 1995 filed with the US Securities and Exchange Commission or with state regulatory bodies that make such information public. Presented are the number of new filed alliances each year, the sum of all promised pre-commercialization payments in the filed alliances that year (the sum of the nominal payments is expressed in millions of 1995 dollars), and the actual payments to a sample of 49 of the largest biotechnology firms in each year (in millions of 1995 dollars).

Panel A: Inter-firm alliances by US firms in three research-intensive industries, 1980–1994
Number of new alliances publicized, by nationality of firms

Year	*US-US*	*US-Europe*	*US-Japan*
1980	42	40	15
1981	48	30	26
1982	57	54	39
1983	51	37	51
1984	88	60	55
1985	86	82	52
1986	118	78	47
1987	133	95	53
1988	141	98	39
1989	122	86	44
1990	121	66	34
1991	106	53	51
1992	155	89	43
1993	192	104	45
1994	235	145	40

Panel B: Inter-firm alliances by US biotechnology firms, 1981–1995
Payments through alliances (millions of 1995 dollars)

Year	*Number of new filed alliances*	*Pre-commercial payments promised in new alliances*	*Actual payments during year to 49 leading firms*
1981	30		9
1982	35		111
1983	31		152
1984	42		210
1985	57		149
1986	63		184
1987	62		415
1988	64		298
1989	71		205
1990	81		851
1991	115	741	647
1992	75	931	392
1993	113	1373	806
1994	66	1772	
1995	171	3421	

Source: Panel A is from National Science Board [1996]. The number of new alliances and pre-commercialization payments series in Panel B are from Recombinant Capital's published (www.recap.com) and unpublished databases. The actual payments series is from Shane [1994]. It has not been extended beyond 1993 or to include additional firms. These tabulations of dollar values are admittedly an imperfect way to measure alliance activity: for example, the third column of Panel B in Table II only compiles promised payments prior to commercialization, while much of the value may lie in the ultimate royalty payments. This approach nonetheless provides a rough proxy for the growth of alliance activity.

annually. Panel B of Table II illustrates the growth in the number of alliances involving US biotechnology firms and other private-sector entities. The economic importance of these transactions is also illustrated by the willingness of firms to spend substantial amounts litigating them and the size of the damage awards: e.g. Genentech and Eli Lilly's dispute over their alliance to develop human growth hormone, which led to the filing of at least six suits between 1987 and 1993.

This paper has two components. First, we report three case studies of alliances between biotechnology and pharmaceutical firms. These case studies illustrate the influence of the situations of firms entering into alliances on the allocation of control rights. Second, we analyze a unique database assembled by Recombinant Capital, a San Francisco-based consulting firm specializing in documenting biotechnology alliances. We examine the determinants of control rights within a sample of 200 alliances, defined as long-term contractual arrangements that (i) lasted at least one year, (ii) focused on research or product development between two firms, and (iii) were sufficiently material to at least one party to justify filing with the US Securities and Exchange Commission (SEC). We analyze the share of twenty-five key control rights allocated to the financing firm by regressing the assigned number of rights on independent variables denoting the project stage and financial conditions, as well as controls for a variety of alternative explanations.

Consistent with the framework developed by Aghion and Tirole [1994], the greater the financial resources of the R&D firm, the fewer control rights allocated to the financing firm. For instance, a one standard deviation increase in shareholders' equity at the mean of the independent variables leads to an 11% drop in the predicted number of control rights assigned to the financing firm. Evidence regarding the relationship between control rights and the stage of the project at the time the alliance is signed is less consistent with existing theory. Projects in their early stages at the time of alliance formation actually assign significantly less control to the R&D firm. Interactions between the stage of the project at alliance formation and the R&D firm's financial condition are consistently statistically significant. The analysis does not provide much support for the claims that concerns about underinvestment drive the allocation of control rights. Thus, the results stand in contrast to much of the theoretical literature on the theory of the firm, which argues that contractual arrangements primarily maximize joint value.

We discussed the results with a variety of practitioners. All concurred with the importance of financial resources in determining the allocation of control rights. Several observers also attributed the apparent failure of alliance parties to maximize joint value to agency problems within major corporations. In particular, some financing firms reward business develop-

ment officials on the basis of the number of control rights they retain in negotiations.

In view of the wealth of theoretical literature on technology licensing and alliances, dating at least back to Arrow [1962], it is surprising that there has been relatively little prior empirical research into this issue. Much of the analysis has focused on the question of whether and with whom firms enter into alliances (for an overview of the extensive strategy literature on this question, see Kogut, [1988]; for two recent biotechnology-specific studies, see Shane, [1994] and Majewski, [1997]). A second avenue of research has examined the stock price reaction to the announcements of alliances (see, e.g. Chan, Kensinger, Keown, and Martin, [1997]). There is a small body of literature on the structure of technology alliances, much of which has focused on the nature of the payments from licensees to licensors. Examples include Taylor and Silberston's [1973] survey of 26 British manufacturers, Contractor's [1981] analysis of 102 international technology licenses, and Hall's [1991] examination of 38 SEC-filed alliances. The most similar papers to our effort are Caves, Crookell, and Killing's [1983] survey of 62 licensors and licensees regarding several alliance provisions, and Pisano and Mang's [1993] examination of the allocation of manufacturing rights in a set of 70 biotechnology alliances.[2] Another body of work related to our paper examines the determinants of terms in procurement contracts [see, e.g. Joskow, 1987; Crocker and Reynolds, 1993]. The papers most relevant to this one are Hubbard and Weiner's [1991] examination of natural gas supply contracts and Gompers and Lerner's [1996] study of venture partnership agreements. Both test whether contractual restrictions are determined by concerns about behavior after the contract is signed or the bargaining power of the parties at the time of the negotiation. Hubbard and Weiner find weak evidence for the second hypothesis; Gompers and Lerner find evidence supporting both views.

This paper does not explore the relationship between the allocation of control rights and the payments received by the biotechnology firm, because the necessary proprietary financial information has been excised from SEC filings. This paper also does not provide an analysis of alliance outcomes. While the sample is constructed to mirror the growth in alliance activity over a sixteen-year period, it is less suitable to analyze alliance success. Over three-quarters of the alliances reviewed had not begun clinical trials at the time that the alliances were signed. Since it frequently takes a decade or longer for a therapeutic product to move from animal

[2] In addition to examining a broader number of terms and alliances, our project is distinguished from these two earlier examinations by its joint emphasis on how deal structures change with the risk of underinvestment and with the relative bargaining power of the parties.

studies to approval by the US Food and Drug Administration (FDA), in most cases it would be premature to assess whether the project has succeeded or failed.

The plan of this paper is as follows. Section II discusses the theoretical framework and the key challenges facing any empirical test of these issues. Section III presents evidence from three case studies of alliances. Section IV describes the construction of the sample. Section V presents the quantitative analysis of the allocation of control rights. Section VI concludes the paper.

II. THEORETICAL FRAMEWORK AND EMPIRICAL TESTS

Aghion and Tirole [1994] explore the determinants of control rights in an alliance between a research unit and a customer firm to develop new technologies. We briefly summarize several key insights of this model, then discuss the challenges associated with testing its predictions.

Aghion and Tirole assume that the research unit lacks financial resources of its own, cannot borrow funds, and cannot commercialize the innovation itself. As a result, it turns for financing to a potential customer, a firm which may intend to use the product for its own use or to resell it to others but cannot make the discovery independently. (In refinements of the model, Aghion and Tirole allow the research unit to instead choose to finance the project through a third party, such as a venture capitalist, and to commercialize the project itself.) The success of the research project is an increasing concave function of both the effort provided by the research unit and the resources provided by the customer.

Developing a contract between the two parties is challenging. While the ownership of the product can be specified in an enforceable contract, and the resources provided by the customer may be so specified, the uncertain nature of the innovation precludes writing a contract for the delivery of a specific innovation. Similarly, an enforceable contract cannot be written that specifies the level of effort that the research unit will provide.

Aghion and Tirole consider two polar cases: when the research unit has the *ex ante* bargaining power, and when the customer does. To illustrate the first state, a new biotechnology firm with a promising research initiative may attract several pharmaceutical companies who compete to undertake an alliance. When the research unit has the bargaining power, the ownership of the research output will be efficiently allocated. If the marginal impact of the research unit's effort on the innovative output is greater than the marginal impact of the customer's investment, then the research unit will receive the property rights. If not, the research unit will transfer ownership to the customer in exchange for a cash payment. This result is similar to that of Grossman and Hart [1986].

When the customer has the bargaining power, however, a different pattern emerges. If it is optimal for the customer to own the project, it will retain the project. If, however, it is optimal for the property rights to be transferred to the research unit, the best outcome will not be achieved. In particular, the customer will be willing to transfer ownership, but the cash-constrained research unit will not have enough resources to compensate the customer. As a result, an inefficient allocation of the property rights occurs, with the customer retaining the rights to the invention.

This model suggests two predictions for the empirical analysis below. Control rights should be assigned to the R&D firm when the marginal impact of its research effort on the value of the final output is greater than the marginal impact of the financing firm's financial investment. We might anticipate that this will be most true among projects consummated in the earliest stages of development. In these settings, the success of the alliance is certain to depend upon the scientific knowledge in which new biotechnology firms specialize and the contribution of the R&D firm is likely to be most difficult to contractually specify.[3] We employ two measures of the project's *stage of development*: (i) the stage in the drug approval process of the initial product being developed in the alliance and (ii) the count of related patents awarded to the biotechnology firm. Projects which are in their earliest stages—i.e. when in the earliest stage of the drug approval process or with few patents yet awarded—should have more control rights assigned to the R&D firm. In addition, when biotechnology firms have less capital, they may be unable to retain control rights. Thus, we should also observe a positive relationship between the financial health of the R&D firm and the number of control rights that it retains.

At the same time, it is important to acknowledge that in at least five respects, actual alliances involving biotechnology firms engage in more complex activity than depicted in the Aghion–Tirole model. These complexities challenge our ability to test the theory. We will outline these concerns, and discuss how we at least partially address them:

- The Aghion–Tirole model assumes a one-time contracting process between the two parties. Actual alliances reveal more complex contracting patterns than the 'one-shot' contracts depicted in Aghion and Tirole. For instance, pairs of firms undertake repeated sets of alliances on different topics. Pharmaceutical firms and large biotechnology firms may make equity investments in small biotechnology concerns before

[3] Public policy also recognizes the importance of these factors: when Congress reformed ownership rights to federally-funded inventions in 1980, it assigned patent rights to the universities and companies that actually perform the research. It did so on the explicit theory that the law should place the incentive on the party exerting the research effort, because its marginal impact on the value of the research product was highest [Eisenberg, 1996].

negotiating alliances. We can control, however, for alliance pairs where the firms have a prior contractual relationship or an equity investment.

- A related complexity is posed by renegotiations of agreements. As an illustration, in some cases as the R&D firm accumulates substantial numbers of patents over time, especially in a setting with considerable asymmetric information, it gains considerable bargaining power. It may threaten to terminate the alliance on a technicality, and to sue its former partner for patent infringement. In order to minimize such complex cases, we focus the analysis on initial alliances and eliminate re-negotiations of existing alliances from the sample.
- The Aghion–Tirole model assumes a vertical relationship between a customer and a research unit. In actuality, the relations between some alliance parties are likely to have horizontal elements. For instance, some of the alliances are between pairs of biotechnology concerns. In these cases, both firms may face financial challenges, and consequently these pressures may have no impact on the allocation of control rights. Furthermore, in these and other alliances, both firms may contribute knowledge. We control, at least partially, for these contingencies by identifying proxies for alliances that are likely to have horizontal elements.
- In the basic Aghion–Tirole model, the parties bargain over a very small set of parameters. As they relate, 'the contract only specifies the allocation of the *property right* on any forthcoming innovation, a *sharing rule* on the verifiable revenue (license fee) obtained by the research unit, and any *verifiable* amount of *customer investment*' [Aghion and Tirole, 1994, p. 1189 (emphasis in original)]. Actual alliances assign a wide variety of control rights, and control rights over various aspects of the alliance are assigned in different ways. Practitioners suggest that no single control right stands out as critical. Rather it is the accumulation of rights to control contingencies that makes an alliance particularly favorable to the R&D or the financing firm.[4]
- Finally, in the Aghion–Tirole model, both parties are fully informed at the time the agreement is signed: the parties' major concern is reducing the potential for sub-optimal effort after the agreement is signed. In

[4] The detailed control rights assigned in alliance contracts are aspects of ownership that must be distinguished from mere contractual contingencies. They do not spell out a myriad of possible world-states, dictating outcomes under each of many scenarios. Instead, they are discrete aspects of the fundamental ownership right over the research results. In virtually every instance, they stem from patent and trade secret rights in those research results. The control rights cover acts which, if not performed by an owner or his authorized agent, would infringe those rights. Hence they are aspects of ownership, rather than conventional contractual obligations. In fact, they shed light on the simple assumption of many 'incomplete contracting' models that efficiency is achieved via assignment of a large, undifferentiated 'ownership' right. In actual alliances, practitioners break this right into its constituent parts and assign individual aspects of the residual rights that flow from ownership.

actuality, the situation may be more complex. In particular, the financing party may not be fully informed about the prospects for the project. This may lead to contractual terms that seek to force the informed party to reveal if he has additional information, such as making payments contingent on achieving technological or product market milestones.

III. EVIDENCE FROM CASE STUDIES

To understand the challenges posed by technology alliances, one of the authors conducted three case studies of young companies developing advanced human therapeutics. The biotechnologies pursued by the three firms are quite different: antigen-based allergy drugs (ImmuLogic Pharmaceutical Corporation), advanced drug delivery mechanisms (ALZA Corporation), and monoclonal antibody-based treatments of inflammation (Repligen Corporation). The location and sophistication of strategic partners and the stage of development of the technologies varied considerably across the three firms.[5]

These case studies (Lerner, [1992]; Lerner and Tufano, [1993]; Kane and Lerner, [1994]) are based on public securities filings, internal corporate documents, numerous interviews with senior managers of these firms, and supplemental discussions with investors, outside directors, strategic partners, and other observers. We briefly discuss the allocation of control rights in these alliances and the parallels to the theoretical literature summarized above. (The interested reader seeking details of the case studies is directed to the Journal's editorial Web site.)

These cases illustrate how the allocation of control rights are determined both by concerns about behavior after the alliance is signed and by relative bargaining power, the two factors in Aghion and Tirole. In Repligen's May 1992 alliance with Eli Lilly regarding a very early-stage effort to develop a monoclonal antibody-based treatment of inflammation after heart attacks, three control rights were the subject of protracted negotiations:

- the management of clinical trials: the right to decide which drugs would be pursued and in which order.
- the control over the marketing strategy, an arena in which Lilly had much more extensive experience than Repligen.
- the control over the process development and ultimate manufacturing of the drug.

[5] The preparation of these cases was complemented by a series of academic-practitioner roundtable discussions on the role of alliances in the biotechnology industry organized by this author (see this Journal's editorial web-site for a detailed description).

Consistent with Aghion and Tirole, the terms of the alliance that emerged from the negotiations appeared to assign the control rights to the parties whose behavior would have the greatest impact on the product development effort. Repligen was allowed a great deal of control over developing the lead product candidate, an area where it had considerable experience, but tangential product development activities were subject to extensive review by Lilly. Lilly was assigned control over all aspects of marketing; while Repligen was assigned all manufacturing control rights, unless it encountered severe difficulties with regulators.

Other alliances illustrate the importance of the relative bargaining power of the two parties. At the time of its alliance with Ciba-Geigy, ALZA faced a major financial crisis.[6] The alliance assigned almost total control to Ciba-Geigy. It was given a super-majority on the joint board that reviewed and approved potential research projects, the right to license and manufacture any of ALZA's current or future products, the ability to block any other alliances that ALZA proposed to enter into, and eight of the eleven seats on ALZA's board of directors. In addition, Ciba-Geigy received a new class of preferred shares. If converted into common stock, the new preferred shares would represent 53% of the equity in ALZA. Until conversion, however, Ciba-Geigy had 80% of the voting rights, an allocation which allowed it to employ ALZA's tax losses.

A second illustration of the importance of bargaining power was presented by ImmuLogic. In March 1991, the firm was considering either entering into an alliance or raising equity in an initial public offering. One concern that led ImmuLogic to decide to go public was the fear that a potential strategic partner might exploit ImmuLogic's relatively weak financial condition. Specifically, ImmuLogic feared that a pharmaceutical company might press more vigorously for concessions on key governance and financial issues by protracting the negotiations until ImmuLogic was close to running out of capital. ImmuLogic consequently deferred negotiating an alliance to develop and market its allergy drugs until going public in May 1991. The firm announced an alliance with Marion Merrell Dow in December 1991, which allowed ImmuLogic to retain numerous control rights, such as an equal role in planning marketing strategy in the US: *In Vivo* magazine hailed the transaction as 'push[ing] the limit of the biotech deal . . . a partnership in fact as well as name' (quoted in Lerner, [1992], Teaching Note 5-293-118, p. 7). Just as ALZA's cession of almost total control to

[6] The firm had little more than $1 million in the bank, was spending $2 million more per month than it was receiving in revenues, had nearly exhausted its bank credit line, was in violation of several loan covenants, and was deterred from a sale of equity to the public by unfavorable market conditions and the perception that ALZA had been excessively optimistic in its earlier communications with investors and analysts.

Ciba-Geigy was in large part a consequence of its weak financial position, ImmuLogic's ability to obtain these control rights reflected its financial strength.

IV. CONSTRUCTION OF THE SAMPLE

The quantitative analysis performed for this paper was based on a database of alliances compiled by Recombinant Capital, a San Francisco-based consulting firm specializing since 1988 in tracking the biotechnology industry. Publicly traded biotechnology firms, like other concerns, are required by the SEC to file material documents. Biotechnology companies tend to interpret this requirement conservatively, and often file the contracts specifying alliances as amendments to 10-K, 10-Q, S-1, or 8-K statements. In addition, a number of state governments require privately held companies with employee stock option plans to file material documents, which are then made available to the public.

As of July 1996, Recombinant Capital had identified approximately 3500 alliances between private firms by examining SEC and state filings, news accounts, and press releases. This total excludes any alliances that involve universities, hospitals, non-profit research institutions, or the US Government. By July 1996, Recombinant Capital had analyzed about 500 of these 3500 alliances. Recombinant Capital updates its database of previously filed alliances by examining subsequent filings by the same firms, which sometimes reveal royalty rates or lump-sum payments redacted from the original agreements.[7] The Recombinant Capital database is typically licensed by major pharmaceutical, accounting, and law firms for a considerable annual fee, and has not been previously made available to academics.

For our analysis, we selected a random sample of 200 of the analyzed alliances to encode. We sought to create a population free of undesirable heterogeneity. In particular, we eliminated alliances in which:

- one of the parties was a university, medical center, other non-profit organization, or government agency;
- one of the parties had a controlling interest in the other, either through a majority equity stake or through a purchase option (e.g. an alliance between a firm and one of its R&D limited partnerships);
- the two parties had a previous alliance covering the same set of

[7] Firms can request confidential treatment for the key information in these alliances. Their failure to disclose this information, however, may become an issue if the firm is sued for security law violations. Shareholder class-action litigation has occurred frequently in high-technology industries.

technologies, and consequently were primarily renegotiating the terms of an earlier alliance;
- there was neither a research nor a product development component, but the alliance simply involved the marketing of an existing product;
- more than two firms were involved, making the analysis of the division of control rights less tractable.

As part of its analysis, Recombinant Capital systematically divides the alliance terms into 58 categories. We summarized the key control rights in a database.

For each of the 200 alliances, we gathered supplemental information. First, we devised two measures to gauge the progress of the project under development: (i) the lead product candidate's stage in the regulatory approval process at the time of alliance signing (see Appendix A for a summary), and (ii) the number of US patent awards to the R&D firm in the same area as the alliance and the total number of patents awarded to the R&D firm at the time of alliance signing. Patents in the same area as the alliance were determined through searches of the LEXIS PATENTS/ALL database, using keywords from the alliances. We included awards to these firms' subsidiaries, joint ventures, and R&D limited partnerships. We identified name changes, joint ventures, subsidiaries, and R&D limited partnerships from a variety of reference sources [see Lerner, 1995, for a description of this process].

Second, we measured the relative bargaining power of the biotechnology firm, using (i) the biotechnology firm's financial status at the end of the fiscal year immediately prior to the alliance, and (ii) an estimate of the public market conditions for biotechnology firms at the time of the alliance. The first measure was created from Compustat data, or, if that were unavailable, from 10-K filings, IPO prospectuses, and other SEC filings. The second measure was created from a variety of sources: the volume of public equity issues by all biotechnology firms in the quarter and year immediately preceding the transaction, as well as the level of an inflation-adjusted index of publicly traded biotechnology equities at the end of the quarter immediately prior to the signing [see Lerner, 1994, for a detailed description].

We gathered various supplemental data:

- The nature of the regulatory review facing the biotechnology being developed. The review of new human therapeutics by the FDA often stretches for a decade or longer. Agricultural and industrial bio-engineered products and diagnostic products face somewhat less arduous and lengthy reviews.
- The prior relationship between the two parties in the alliance. Using Recombinant Capital's database, which lists all alliances disclosed in

securities filings, press releases, or other news accounts, we determined whether the two firms had any previous alliances. We eliminated cases from the sample where the two parties had a previous alliance covering the same set of technologies. We also determined whether the financing firm had previously made an equity investment in the R&D firm by searching Recombinant Capital's database of biotechnology firm financing activity and the records of two venture capital and corporate development investment consultants, Venture Economics and VentureOne.

- Whether the alliance was horizontal or vertical. One concern with empirically examining the Aghion–Tirole model is that many alliances contain horizontal elements, such as when both firms contribute patents or informal know-how to the agreement. We identified horizontal alliances as (i) those between two biotechnology firms (as opposed to

TABLE III

Characteristics of all filed agreements, those summarized by Recombinant Capital, and those included in the sample. Each column indicates the year, stage at the time the agreement was signed, and primary focus for a different set of agreements. The second column indicates the distribution of all alliances, licensing arrangements, and asset sales involving biotechnology companies between 1980 and 1995 filed with the US Securities and Exchange Commission or state regulatory bodies who make such information public. The third column indicates the distribution of all such agreements summarized by Recombinant Capital. The final column characterizes the final sample of 200 technology alliances initiated between biotechnology and pharmaceutical companies or between biotechnology firms in the 1980–1995 period.

	All filed agreements (%)	*All summarized agreements* (%)	*Final sample* (%)
Time period			
1980–1987	20	11	14
1988–1990	18	21	16
1991–1992	26	26	34
1993–1995	36	42	36
Stage of product at signing			
Discovery/lead molecule	65	57	64
Pre-clinical development	9	11	14
Undergoing regulatory review	17	23	22
Approved for sale[a]	9	9	1
Primary focus of agreement			
Human therapeutics	75	83	92
Human diagnostics[b]	18	15	4
Agricultural or industrial applications	6	2	4

[a] The sample is constructed to include only alliances with a research or a product development component. Thus, many of the agreements in the database involving approved products, which solely entail the marketing or sale of an existing product or process, are excluded from the sample.

[b] Many of the agreements involving human diagnostics entail the marketing or sale of an existing product or process developed by a biotechnology company in the course of a program to introduce a new therapeutic. (Because diagnostics tests are frequently of modest economic importance and viewed as tangential to the firm's product development focus, biotechnology firms often sell these outright to major firms specializing in this area.) Because these agreements are not alliances with a research or product development component, they are excluded from the sample.

between a biotechnology and a pharmaceutical concern, and (ii) those between relatively equally sized firms, which we operationalized to mean those alliances in which the larger firm had no more than five times the assets of the smaller firm.

Table III compares the alliances in the sample with the universe of filed agreements, and with the subset summarized by Recombinant Capital. Table III highlights the fact that our criteria disproportionately eliminated several classes of agreements (such as licenses of approved products or diagnostic kits) from the Recombinant Capital database, mainly because the eliminated agreements did not contain a research or product development element.

Table IV summarizes the characteristics of the alliances and contracting firms in more detail. Several patterns can be observed from these summary statistics. First, the observations are concentrated towards the end of the sample period, reflecting not only the increasing level of alliance activity in recent years, but also Recombinant Capital's propensity to summarize more recent alliances, due to their greater interest to its clients.

Second, most of these alliances are arranged at a very early stage. In nearly two-thirds of the sample, pre-clinical (animal) studies have not yet begun. Nearly four-fifths of the alliances involve products that are not yet in clinical trials, and over 99% of the alliances involve products that have not yet received regulatory approval. One atypical alliance in the sample involves a joint effort to undertake further product development on an already approved drug. In the analyses below, this observation can be deleted from the sample without altering the results.

Third, the limited financial resources of these R&D firms is apparent. In the fiscal year before the alliance, the typical firm had taken in almost $10 million in revenue (primarily grants, interest earnings, and payments associated with other alliances), but had expenditures of over $21 million, mostly on R&D activities. The loss in the prior year represented one-third of the average firm's shareholder equity and nearly one-half of its cash and equivalents.

Finally, the analysis makes clear the gap between the firms financing the alliances and those performing the R&D. Compared using any financial measure, the firms performing the R&D are much smaller than their alliance partners. For instance, the average ratio of the assets of the financing firm to the R&D firm is over 900, with a median ratio of about 200. Only in three cases is the ratio of the two firms under 5. Even among the alliances between biotechnology firms, the two parties are typically very different in size, with the mean ratio of assets over 60 and the median, about 40.

TABLE IV

Characteristics of the sample. The sample consists of 200 technology alliances initiated between biotechnology and pharmaceutical companies or between biotechnology firms in the 1980–1995 period. The table summarizes the financial market conditions around the time of the alliance and the characteristics of the firms in the alliance. The date variable is expressed as a decimal (e.g. July 1, 1995 is coded as 1995.5). The stage of product measures are all dummy variables. The public equity raised and financial position variables are expressed in millions of 1995 dollars. The biotechnology index reflects inflation-adjusted public equity values and is normalized to 1.0 on January 1, 1978.

Variable	*Mean*	*Median*	*Stan. dev.*	*Minimum*	*Maximum*
Basic characteristics					
Date of alliance	July 1991	Mar. 1992	3.1 years	Jan. 1980	Dec. 1995
Minimum length of alliance (years)	3.91	3.00	3.14	0.92	31.00
Stage of product at time of alliance:					
Discovery/lead molecule	0.63			0	1
Pre-clinical development	0.14			0	1
Undergoing regulatory review	0.22			0	1
Approved for sale	0.01			0	1
Focus of alliance					
Human therapeutics	0.92			0	1
Human diagnostics	0.04			0	1
Agricultural or industrial applications	0.04			0	1
Condition of biotech equity markets:					
Total public equity raised in prior quarter	402.86	184.04	467.31	0.00	1699.87
Total public equity raised in prior year	1600.42	1150.67	1323.35	0.00	4832.43
Biotech index at end of prior quarter	1.67	1.61	0.46	0.91	2.75
Financial position of financing firm:					
Revenues in prior year	6420.52	4210.80	8103.25	0.09	48959.37
R&D expenditures in prior year	562.36	398.46	536.35	2.68	2075.79
Net income in prior year	562.82	353.33	614.91	−457.44	2231.98
Cash and equivalents at end of prior year	913.92	538.30	1038.30	0.70	4938.42
Total assets at end of prior year	6902.54	4564.25	7448.66	5.24	35253.06
Shareholders' equity at end of prior year	3449.73	2216.58	3669.47	0.22	17504.68
Financial position of R&D firm:					
Revenues in prior year	9.92	1.29	40.31	0	494.57
R&D expenditures in prior year	11.17	5.57	21.32	0	229.11
Net income in prior year	−11.13	−4.99	30.75	−284.06	47.69
Cash and equivalents at end of prior year	25.89	7.36	59.49	0	554.24
Total assets at end of prior year	48.24	18.04	119.95	0.49	1325.02
Shareholders' equity at end of prior year	33.44	14.26	88.62	−17.08	1021.88
Patent holdings of R&D firm:					
Total patent awards	5.32	0	14.44	0	114
Patent awards related to alliance	1.14	0	7.80	0	102
Characteristics of pair of firms in alliance					
Previous alliance between firms?	0.06			0	1
Previous equity investment in R&D firm by funding firm?	0.02			0	1
Ratio of funding to R&D firm's assets	932.20	202.37	1959.94	1.48	12128.56
Are two firms' assets within five times of each other?	0.02			0	1
Is the alliance between biotech firms?	0.17			0	1

V. QUANTITATIVE ANALYSIS

In this section, we analyze the relationship between the control rights in the alliances included in our sample and the characteristics outlined above. We focus on twenty-five sets of control rights which appear in some, but not all, of the alliances. After briefly describing the rights, we present both univariate and regression analyses of their determinants.

V(i). *Identifying the Control Rights*

Alliances to develop new biotechnologies are complex. Many variants of each control right are found in the alliances. Fully capturing the complexity of these rights in a quantitative analysis is difficult. We focus in this paper on the broad control rights that appear in between 10 and 190 out of the 200 alliances. In this way, we eliminate rights that provide little variation because they are either standardized boilerplate and/or exceedingly rare. In the analyses below, we examine how many of the 25 control rights are included in each agreement.

This empirical approach, however, has two important limitations. In particular, we are implicitly assuming that each control right is equally important, which is unlikely to be true. To partially address this problem, we repeat the analyses below, employing only the five control rights identified as the most critical during the case study interviews and informal conversations with practitioners.

We also ignore the considerable heterogeneity within particular control rights. Consider, for example, the variable denoting the control of patent litigation. We indicate that the financing firm has control of the litigation process whether or not the R&D firm has the option of taking control of the litigation if the financing firm does not pursue it, and whatever the rules are for sharing the cost of the litigation.

Table V summarizes the frequency with which these 25 control rights appear in the sample. In each case, the variables are binary, with a value of one indicating that the particular right is allocated to the financing firm, and zero if not. This structure for the analysis is suggested by the legal treatment of technology licenses, which reserves for the licensor any rights not explicitly granted to the licensee (Merges, [1995]).

Before beginning the quantitative analysis, however, we briefly describe the 25 control rights. The five most important control rights, identified as key to the management of alliances, belong to the first set in Table V. They are as follows:

1. Management of clinical trials. Not only are applications for regulatory approval of human and agricultural bio-engineered products protracted and costly, they also involve many decision points. For instance, while a human therapeutic product may have diverse potential uses, regu-

TABLE V

Percentage of alliances allocating control rights to the firm financing the R&D activity. The sample consists of 200 technology alliances initiated between biotechnology and pharmaceutical companies or between biotechnology firms in the 1980–1995 period. The table divides the tabulations into four chronological periods. The mean number of control rights is the average number of control rights (out of the possible 25) included in alliances in each sub-period.

Control right	*1980–87* (%)	*1988–90* (%)	*1991–92* (%)	*1993–95* (%)	*Total sample* (%)
Key aspects of alliance management:					
1. Right to manage clinical trials	64	62	46	62	57
2. Right to undertake process development	4	3	9	11	8
3. Right to manufacture final product	50	66	66	64	63
4. Right to market universally	89	53	69	63	67
5. Right to market product alone	96	91	82	68	80
Determination of alliance scope:					
6. Right to expand alliance	7	9	7	15	10
7. Right to extend alliance	32	25	21	18	22
8. Right to terminate alliance without cause	46	50	33	18	32
9. Right to terminate particular projects	11	12	12	11	12
10. Right to sub-license	18	25	31	23	26
11. Right to license after expiration/ termination	39	41	54	41	45
12. Right to 'shelve' projects	96	94	99	86	93
Control of intellectual property:					
13. Ownership of patents	18	6	7	10	10
14. At least partial patent ownership	71	56	73	78	72
15. Control of patent litigation	29	25	22	25	25
16. Right to know-how transfer	54	28	43	51	45
17. Ownership of core technology	11	0	9	5	6
18. Right to delay publications	14	22	33	51	35
19. Right to suppress publications	32	9	16	19	18
Governance structures:					
20. Control of top project management body	7	12	3	5	6
21. Seat on R&D firm's board	14	34	15	23	21
22. Equity in R&D firm	32	56	45	62	51
23. Right to participate in R&D firm's financings	18	34	21	15	20
24. Right to register R&D firm's stock	18	25	36	33	30
25. Ability to make public equity purchases	89	81	81	66	76
Mean number of control rights in each agreement	9.6	9.2	9.3	9.2	9.3
Number of observations	28	32	67	73	200

latory approval is given only for specific uses. Thus, the financing firm may not wish to apply for approval of a therapeutic treatment for a disease for which it has an existing product, lest it cannibalize existing sales, even if its R&D partner may believe that this use offers the highest potential returns.

2. Control of the initial manufacturing process. Often the processes discovered at the test-tube level must be fundamentally altered as manufacturing is scaled up. The development of manufacturing technologies may also require the release of information not protected by

patents. Retaining rights to undertake initial manufacturing may be more important to the party who has more manufacturing expertise.

3. Control of manufacturing after product approval. This is a particularly significant right for human therapeutic products. When the FDA approves a new drug, the approval extends only to the particular facility where it is being manufactured. If a pharmaceutical company seeks to move production from the facility of an R&D partner to one of its own, it must undergo another extensive and time-consuming FDA review. Thus, the assignment of manufacturing rights is frequently an item of contention.

The final two key control rights relate to the marketing of the bioengineered product. Almost all pharmaceutical firms have large sales forces, which engage in the time-consuming process of developing personal relationships with doctors and hospital administrators. At least until very recently, most biotechnology firms have sought to develop similar capabilities. These firms believed that a sales force would allow them to increase their profit margins and that this sales force would gather strategically important information. These were:

4. Creation of exclusive territory for R&D firm. The presence of this control right would grant exclusive rights to the R&D firm to market the product in one or more markets defined by geography (country) or product type (disease indication).
5. Creation of co-marketing rights for R&D firm. The presence of this control right would allow the R&D firm to participate in the marketing of the product in one or more markets.

The second set of control rights displayed in Table V addresses alterations to the scope of the alliance. Several alliances provide the funding firm with the right to expand the breadth of the alliance, either by adding to the technologies under development (shown as Right #6 in Table V) or by extending the duration of the project (#7). Nearly all alliances include some provisions for the cancellation of the alliance in particular circumstances (e.g. the bankruptcy or acquisition of one of the parties). In some cases, however, the financing firm has the right to cancel the alliance without cause (#8) or to terminate particular projects (#9). A related cluster of terms addresses the control of the licensed technologies. In some cases, the firm funding the R&D has broad powers to sub-license the technology to other firms (#10) and to continue to sell products developed by the alliance, even after the alliance ends (#11). In many cases, the pharmaceutical company has the right to 'shelve' the project, continuing to maintain its exclusive rights even if it decides not to pursue product's development (#12).

The third cluster of control rights displayed in Table V relates to intellectual property. Patents and associated scientific knowledge are the

most important assets of many biotechnology firms, so it is not surprising that they are the focus of negotiations. The most crucial of these rights relates to the ownership of the patents generated by the project. In some cases, the financing firm owns the patents generated by the alliance outright (#13). A somewhat weaker right (#14) provides at least partial ownership of these patents: if not restricted by another agreement, a part-owner can freely license a patent to other users. Financing firms often demand control of the patent litigation process (#15).

Other alliance terms relate to 'know-how' (unpatented intellectual property). Some alliances stipulate that the financing firm is entitled to transfers of the R&D firm's know-how (#16). In a few cases, ownership of know-how is assigned to the financing firm (#17).[8] The control of the R&D firm's scientific publications is also frequently addressed. Many biotechnology firms recruit academic researchers, who are eager to maintain an active publication record. Publications by small biotechnology firms may serve as a favorable signal to the stock market, but premature publications may jeopardize the ability of the parties to obtain patent protection. Consequently, the financing firm may delay publications of the R&D firm (#18) or even suppress them entirely (#19).

The final set of control rights frequently encountered in these alliances covers the governance of the alliance. These alliances typically have one or more oversight boards. While control of the governing board is typically divided evenly between the two firms, occasionally the funding firm is assigned the chairmanship or the tie-breaking vote (#20). The firms funding the R&D have also adopted many of the control rights employed by venture capital organizations while financing small private firms. These include a seat on the firm's board (#21), as well as an equity stake in the firm, with the associated voting rights (#22). In many cases, instead of receiving common stock, the funding firm receives preferred shares with additional control rights. Among these are the right to participate in future financings of the firm on a *pro rata* basis or anti-dilution provisions, which make it difficult for the R&D-performing firm to sell shares at a lower price (#23). These provisions give the financing firm substantial control over the R&D firm's ability to raise outside financing in the future, and consequently influence the firm's future direction. Registration rights (#24) can be even more onerous to the R&D firm, since they provide a mechanism through which the financing firm can demand that the R&D firm arrange for the sale of its shares in the public market. Such a sale may be very costly or, at times, impossible to arrange. In many cases, the

[8] Even in the cases where ownership of the core technology is being assigned to the strategic partner, however, the biotechnology firm can maintain control over disclosures by its employees. A detailed discussion of employer rights concerning employees' discoveries is in Neumeyer [1971].

financing firm retains the right to purchase additional shares in the public market (#25). This gives the financing firm the option to acquire the R&D firm, or preserves the threat of such an acquisition.

The columns in Table V divide the alliances into four chronological periods. The penultimate row indicates the number of restrictions, out of the possible 25, in the average alliance in each period. No clear trend appears over time in the cumulative number of control rights allocated to the financing firm: a test of the null hypothesis of the equivalence of the number of restrictions in each period yields an F-statistic of 0.18 (with a p-value of 0.911). This leads us to suspect that it is not intertemporal variation that accounts for the dispersion of control rights, but rather cross-sectional differences across the firms.

One concern with this analysis is the extent to which the allocation of individual control rights are independent of one another. If these rights are essentially being included on an all-or-nothing basis, it might distort our interpretation of the results. We address this concern by examining whether particular rights appear together or not. There are relatively few cases where two rights appear closely in tandem. For instance, in only 10 out of the 300 possible pairs does one control right in the pair appear at least two-thirds of the time when the other control right does.[9] In a supplemental analysis discussed in Footnote 15, we calculate the count of control rights eliminating four classes: the rights to manufacture the final product (#3), to market to product alone (#5), to shelve the project (#12), and to make public equity purchases (#25). After these deletions, no pairs of control rights overlap as described above.

V(ii). *Statistical Analyses*

In this section, we analyze the use of control rights. In both correlation and regression analyses, we find evidence consistent with the hypothesis that the financial condition of R&D firms affects their ability to retain control rights in technology alliances. We uncover mixed evidence regarding the influence of concerns about behavior after the alliance is signed. While several of these variables have significant explanatory power, their signs in our results are not always consistent with the Aghion–Tirole model.

[9] To cite one example of such a pair, Right #1 appears 69% of the time that Right #3 does, and Right #3 appears 76% of the time that Right #1 does. Results are similar when we compute correlation coefficients. Correlations are generally positive but modest in magnitude. The average correlation coefficient between the key alliance management rights is 0.026. The others are slightly larger as follows: between the alliance scope rights, 0.030; intellectual property rights, 0.043; governance structures, 0.081. The correlations across the different groups are lower. For instance, the average correlation coefficient between the key alliance management rights and the intellectual property rights is 0.001.

We have examined the correlation between the number of control rights assigned to the financing firm and the characteristics of the firms and the public equity market at the time of the alliance.[10] Because we are concerned that the results may be shaped by horizontal alliances as discussed above, we also undertake these analyses eliminating two sets of observations, alliances between biotechnology firms and between firms with similar financial resources. We again define these as firms whose assets are within five times of their partners' assets at the end of the year prior to the signing of the alliance.

The correlation analysis reveals a strong negative relationship between the number of control rights allocated to the financing firm and the financial strength of the R&D firm. Biotechnology firms with more revenues in the year before the alliance is signed, as well as those spending more on R&D and having more cash and equivalents, total assets, and shareholders' equity are less likely to negotiate away important control rights.[11]

The interpretation of the results using the two measures of the stage of the project is more problematic:

- First, we indicate the stage of the lead product at the time of the alliance through an ordinal rank, with 1 being discovery research and 10 being regulatory approval (see Appendix A). (As discussed above, only one project had received regulatory approval at the time the alliance was signed.) When the technology is in its early stages (the first five stages using this ranking scheme), there are significantly more control rights allocated to the financing firm.
- Second, we examine the number of patents that the R&D firm has at the time of the alliance as a proxy for the maturity of the project. In two of these analyses, a similar pattern is significant at the 10% confidence level: R&D firms with fewer patents give up more control rights.

The stage of project and patent results seem to contradict the Aghion–Tirole model, since we would anticipate that contractual incompleteness would pose the greatest problem in early-stage projects. As discussed above, in those settings project outcomes and R&D firm effort should be difficult to specify in an enforceable contract. These partial correlations,

[10] Details of the analysis can be found on the Journal's editorial web site.

[11] The one exception is that there is not a strong relationship between net income and the allocation of control rights. This reflects the peculiar economics of the biotechnology industry. While firms attracting more external research funding and receiving revenues from product market sales will report higher net income, early-stage companies with significant financial resources may spend more aggressively on R&D and, consequently, report lower net income (greater losses) than their less well-endowed peers. Thus, net income is a poor indicator of the financial resources of young biotechnology firms.

TABLE VI

Regression analysis of the control rights allocated to the funding party. The sample consists of 200 technology alliances initiated between biotechnology and pharmaceutical companies or between biotechnology firms in the 1980–1995 period. The dependent variable in the first and third panels is the number of control rights included in each alliance out of the twenty-five rights appearing in between 5% and 95% of the alliances, while in the second panel, it is the number out of the five rights identified as critical in discussions of these alliances (Rights #1-#5 in Table V). The public equity raised and the financial position variables are in billions of 1995 dollars. The biotechnology index reflects inflation-adjusted public equity values and is normalized to 1.0 on January 1, 1978. The dummy variable for early-stage alliances is coded as 1.0 for projects in the discovery through pre-clinical research phase. The third panel includes interaction terms between the patent counts and the financial variables. The constant terms are not reported for the ordered logit regressions. Absolute *t*-statistics in brackets.

Independent variables	*Using OLS specification*		*Using ordered logit specification*	
Panel A: Dependent variable is number of control rights out of 25 rights				
R&D firm's patent awards related to alliance	0.08 [2.16]	0.08 [2.27]	0.06 [2.05]	0.04 [1.43]
Total public equity raised in prior quarter	0.001 [0.00]		−0.01 [0.03]	
Biotech index at end of prior quarter		−0.31 [0.80]		−0.24 [0.82]
R&D firm's shareholders' equity at end of prior year	−11.44 [3.47]		−11.31 [3.79]	
R&D firm's total assets at end of prior year		−8.16 [3.53]		−6.70 [3.25]
Constant	9.59 [38.89]	10.12 [14.84]		
F-statistic	4.21	4.55		
χ^2-statistic			15.50	14.47
p-value	0.01	0.00	0.00	0.00
Adjusted R^2	0.05	0.06		
Log likelihood			−401.47	−393.47
Number of observations	180	176	180	176
Panel B: Dependent variable is number of control rights out of five critical rights				
Early-stage alliance	0.50 [2.96]	0.51 [2.94]	0.84 [2.61]	0.84 [2.59]
Total public equity raised in prior quarter	−0.31 [1.97]		−0.62 [2.05]	
Biotech index at end of prior quarter		−0.09 [0.52]		−0.14 [0.46]
R&D firm's shareholders' equity at end of prior year	−1.91 [2.20]		−4.13 [1.99]	
R&D firm's total assets at end of prior year		−1.57 [2.39]		−3.21 [2.29]
Constant	2.60 [15.82]	2.63 [8.49]		
F-statistic	8.06	6.80		
χ^2-statistic			20.13	16.52
p-value	0.00	0.00	0.00	0.00
Adjusted R^2	0.11	0.09		
Log likelihood			−242.80	−239.36
Number of observations	180	176	180	176

Panel C: Dependent variable is number of control rights out of 25 rights				
R&D firm's patent awards related to alliance	0.19 [3.45]	0.20 [3.49]	0.13 [3.09]	0.13 [3.18]
Total public equity raised in prior quarter	0.03 [0.07]		0.02 [0.08]	
Biotech index at end of prior quarter		−0.31 [0.79]		−0.23 [0.78]
R&D firm's shareholders' equity at end of prior year	−7.18 [1.97]		−6.21 [1.82]	
R&D firm's total assets at end of prior year		−5.38 [2.14]		−3.93 [2.03]
Patent awards ∗ shareholders' equity	−0.17 [2.57]		−0.16 [1.92]	
Patent awards ∗ total assets		−0.13 [2.64]		−0.13 [2.10]
Constant	9.41 [37.11]	9.93 [14.72]		
F-statistic	4.91	5.28		
χ^2-statistic			22.24	23.25
p-value	0.00	0.00	0.00	0.00
Adjusted R^2	0.08	0.09		
Log likelihood			−398.10	−389.08
Number of observations	180	176	180	176

however, may reflect other factors. For example, firms with few patents may also have few financial resources.[12]

We then examine the allocation of control rights in a regression framework. Our dependent variable is the number of the 25 control rights allocated to the financing firm. We also undertake a supplemental analysis, using only the control rights identified as key (Rights #1-#5).[13] We estimate both ordinary least squares and ordered logit regressions. The ordered logit specification avoids some of the problems associated with the differing importance of the various control rights: it treats an alliance assigning twelve control rights to the funding party as more favorable to the financing firm than one with six such control rights, but not necessarily twice as favorable.

The independent variables in the regressions include a dummy variable denoting early-stage projects at the time of the signing of the alliance (denoting those projects between the earliest discovery stage and pre-clinical research), the number of patent awards to the R&D firm in fields related to the alliance, the total amount of equity collectively raised by biotechnology firms from the public markets in the previous quarter, the index of biotechnology equity valuations, and two measures of the financial resources of the R&D firm (shareholders' equity and total assets). All financial variables are expressed in billions of 1995 dollars.[14]

The regression analyses are reported in Table VI. In each case, the coefficients of the measures of the financial condition of the firm are significantly negative, at least at the 95% confidence level. When the R&D firm is in a stronger financial position, it retains more of the control rights in the alliance. The coefficients suggest that these considerations have a significant economic impact. For example, in the first regression in Panel A of Table VI, a one standard deviation increase in the R&D firm's

[12] We also examine the correlations between the four subsets of control rights and the independent variables. When we examine the key alliance management control rights, designated Rights #1-#5 in Table V, the patterns seen above continue, but other significant patterns emerge. In particular, when more equity is raised by all biotechnology firms in the public markets during the quarter preceding the signing of the alliance, fewer control rights are assigned to the financing firm. This is consistent with the patterns found using the measures of the R&D firm's financial condition. The other three groups of control rights display correlations similar to those of the sample as a whole.

[13] See the Journal's editorial Web site for details.

[14] A natural question is the extent to which the independent variables are correlated with each other. The greatest correlations are between the variables used in alternative regressions: for example, the dummy variable denoting an early-stage agreement and the number of patent awards. Correlations between the firm-specific variables, such as shareholders' equity and patent awards, and the measures of market activity are low and statistically insignificant. There is virtually no correlation between the number of related patents and the company's financial resources, but the correlations between the dummy variable denoting early-stage deals and the financial resources variables are negative and of borderline statistical significance. For instance, the correlation coefficient between early-stage deal dummy and shareholders' equity, −0.14, is significant at the 7% confidence level.

shareholders' equity at the mean of the independent variables leads to an 11% drop in the predicted number of control rights assigned to the financing firm, declining from a predicted 9.3 to 8.3. In two regressions, consistent with the other patterns, R&D firms in weaker external financing markets cede more control rights.

The evidence regarding the maturity of the project, however, is somewhat at odds with value-maximization theory. Alliances whose lead product is in the early stages at the time the alliance is consummated tend to allocate more control rights to the financing firm. As Panel B of Table VI reports, the 'early stages' dummy variable is positive, even after controlling for the R&D firm's financial condition. As discussed in Section II, Aghion and Tirole predict that control rights should be assigned to the R&D firm when the marginal impact of its research effort on the value of the final output is greater than the marginal impact of the financing partner's financial investment, which we anticipate will be especially true for projects in the earliest stages of development at the time of the alliance signing. Thus, the empirical finding appears to contradict the theoretical predictions.

When the number of patents is used as the measure of project maturity instead of the stage of the lead project, the effect is in the predicted direction. As reported in Panel A of Table VI, the coefficient on the number of patents is positive. R&D firms entering into alliances with already-strong patent positions (where we may anticipate that much of the initial research is already completed, and the relative contribution of the R&D firm to the alliance will be more modest and writing an enforceable contract covering outcomes and effort easier) are assigned fewer control rights. At the mean of the independent variables in the first regression in Panel A, a one standard deviation increase in the number of related patent awards to the R&D firm at the time of the alliance leads to an increase from 9.3 to 9.9 rights assigned to the financing firm.[15]

[15] We also explore the robustness of the results to a variety of changes in unreported regressions. For instance, the insignificance of the variables measuring public market conditions in many of the regressions may reflect the extended negotiations that often characterize these alliances. We employ the same measures of market conditions as before, using the equity index and total equity raised, but examine these values during (or at the end of) the penultimate quarter before the transaction, rather than the quarter immediately prior to the transaction. Alternatively, the effects might reflect some unobserved inter-temporal variation. To address this concern, we add dummy variables for the year in which each alliance was signed. We also examine the impact of dropping the control rights that frequently appear alongside others, and the addition of independent variables to address alternative hypotheses. Other steps include the substitution of several alternatives for the independent variables, such as the amount of public equity raised by biotechnology firms in the previous four quarters for the measures of the previous quarter's fundraising or the biotechnology index, and the measures of the R&D firm's sales, R&D, and cash and equivalents instead of assets or shareholders' equity. To examine whether the results may be driven by a few outliers, we express the continuous independent variables in logarithms. We explore the robustness of the results to the addition and subtraction of particular control rights, for

In Panel C of Table VI, we add an interaction between the number of related patent awards and the shareholders' equity or the total assets of the R&D firm. The interaction term is significantly negative. The R&D firm's additional patents are associated with more control rights being assigned to the financing firm, but only in cases when the R&D firm has few financial resources. If the R&D firm has more financial resources, a stronger patent position leads to the R&D firm ceding fewer control rights. This finding may be considered as the strongest evidence for the presence of financial effects on the allocation of control rights. While there may be alternative explanations for why patents should lead to more or fewer control rights being assigned to the financing firm, they would be hard-pressed to explain this interaction pattern.

V(iii). *Practitioner Perspectives on the Results*

We discussed these results with a number of industry practitioners, including business development officials responsible for negotiating alliances, senior officials of smaller biotechnology firms, venture capitalists, and consultants. Our findings regarding the importance of financial constraints on the allocation of control rights met with nearly unanimous agreement. Many individuals related accounts of dramatically different alliances involving similar technologies being negotiated months apart, where the only material event in the interim was a cash infusion into the R&D firm. Others told of deliberate efforts by pharmaceutical firms to protract negotiations until the R&D firm was in a financial crisis, apparently in the hope of extracting key control right concessions.

The results regarding the stage of project were more controversial. Some practitioners believed that control rights are indeed usually allocated to the party with greater capacity for sub-optimal behavior after the alliance is signed, and that our analysis was simply too crude to pick up many of the patterns. Others believed that the allocation of control rights is dominated by the presence or absence of financial constraints, and that any other factors are secondary.

Several practitioners attributed the failure to allocate the control rights to the optimal party to a second factor. They argued that in addition to financing constraints, agency problems within corporate business development groups in financing firms can lead to sub-optimal allocations of control rights. Practitioners pointed out that the individuals who hold

example using only those control rights that appear in between 10% and 90% of the alliances. All of these changes have relatively little influence on the strong positive relationship between the R&D firm's financial condition and the number of control rights that it retains, or the much more ambiguous relationship between the stage at which the alliance is entered into and the allocation of control rights.

business development positions change jobs frequently. Meanwhile, it is often a long time until the success of an alliance is known. Even the costs of an agreement to the financing firm may be difficult for senior managers to assess: e.g. the number of milestone payments—which are usually contingent on scientific or regulatory progress by the R&D firm—that the financing firm should expect to make is often difficult to determine. As a result, performance evaluation is challenging. One of the few measures of the success of such an official is the toughness of the deals that he negotiates, as measured by the number of concessions extracted from the R&D firm. As a result of this approach to performance measurement, business development officials at some organizations are reputed to demand as many control rights as possible, no matter what allocation would maximize joint welfare.

VI. CONCLUSION

In this paper, we examine the determinants of control rights in alliances between biotechnology companies and sponsoring firms. Aghion and Tirole [1994] argue that these rights will be assigned so as to maximize the value of the final output, as long as the R&D firm has sufficient financial resources. We undertake three case studies as well as a quantitative analysis of 200 alliances. Consistent with the Aghion–Tirole framework, the allocation of control rights to the R&D firm increases with its financial resources. Evidence regarding the relationship between control rights and the stage of the project at the time the alliance is signed is less consistent with theoretical frameworks.

These findings, which underscore the importance of external financing, are somewhat provocative. In the Aghion–Tirole model, the allocation of control rights is affected by the inability of the R&D firm to commit to the effort that it will devote to pursuing the innovation and its lack of financial resources. Most of the literature following Grossman and Hart [1986], however, emphasizes only the first of these factors. We suggest that the most profound effect on the allocation of control rights, at least in technology alliances in the biotechnology industry, is the financial condition of the R&D firm, rather than mutual concern about maximizing joint value.

The findings in this paper also suggest a series of further research questions. The relationship between the structure of compensation and the allocation of control rights is an important, but little explored, issue. Another area that may reward future researchers is a more refined micro-level analyses of contractual terms. Finally, the relationship between contractual structure and the ultimate success of the alliance is an important but little-explored issue.

ACCEPTED DECEMBER 1997

APPENDIX A: THE DEFINITION OF ALLIANCE STAGE

From Federal and corporate documents, Recombinant Capital codes the stage of the lead product candidate in the agreement according to a ten-part scheme. These are arranged for the purposes of this analysis approximately in the sequence of the approval process. Discovery research (#1) concerns a research program for which no lead product candidate was identified at the time of the agreement. Lead molecule (#2) concerns a therapeutic discovery program for which a lead product candidate was identified at the time of the agreement, but no animal testing has been undertaken. Pre-clinical (#3) concerns a therapeutic discovery program for which some animal data had been obtained at the time of the agreement signing, but human trials had not yet began. Formulation (#4) and other pre-clinical (#5) concern research programs not yet at the clinical testing stages that do not involve traditional therapeutic products: formulation refers to the combination of approved or development stage drugs with a vehicle or agent for the administration of such drugs, and other pre-clinical refers to diagnostic or agricultural products. (These are ranked after pre-clinical therapeutic discovery programs since the length of time to approval is typically shorter in these cases.) Phase I (#6) concerns a therapeutic development program for which Phase I (safety) human testing was underway at the time of the agreement. Phase II (#7) concerns a therapeutic development program for which Phase II (small-scale efficacy) human testing was underway at the time of the agreement. Phase III/Field testing (#8) concerns a therapeutic development program for which Phase III (large-scale efficacy) human testing was underway at the time of the agreement or an agricultural development program for which field testing was underway at the time of the agreement. PLA/NDA filed (#9) concerns a research program where testing of the lead product was complete and pending regulatory review at the time of the agreement. Approved (#10) concerns a case where the lead product has already been commercialized at the time of the agreement. In the tabulations in Tables III and IV, discovery/lead molecule refers to agreements signed at stages #1 and #2, pre-clinical development refers to #3, #4 and #5, undergoing regulatory review refers to #6 through #9, and approved for sale refers to #10. In Table VI, 'early-stage alliance' refers to agreements signed at stages #1 through #5.

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