Technological Discontinuities and Interfirm Cooperation: What Determines a Startup's Attractiveness as Alliance Partner?

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***Abstract*—Incumbent firms often face severe challenges when confronted with technological discontinuous change. However, interfirm cooperation between incumbents and new entrants has been suggested as one way that incumbents can adapt to radical technological change. In particular, the authors are interested in the question of *how* incumbent pharmaceutical firms go about selecting alliance partners from the population of new biotechnology firms, in their quest to commercialize a discontinuous innovation. The authors propose that a startup's new product development, economies of scale, public ownership, and geographic location in a regional technology cluster are positively associated with the startup's attractiveness as an alliance partner. The authors find broad support for their model.**

***Index Terms*—Biopharmaceutical industry, complementary assets, incumbent—new entrant cooperation, technological discontinuities.**

I. Introduction

TECHNOLOGICAL discontinuities often create tremendous difficulties for incumbent firms. For example, the successful commercialization of xerography put manufacturers of carbon paper out of business. Xerox, the innovator, rose to dominance. Many other examples of discontinuous technologies igniting a Schumpeterian process of creative destruction can be cited: incandescent light bulb, internal combustion engine, radial tire, quartz, transistor, microprocessor, laser, computerized axial tomography (CAT scan), digital imaging, and so on. The fact is that discontinuous innovations often initiate a Schumpeterian process of creative destruction that frequently leads to the replacement of incumbents by new entrants [19], [31], [50], [51].

Nonetheless, some empirical evidence suggests that incumbent firms may be able to successfully commercialize a discontinuous innovation if the incumbents have the necessary financial and managerial resources and capabilities to master such an adaptation. In their study of the U.S. auto industry, Abernathy and Clark [1] showed that incumbents are able to benefit even from radical technological change that disrupts or makes obsolete the firm's existing technological competence, provided that the technological change simultaneously entrenches the incumbent's existing market customer linkages. Moreover, Christensen [10] has found empirical evidence for his claim that incumbents will generally succeed in adapting even to discontinuous technological change as long as the new technology is critical to the incumbents' existing value network. He defines the value network as the context within which the firm competes and satisfies important customers. In a similar fashion, Tripsas [58] demonstrated that incumbents may be buffered from the gale of creative destruction if they have the necessary complementary assets to commercialize the new technology. Further, Rothaermel [44], [45], found evidence that incumbents that possess complementary assets necessary to commercialize a radical new technology may be in an advantageous position to leverage their complementary assets via interfirm cooperation with new entrants and accomplish a successful transition to the new technology.

While existing empirical evidence explains *why* incumbents may survive and even thrive on radical technological change, the question of *how* incumbents adapt to radical technological change has received little attention. Interfirm cooperation has been suggested as one way for incumbents to adapt to radical technological change [26], [44], [45]. In this paper, we pursue the question: *what determines the attractiveness of new entrants as alliance partners for incumbent firms in the aftermath of a discontinuous innovation?* We study the biopharmaceutical industry, which more than 1600 firms entered in order to commercialize the new technology following Cohen and Boyer's breakthrough in recombinant DNA in 1973. This industry is characterized by extensive interfirm cooperation; indeed, it exhibited the highest number of alliances among all industries studied by Hagedoorn [27].

Yet, the incumbent pharmaceutical industry, composed of companies established during the drug discovery framework based on chemical synthesis, is fairly concentrated and oligopolistic in nature [5]. The measure that is most commonly used to proxy an industry's structure is the four-firm concentration ratio (CR4), which represents the share of industry sales accounted for by the four largest firms [9]. The CR4 for the pharmaceutical industry in 2000 was 33%. The top-ten leading pharmaceutical companies, which account for 60% of the entire market share, are all characterized by heavy R&D spending and a focus on the development of proprietary drugs [29]. Moreover, the incumbent pharmaceutical firms are on average many times larger than the new biotechnology entrants. For example, Merck, which is third worldwide in sales, had 50% more revenues ($33 billion) in 1999 than did the entire biotechnology industry ($22 billion) [22]. Given the synthesis

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of the pharmaceutical and biotechnology industries into the emerging biopharmaceutical industry, the question arises as to how these large incumbent pharmaceutical firms, in their quest to adapt to the new biotechnology, select alliance partners from the population of new entrants. We argue that the selection of potential alliance partners is determined by new entrant firm-specific factors that serve as guideposts for the incumbent pharmaceutical firms.

In Section II, we build theory and derive hypotheses predicting a new entrant's attractiveness as an alliance partner for incumbents. We subsequently discuss the biopharmaceutical industry, which is the research setting for this empirical study. In particular, we analyzed 973 strategic alliances between traditional chemical-based pharmaceutical companies and new biotechnology firms in the 25 year period between 1973 and 1997. We then introduce our research design and methods before presenting our results. We conclude the paper with a discussion of our results, the contribution and limitations of this study, and its implications for practice and future research.

II. Theory and Hypotheses Development

Competence-destroying technological discontinuities are generally commercialized by new entrants [59]. The impact of competence-destroying technological discontinuities on the incumbent firm's value chain is narrow but drastic. By definition, this kind of technological change destroys the incumbents' upstream, technology-oriented value chain activities. If the incumbent has valuable downstream assets that are needed to commercialize the new technology, i.e., complementary assets [55], and the new entrants are unable to integrate forward because of lack of capital and/or difficulty in building the appropriate downstream assets, then extensive interfirm cooperation between incumbents and new entrants may ensue [44], [45]. Such interfirm cooperation is motivated by a search for mutually complementary assets [56]. It generally occurs in an industry where a few dominant incumbents control access to the market while many new entrants provide the new technology [46].

For example, the emergence of cellular telephony constituted a technological discontinuity in the way telephone communication is provided [46]. In cellular telephony, signals are carried from the user's telephone to the switching network by radio transmission rather than by wire. The incumbents in the telephone industry, the public and private switching companies, were in need of radio technology. On the other hand, the new entrants, i.e., the radio-communication companies, were in need to access the traditional switching networks since cellular calls are generally routed from the sender to the switching network and then to the receiver. Thus, the complementarity of the assets held by incumbents and new entrants led to extensive interfirm cooperation in the telecommunications industry [17], which basically suspended a Schumpeterian process of creative destruction [46].

Following radical technological change, many new entrants enter the market to commercialize the new technology [31], [50], [59]. Assuming that the incumbents retain valuable complementary assets needed to commercialize the new technology, extensive interfirm cooperation between incumbents and new entrants ensues in order to successfully commercialize the new technology [46]. In general, the new entrants provide the new technology and the incumbents provide the necessary complementary assets. These complementary assets are regularly embedded in the downstream value chain activities like distribution, marketing, and sales [56]. In such a situation, the question arises: *how do these incumbent firms select alliance partners from the population of new entrants?* We argue that the incumbents use certain cues and signals to make their selection decision with respect to whom they will choose as allies.

On the other hand, one may wonder why new entrants should cooperate with incumbents to commercialize the new technology. It is important to note that new entrants have numerous incentives to enter into alliances with incumbents, including access to capital and the market as well as increased external legitimacy. For example, new entrants may gain access to much needed capital to fund their resource intensive research [41].[1] In her study of the causes and consequences of alliance formation in the biopharmaceutical industry, Majewski [35] has shown that there exists an informational asymmetry between established pharmaceutical companies (informed investors) and the (less informed) capital markets in assessing the quality and potential impact of the research conducted by new biotechnology firms. Thus, new biotechnology firms may use alliances with established pharmaceutical companies as a substitute for equity financing because the incumbents are a source of comparatively cheaper capital. In addition, new entrants may be forced to enter into alliances with incumbents in order to access the market, especially when the sales and distribution channels are dominated by incumbents [41].

Further, institutional theory argues that firms pursue certain actions and strategies to increase their external legitimacy [38]. Pursuing legitimacy enhancing strategies is particularly critical for new ventures as their perceived potential for success is highly uncertain, which leads many new ventures to fall prey to the liability of newness [53]. The legitimacy of a new entrant increases when an incumbent chooses to enter into an alliance with the new venture. Incumbent firms have overcome the liability of newness and have an established track record of performance. Further, incumbents have accumulated social capital, reputation, and status in the process [4], which spill over to new entrants. Stuart *et al.* [54] showed that interorganizational endorsements by reputable partners lead startups to faster initial public offerings (IPO) and higher IPO valuations.

A. New Product Development and Attractiveness

We argue that a startup's new product development success attracts the attention of incumbents. Successful new product development is critical for new entrants to gain access to cash flows, enhance external legitimacy and visibility, obtain first mover advantages, and as a consequence increase the chances of their survival [49]. However, new entrants have, by definition, no track record of prior performance since they are struggling to commercialize a new unknown technology. Any progress a new

[1]Chiron, as the most research intensive biotechnology firm, spends 37% of its revenues on R&D in comparison to Pfizer, the most research intensive pharmaceutical company, which spends 17% of its revenues on R&D [22].

entrant makes with respect to further developing the new technology toward commercialization should make the new entrant more attractive as an alliance partner for incumbents.

From the incumbent perspective, alliances with new entrants can be viewed as real options on emerging products [18]. Thus, incumbents allying with new entrants are creating cost effective options—in comparison to acquiring new entrants outright—with respect to the innovative products developed by new entrants. The cooperation between the old-line pharmaceutical firm Eli Lilly and the new biotechnology firm Genentech is a case in point. Genentech developed the biotechnology drug Humulin (human insulin), which attracted the attention of Eli Lilly, the market leader in insulin. Humulin was the first biotechnology drug to receive approval from the Food and Drug Administration (FDA) and was commercialized through a licensing agreement between Eli Lilly and Genentech. At the industry level, we observe that the incumbent pharmaceutical firms marketed and distributed seven of the top-ten selling biotechnology drugs in 1999, even though none of the drugs were developed by incumbents [22]. Thus, the new product development success of new entrants seems to enhance their attractiveness as alliance partners for incumbents.

Hypothesis 1: The relationship between the startup's new product development and its attractiveness as an alliance partner for large incumbent firms is positive.

B. Economies of Scope and Attractiveness

The probability of success for commercializing a new technology is *a priori* unknown. Many new technologies have trajectories that are based in a number of subfields [16]. A new entrant, in its attempt to commercialize a new technology, may benefit from economies of scope by participating in a number of related technological subfields. These startups may leverage knowledge and techniques across several technological subfields. At the same time, the new entrants may be able to generate revenues from one technological subfield in order to finance research in another technological subfield. For example, many new biotechnology startups focus on diagnostics and therapeutics at the same time. The idea behind this strategy is to commercialize diagnostic products and then to use the revenue stream generated by the diagnostic products to finance drug discovery and development [57]. Thus, new entrants that focus on several technological subfields may be in a position to benefit from economies of scope and thus improve their performance.

On the other hand, incumbents are generally active in several lines of business. Owing to a greater likelihood of similarity with their research or general business orientation, new entrants that realize economies of scope may be more attractive as alliance partners for large incumbent firms than are startups that focus only on one technological subfield. Lane and Lubatkin [33], in their study of strategic alliances between incumbents and new entrants in the biopharmaceutical industry, found that the ability of firms in an alliance to learn from one another was strongly influenced by the similarity between the knowledge base and the internal knowledge processing structures of the two firms. We argue that the probability of such a similarity is higher if the new entrant participates in several technological subfields in order to benefit from economies of scope.

Hypothesis 2: The relationship between a startup's economies of scope and its attractiveness as an alliance partner for large incumbent firms is positive.

C. Public Ownership and Attractiveness

Many startups in high technology industries are partly, if not mostly, financed by venture capital. The goal of many venture capitalists is to take the startup public as soon as they expect a return above their predetermined benchmark hurdle [20]. A favorable valuation at the IPO returns cash for the risky investment undertaken by the venture capitalist. The management of the startup may also favor an early IPO because selling equity to the public generates much-needed cash to finance the new venture's research, development, and growth. In addition, the IPO allows managers to exchange personal stockholdings for cash. Further, new ventures may seek an early IPO to enhance their external legitimacy. Going public enhances the legitimacy of the new venture because it demonstrates to the company's external stakeholders that the firm has followed and passed the accepted and time honored rules and regulations required in order to go public. Further, in highly uncertain environments found in high technology industries, startups may opt to go public as an outcome of mimetic isomorphism [15], i.e., the intention of the startup might be to become more like the successful companies in their environment, which are generally publicly traded.

We argue that startups with the stamp of approval from Wall Street may be more attractive alliance partners than are privately held startups without such an endorsement. Shan *et al.* [52] found that publicly traded startups had significantly more alliances than did privately held companies. By going through the IPO, publicly held start ups have established a track record of adherence to rules and regulations that privately-held startups lack. Further, the public startup was endorsed by the investment banker that took the firm public [54]. Thus, the uncertainty for a large incumbent entering an alliance with such a new entrant is reduced. Further, publicly traded companies in general obtain more coverage in the business press, which in turn may alert incumbents to pursue such startups as potential alliance partners. H. S. Parker [40], the CEO of the biotechnology startup Targeted Genetics, indicated that every time there is an article about Targeted Genetics in the Wall Street Journal, the telephone will ring off the hook with incumbent pharmaceutical companies calling and offering alliance possibilities.

Hypothesis 3: A publicly traded startup is more attractive as an alliance partner for large incumbent firms.

D. Geographic Location and Attractiveness

The geographic location of firms has been of interest to scholars ever since Marshall [37] studied what he called "industry nodes" and remarked that there was steel in the air in Sheffield. If we fast forward to the beginning of the 21st century, we witness that the importance of the regional technology cluster is still prevalent despite globalization and drastic advancements in telecommunications that might lead us to believe that geography would be less important. For example,

in the U.S. we see clusters of semiconductor firms in Silicon Valley, computer manufacturers in Austin, biotechnology firms in Seattle and San Diego, ceramics firms in Corning, and electrooptics firms in Orlando. In Europe, we see regional technology clusters in the car industry in southern Germany, the textile industry in the Emilia Romagna region in Italy, the Scientific City in France, and the Motor Sport Valley in the U.K.

Porter [42] has defined a regional cluster as a geographically proximate group of firms and supporting associations in a particular field linked by commonalities and complementarities. These firms and associations are interconnected through formal and informal networks. There are several benefits associated with firms that are located in a regional technology cluster. Saxenian [48], in her study of interfirm networks in the semiconductor industry in Silicon Valley, notes that being located in that technology cluster allows firms to be part of a regional network-based industrial system that fosters organizational learning and flexible adjustments among specialist producers of related technologies. Further, she argues that the region's open labor market combined with dense social networks based on formal and informal ties allows for personnel to move easily between firms and to spread cutting-edge knowledge and practices throughout the region. In addition, dense social networks and open labor markets encourage the creation of new ventures as well as low cost experimentation at established firms [7].

Thus, it is important to note that firms commercialize a new technology not only through internal R&D efforts, but also through the absorption of knowledge from external sources such as competitors, suppliers, customers, trade associations, formal and informal meetings, and the movement of personnel [12]. External sources of innovation available in technology clusters create knowledge spillovers that benefit firms that are located in a technology cluster. It has been suggested that these spillovers are more important catalysts for innovation than are inventions undertaken within the firm [36]. Deeds *et al.* [14] showed that firms that are located in a regional technology cluster may experience advantages over firms that are not located in a regional technology cluster with respect to the development of innovative products. In addition, Jaffe *et al.* [30] found that knowledge spillovers are generally limited to the geographic location of the specific technology cluster.

Further, Porter [42] argued that the competitiveness of a region depends on factor endowments, local demand conditions, competitiveness of related and supporting industries, and strategy, structure, and rivalry. Firms located in a technology cluster benefit from those re-enforcing factors as they have a positive impact on the firms' competitiveness and innovativeness. This, in turn, should enhance the attractiveness of a startup as a potential alliance partner for an incumbent that is attempting to adapt to a new technology via interfirm cooperation. Through an alliance with a new entrant located in a regional technology cluster, the incumbent firm is in a position to not only tap into the knowledge contained in its alliance partner but also to tap into the knowledge and expertise embedded in the cluster through spillover effects. Further, establishing alliances with firms located in a regional technology cluster is a cost-effective way to tap into the knowledge embedded in the regional technology cluster when compared to the cost of acquiring a firm located in the cluster or establishing a physical presence in the cluster.

Hypothesis 4: A startup located in a regional technology cluster is more attractive as an alliance partner for large incumbent firms.

III. Research Setting

The research setting is the biopharmaceutical industry. This term comprises the industrial sector composed of nonprofit organizations conducting basic and applied research in biotechnology such as universities and other research institutions, new biotechnology firms dedicated to commercializing the new technology such as Amgen and Chiron, and traditional pharmaceutical companies such as Merck or Pfizer that participate in biotechnology for drug discovery, development, and commercialization. In this study, however, we focus on a subset of the biopharmaceutical industry, i.e., we study how large established pharmaceutical companies (incumbents) go about selecting alliance partners among small biotechnology startups (new entrants).

The emergence of biotechnology can be seen as a competence-destroying technological discontinuity in the way drugs are discovered and developed [54]. Competence-destroying technological discontinuities are generally commercialized by new entrants [59]. This is the situation in the biopharmaceutical industry, as many new biotechnology firms emerged to commercialize this technological breakthrough. Since the mid 1970s, more than 1600 new companies have entered the industry to commercialize biotechnology, the majority of them with a focus on pharmaceuticals. These new biotechnology firms focus primarily on basic research, drug discovery, and development. Since forward integration is difficult, new biotechnology entrants generally pursue alliances with incumbent pharmaceutical firms to access the downstream capabilities of the incumbents in order to enter the market for pharmaceuticals. Traditional pharmaceutical companies are, in turn, motivated to partner with new entrants as this allows the incumbents to leverage their existing complementary assets in the drug approval process and in sales and distribution through detail people [44], [45]. The cooperation between Biogen and Schering-Plough in commercializing Intron A as the first biotech-interferon product approved for cancer treatment and the cooperation between Chiron and Merck to commercialize the drug Engerix-B for the prevention of hepatitis B are examples of cooperative arrangements in which incumbents and new entrants searched out their mutually complementary assets.

IV. Research Design and Methods

A. Sample and Data

We identified all new biotechnology firms fully dedicated to human *in vivo* therapeutics listed in the BioScan [6] industry directory. This segment of the biotechnology industry is comprised of new biotechnology startups engaged in the discovery and development of biotechnology drugs and diagnostics that

are placed inside the human body (*in vivo*) as opposed to *in vitro* therapeutics that are used outside the human body. We focused on *in vivo* therapeutics because the firms engaged in this segment of biotechnology are subject to extensive regulatory requirements (e.g., FDA in the U.S.), which require detailed reporting of the products in development. The stringent reporting requirements imposed by regulatory authorities ensured a homogenous sample of firms focusing on the same segment in biotechnology and aided us in coding the qualitative data.

BioScan provides one of the most comprehensive publicly available directory covering the global biotechnology industry. It has been used in a number of different studies (e.g., [13], [33], [43]–[45], and [47]). Our sample is comprised of 325 new biotechnology firms that entered 973 strategic alliances with incumbent pharmaceutical firms in the 25 year period between 1973 and 1997. BioScan contains detailed qualitative information on each alliance that a new biotechnology firm is engaged in. The qualitative information about the alliance agreements includes information about whom the alliance is formed with, when it was entered, what activity of the value industry chain it encompasses (e.g., drug discovery, development, production, clinical trials, FDA regulatory process, sales and distribution), and the type of agreement (research, development, licensing, marketing, equity investment, etc.). We studied all 973 alliance descriptions and coded the qualitative data based on a coding scheme discussed below. In order to gain a better understanding of interfirm cooperation in this highly dynamic industry, we augmented the secondary data with a dozen semi-structured interviews conducted with company founders, executives (including CEOs), board members, managers, and scientists in the biopharmaceutical industry.

B. Measures

1) *Attractiveness as Alliance Partner*. The dependent variable is the *attractiveness of a new biotechnology firm* as an alliance partner for established chemical-based pharmaceutical companies. We measured the attractiveness of a new biotechnology firm by the number of times the new entrant was chosen as an alliance partner by incumbent pharmaceutical firms, i.e., by the number of its pharmaceutical alliances. The number of a startup's pharmaceutical alliances corresponds positively to its attractiveness as a collaborative partner for large pharmaceutical companies.

2) *New Product Development*. BioScan includes a section describing in detail each biotechnology firm's new product development activities. We coded all products that a new entrant had in preclinical trials, clinical trial phases I-III, or in the FDA approval process as new product development. Once a product has reached the preclinical trial stage, the FDA requires detailed reporting about the product. In addition, the new biotechnology firm generally seeks out the business press to publicize its successful new product development. Moreover, only about 2.5% to 5% of all the compounds screened by a new biotechnology firm reach the preclinical trial stage [22]. This indicates that the products we included in our new product development count have already overcome a major obstacle on their way to becoming a biotechnology drug approved by the FDA. Thus, identifying promising lead candidates is a critical success milestone for new entrants. Moreover, along with publicity and FDA reporting comes the attention of large incumbent pharmaceutical firms.

3) *Economies of Scope*. Economies of scope exist when it is cheaper for a new biotechnology firm to focus on the research and development of two or more products together rather than to pursue each separately [3]. In biotechnology, technology platforms and trajectories are typically based on a number of different subfields [16]. Participating in different biotechnology subfields may allow the new entrant to realize economies of scope.

For example, Immunex has used its expertise in immunology, particularly in cytokine research, to develop Leukine, a product for oncology. Moreover, levering the knowledge gained from the development of Leukine into the field of rheumatology allowed Immunex to develop its blockbuster drug Enbrel. Both the oncology and the rheumatology subfields involve cytokine research. Thus, Immunex was able to expand its subfields of therapeutic indications based on economies of scope derived from its initial research in cytokine. More recently, Immunex has expanded into the cardiovascular subfield with Nuvance for the treatment of asthma and Novantrone for the treatment of multiple sclerosis, again driven by economies of scope derived from its expertise in immunology.[2] Thus, we proxied a startup's economies of scope through inclusion of a count variable representing the number of biotechnology subfields in which a new entrant firm participates [52].

4) *Public versus Private Ownership*. We included an indicator variable to differentiate between public and private ownership, with $1 =$ Public firm.

5) *Regional Technology Cluster*. We identified the top-ten regional technology clusters in the U.S. following the biotechnology industry report by Lee and Burrill [34]. The number one cluster is the San Francisco Bay Area with 204 biotechnology firms (about 16% all biotechnology firms are located here—based on the 1300 firms covered by Lee and Burrill [34]). The number ten cluster is the Austin, TX, area with 53 biotechnology firms (about 4% of all biotechnology firms). Thus, our implicit cutoff point is that at least 4% of all biotechnology firms must be located in the same geographic region for the area to qualify as a regional technology cluster. Based on the geographic location of the biotechnology startup, we included an indicator variable to differentiate between firms located in a technology cluster and firms not located in a technology cluster, with $1 =$ located in a technology cluster.

6) *Other Alliances*. A biotechnology startup can enter into three different types of alliances: vertical-upstream alliances with nonprofit research institutions like universities to procure basic research; horizontal alliances with other biotechnology firms to achieve economies of scope and scale; and vertical-downstream alliances with pharmaceutical companies to access the pharmaceutical companies' expertise in regulatory management and drug distribution [2], [47]. In this study, we focus on 973 vertical-downstream alliances that biotechnology startups have entered with incumbent pharmaceutical firms. However, the number of vertical-downstream alliances that a

[2]Source: Author's interviews at Immunex.

TABLE I
DESCRIPTIVE STATISTICS AND BIVARIATE CORRELATION MATRIX

	Mean	Std. Dev.	Min.	Max.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Attractiveness as Alliance Partner	2.99	3.57	0	31										
2. Other Alliances	3.86	4.47	0	33	0.45									
3. Equity vs. Non-Equity Alliances	0.05	0.16	0	1	-0.01	0.02								
4. Innovativeness	5.02	13.39	0	152	0.49	0.50	0.02							
5. Firm Age	9.61	4.62	1	27	0.33	0.20	-0.02	0.30						
6. Firm Size	164.52	572.88	3	7500	0.43	0.62	0.02	0.61	0.24					
7. Subsidiary	0.08	0.27	0	1	0.01	0.00	-0.06	-0.01	0.05	0.01				
8. New Product Development	5.14	4.06	1	24	0.39	0.46	0.11	0.28	0.18	0.36	-0.07			
9. Economies of Scope	6.23	4.71	1	33	0.42	0.43	0.02	0.37	0.27	0.39	0.03	0.32		
10. Public Ownership	0.69	0.46	0	1	0.22	0.08	-0.01	0.12	0.17	0.09	-0.18	0.22	0.06	
11. Regional Technology Cluster	0.63	0.48	0	1	0.11	0.11	0.09	0.13	-0.01	0.10	0.01	0.16	0.02	0.04

Correlations greater than or equal to 0.28 are significant ($p < 0.05$), $N = 325$.

new entrant has entered should be positively correlated with the number of vertical-upstream and horizontal alliances that it has entered. We controlled for this effect through the inclusion of the variable *other alliances*, which is the sum of the new entrant's nonprofit (vertical-upstream) and biotechnology (vertical-downstream) alliances.

7) *Equity versus Non-equity Alliances*. We controlled for equity alliances (strong ties) versus non-equity alliances (weak ties) [23] through inclusion of the ratio of equity alliances over non-equity alliances for each biotechnology startup.

8) *Innovativeness*. We controlled for the new entrant's innovativeness through inclusion of the number of patents it had obtained in the time period between 1991 and 1995. We chose the five-year period between 1991 and 1995 for three reasons. First, a five-year measure adjusts for the seasonal fluctuation of a new biotechnology firm receiving patents in any given year. Second, new biotechnology firms generally do not receive very many patents (about one per year) since many are small startups. Thus a longer time period should capture patent activity more effectively. Third, the time frame 1991 to 1995 allows for time to elapse prior to December 1997, the date when we took stock of the pharmaceutical alliances the new entrant had entered.[3] A similar measure for innovativeness was used in prior studies [45], [52]. The number of patents should be positively associated with the new entrant's *attractiveness as alliance partner*. The patent data was obtained from the U.S. Patent and Trade Mark Office.

9) *Firm Age*. We controlled for the new entrant's firm age, assuming that older firms are likely to have a higher number of cooperative arrangements than are younger firms.

10) *Firm Size*. We also controlled for firm size. In general, firm size is measured in revenues or market share; however, most new biotechnology startups do not have a positive revenue stream at this point. Thus, we controlled for a new entrant's firm size by using the number of employees as a proxy, assuming that larger firms are likely to have more alliances than are smaller firms.

[3]This is the publication date of the BioScan industry directory [6] used for this study.

11) *Subsidiary versus Independent*. We included an indicator variable to distinguish between independent firms and subsidiaries, assuming that independent firms will be more attractive as alliance partners for incumbent firms, with 1 = subsidiary.

C. Estimation Procedure

The hypotheses were tested using a multivariate regression model. Since the dependent variable is an integer count variable, OLS estimates of regression coefficients would have been asymptotically biased and inconsistent [25]. Therefore, a negative binomial model with a maximum likelihood estimation procedure is indicated to test the hypotheses. We preferred the negative binomial model over the Poisson model since the Poisson model has the restrictive prerequisite of mean and variance equality. In the social sciences, mean and variance equality is the rare exception rather than the rule [32].

V. RESULTS

The 325 firms entered into 973 pharmaceutical alliances and 1253 other alliances, which split into 729 alliances with other biotechnology firms and 524 alliances with nonprofit research organizations. The average new entrant had entered into three pharmaceutical alliances and four other alliances, had 5% equity alliances, had held five patents, had participated in six biotechnology subfields, was 9 1/2 years old, had 165 employees, and had five products in development. About 69% of the firms were public, 63% were located in a regional technology cluster, and 8% of the firms were subsidiaries. A descriptive statistic of the variables as well as a correlation matrix can be found in Table I, while Table II depicts the regression results.

Model 1 depicts the base model including the control variables only. We find that the control variables, *other alliances*, *innovativeness*, and *firm age*, are positive, as expected, and significant at $p < 0.05$ or smaller. The overall model is significant at $p < 0.001$. These coefficients remain significant in all subsequent models (at $p < 0.1$ or smaller). We also see weak support for our variable controlling for equity versus non-equity

TABLE II
REGRESSION RESULTS

Dependent Variable: Attractiveness as Alliance Partner

	Model 1 (Base)	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.3112**	0.1762†	0.2424*	3.45E-4	0.1829	-0.2126†
	(0.1334)	(0.1360)	(0.1337)	(0.1510)	(0.1516)	(0.1647)
Other Alliances	0.0410**	0.0218†	0.0334*	0.0428**	0.0404**	0.0222†
	(0.0144)	(0.0148)	(0.0144)	(0.0141)	(0.0143)	(0.0144)
Equity vs. Non-Equity Alliances	-0.3262	-0.5453†	-0.3127	-0.2965	-0.3497	-0.4807†
	(0.3818)	(0.3842)	(0.3758)	(0.3751)	(0.3796)	(0.3730)
Innovativeness	0.0064*	0.0103*	0.0087*	0.0086*	0.0086*	0.0080*
	(0.0050)	(0.0042)	(0.0049)	(0.0048)	(0.0050)	(0.0046)
Firm Age	0.0513***	0.0426***	0.0429***	0.0434***	0.0524***	0.0332**
	(0.0122)	(0.0120)	(0.0123)	(0.0119)	(0.0121)	(0.0119)
Firm Size	1.52E-5	-3.85E-5	-2.25E5	-1.93E-6	1.17E-5	-6.24E-5
	(1.23E-4)	(1.12E-4)	(1.19E-4)	(1.17E-4)	(1.22E-4)	(1.06E-4)
Subsidiary	-0.070	0.0182	-0.0934	0.0902	0.0785	0.1044
	(0.1957)	(0.1910)	(0.1933)	(0.1958)	(0.1949)	(0.1894)
New Product Development		0.0546***				0.0372**
		(0.0140)				(0.0139)
Economies of Scope			0.0291**			0.0235*
			(0.0109)			(0.0106)
Public Ownership				0.5050***		0.4383***
				(0.1211)		(0.1192)
Regional Technology Cluster					0.1928*	0.1587†
					(0.1098)	(0.1052)
Log Likelihood	-689.46	-681.90	-685.86	-680.95	-687.93	-672.19
Degrees of Freedom	7	8	8	8	8	11
Chi Square	447.87***	462.99***	455.06***	464.89***	450.93***	482.46***
Improvement over Base ($\Delta\chi^2$)		15.12***	7.19***	17.02***	3.06***	34.59***

Standard Errors in Parentheses; $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Models are negative binomial count using a maximum likelihood estimation procedure.

alliances. The coefficient is negative throughout all models, as expected, and marginally significant at $p < 0.1$ in Models 2 and 6. We added the variables of interest individually to ascertain their unique contribution (Models 2–5), before estimating the full model (Model 6). Models 2–6 each represent significant improvements over the base model at $p < 0.001$.

Hypothesis 1 states that the greater the startup's new product development, the higher its attractiveness as an alliance partner for large incumbent firms. Model 2 indicates that *new product development* is positive and significant $(p < 0.001)$. Hypothesis 2 postulates that the greater the startup's economies of scope, the higher its attractiveness as an alliance partner for large incumbent firms. Model 3 shows that *economies of scope* is positive and significant $(p < 0.01)$. Hypothesis 3 indicates that publicly traded startups are more attractive as alliance partners for large incumbent firms than are privately owned startups. Model 4 indicates that *public ownership* is positive and significant $(p < 0.001)$. Hypothesis 4 proposes that startups that are located in a regional technology cluster are more attractive as alliance partners for large incumbent firms than are startups that are not located in a regional technology cluster. Model 5 indicates that *regional technology cluster* is positive and significant $(p < 0.05)$. Thus, we find preliminary support for Hypotheses 1-4.

Model 6, the full model, reveals the following: *new product development* is positive and significant $(p < 0.01)$, *economies of scope* is positive and significant $(p < 0.05)$, *public ownership* is positive and significant $(p < 0.001)$, and location in a *regional technology cluster* is also positive but only marginally significant $(p < 0.1)$. In sum, we find strong support for Hypotheses 1-3 and some support for Hypothesis 4.

Subsequently, we applied a Wald-type test for the differential impact of each coefficient on the startup's *attractiveness as alliance partner* based on the results obtained in the full model (Model 6) [11]. The statistically significant rank order of the variables (1 = most important) with respect to their differential positive impact on the startup's *attractiveness as alliance partner* is: 1) *public ownership*; 2) *regional technology cluster*; 3) *new product development*; and 4) *economies of scope*.[4]

[4]The statistically significant differences were all at the $p < 0.001$ level except the difference between location in *regional technology cluster* and *new product development*, which was at the $p < 0.1$ level.

VI. Discussion

A. Contribution

Abernathy and Clark [1] point out that an incumbent will generally succeed in commercializing a discontinuous innovation that disrupts the incumbent's technological competencies if the innovation simultaneously entrenches or conserves the incumbent's existing market linkages. This kind of innovation—what Abernathy and Clark call revolutionary innovation—seems to be the kind of innovation we are witnessing in the biopharmaceutical industry. The new biotechnology renders obsolete the technological competencies of the incumbent pharmaceutical firms in chemical-based synthesis, while at the same time sustaining the importance of market-oriented competencies like clinical testing, FDA regulatory approval, and drug distribution through a tremendous sales force of detail people [46].[5]

Others have pointed out that incumbents may survive radical technological change through strategic alliances established prior to the emergence of a technological discontinuity [39] or by utilizing complementary assets in the aftermath of a discontinuity [58]. Further, it has been demonstrated that incumbents may be in an advantageous position to commercialize a discontinuous innovation via interfirm cooperation with new entrants when the incumbents control the complementary assets needed to commercialize the new technology [44], [45]. In this paper, we attempted to answer the question: *how do incumbent firms select alliance partners from the population of new entrants?*

We advanced the notion that incumbents choose alliance partners from the population of new entrants based on the startup's new product development, economies of scope, public ownership, and location in a regional technology cluster. In our empirical study of alliance formation in the biopharmaceutical industry, we found support for our theory as the above-mentioned characteristics of startups are statistically significantly associated with their attractiveness as alliance partners for large established firms. Further, it is interesting to note that our results indicate that public ownership has the strongest impact on the startup's attractiveness as an alliance partner, followed by location in a technology cluster and then by a startup's new product development and economies of scope. It seems that public firms have earned legitimacy and thus are attractive alliance partners for incumbent pharmaceutical companies. External legitimacy seems to be particularly important in high-technology industries, where the dynamic environment can lead to the extinction of many new entrants [28]. Firms that have gone public have obtained the stamp of approval from the financial community and have thus reduced their liability of newness [53]. This, in turn, makes them attractive alliance partners for incumbents.

According to our empirical results, the next most important new entrant characteristic is geographic location in a regional technology cluster. It seems that incumbents select startups located in a regional technology cluster not only to tap into the knowledge embedded in the startup but to also to tap into the knowledge contained in the technology cluster. The third most important selection criterion for incumbents is the startup's new product development. Thus, a startup's success in new product development clearly signals that the new entrant is a potential high performer that would make a good alliance partner. Incumbent firms count on the notion that past performance predicts future performance. Finally, a new entrant's economies of scope are significant with respect to the firm's attractiveness as an alliance partner, but to the least extent of all the variables studied. A focus on certain disease categories may be more important than the entrant's economies of scope because it may accomplish a match based on similarities between the incumbent and the new entrant. This should be investigated in future research.

Based on the control variables, our results seem to indicate that startups that engage in alliances with vertical-upstream partners in the industry value chain like universities and in horizontal alliances with other biotechnology firms also seem to be attractive alliance partners for incumbent pharmaceutical firms. Biotechnology startups reach upstream in the industry value chain to access the basic knowledge generated in research institutions. They reach horizontally to other biotechnology firms to achieve economies of scale and scope. Finally, the biotechnology startups reach downstream in the industry value chain to commercialize their new products [47].

Commercializing new biotechnology products is highly risky and resource intensive. It can take up to 15 years and cost over $500 million to bring a promising molecule to the market [8]. Even worse, most of the promising lead candidates will not be able to successfully complete clinical trials and gain FDA approval. Immunex's CEO Fritzky has indicated that the chance that a newly discovered biotechnology molecule will make it from the start through finish in the drug commercialization process is approximately 0.0115% or about 1 in 11 500 [21]. Thus, one blockbuster drug like Amgen's top-selling biotechnology drug Epogen, which generates about $2 billion sales annually, must compensate for all of Amgen's drugs that do not make it through clinical trials and FDA approval or do not perform well on the market. It is important to note that blockbuster drugs like Amgen's Epogen or Genentech's Humulin are the rare exception rather than the rule. Given the difficult and resource intensive nature of the drug development and approval process, large incumbent pharmaceutical firms are advantageously positioned to commercialize promising biotechnology drugs that are discovered and developed by new biotechnology firms. The incumbent firms' financial resources and management expertise in the FDA approval process and drug distribution allow them to secure this advantageous position [44], [45].

Our control variables further seem to indicate that startups that have a higher ratio of equity alliances in their overall alliance portfolio are generally less attractive as alliance partners for large incumbents. Equity alliances are strong ties that signal a pharmaceutical company's ownership position in a biotechnology startup. This may deter other pharmaceutical companies from entering an alliance with a biotechnology startup that is partly owned by one of their competitors. We also found that the more innovative biotechnology startups are consistently more attractive as alliance partners for incumbent pharmaceutical companies. In addition, as expected, older biotechnology

[5]Large pharmaceutical companies have sales forces that approach or exceed 15 000 people.

firms were chosen more often as alliance partners by large pharmaceutical firms. Achieving innovation and gaining external legitimacy occur over time, which is reflected in the significance of the firm age variable.

B. Limitations

We would also like to point out that this study has several limitations. One limitation of this study is that we are focusing only on one kind of technological change, i.e., we focus on a revolutionary innovation [1]. While focusing on one specific type of technological change may be limiting in some aspects, we believe that such a focus allows us to gain insights into how incumbents commercialize this type of discontinuous innovation. Understanding the interfirm cooperation that seems to follow revolutionary innovations is particularly important in light of the fact that seven of the top-ten selling biotechnology drugs on the market are marketed by incumbent pharmaceutical companies even though none of the drugs were developed by incumbents. Sales of these seven products amounted to more than $5 billion in each of 1998 and 1999 [22]. More importantly, the incumbent pharmaceutical companies extract about 50% of the revenues generated. For example, the biotechnology firm Immunex introduced Enbrel, a radical new treatment for rheumatoid arthritis based on a genetically engineered human protein. Enbrel is considered a blockbuster drug that is forecasted to reach $5 billion in sales by 2005. Nevertheless, Immunex must share this revenue stream with American Home Products (AHP), whose sales force copromotes Enbrel (i.e., the revenue partition is 55/45 between Immunex and AHP). Moreover, the biotechnology firm ICOS developed Cialis, which will be managed through the FDA and distributed by the pharmaceutical company Eli Lilly. Cialis is expected to compete head on with Pfizer's blockbuster drug Viagra in the market for sexual dysfunction worth several billion dollars. Once Cialis is commercialized, however, the revenue partition will be 50/50 between Lilly and ICOS.

A further limitation of this study also concerns its generalizability, since the biopharmaceutical industry is heavily regulated. In our theory building, we assume that incumbents control access to the market and have the necessary capital to commercialize a radical new technology. A situation similar to that of the biopharmaceutical industry can be found in the deregulated telecommunications industry after the emergence of cellular telephony, where new entrants and incumbents cooperated to commercialize this radical new technology [17]. Thus, the telecommunications industry may be an ideal setting to test our theory in a different (nonregulated) industry and thus to enhance its external validity.

Another limitation of this study is that we focused only on surviving alliances. While this may introduce a selection bias, we argue that such a potential bias can be neglected. Due to the protracted nature of the product development process, alliances in the biopharmaceutical industry are generally characterized by a low mortality rate and extraordinary longevity. As noted earlier, the product development process can easily take up to 15 years. Further evidence for a low mortality rate of alliances in the biopharmaceutical industry was provided by Shan *et al.* [52], who found that the mortality rate is only around 15%. Moreover, Green [24] reported that the ratio of alliances formed to alliances terminated is about ten to one. Given those numbers, we believe that our results are not materially influenced by a potential survivorship bias.

C. Managerial Implications

The results of our study also have implications for the practicing manager in high-technology startups. We are able to contribute the notion that public startups make more attractive alliance partners than do private startups. Pursuing an IPO may generate many more intangible benefits besides trading equity for cash. Clearly, the manager of the startup should also keep in mind that successful new product development attracts alliance partners. Further, geographic location matters. If possible, the manager should locate the company in a regional technology cluster because this also seems to enhance the firm's attractiveness as an alliance partner for large incumbents.

VII. Conclusion

We believe that attractiveness as an alliance partner is an important variable in the equation that determines the success of high-technology startups. Several studies have shown that there exists a positive relationship between a startup's strategic alliances and its performance [13], [14], [47], [52]. In this paper, we introduced the construct of *attractiveness as alliance partner*, which we view as an antecedent to alliance formation with incumbents and subsequently to new entrant firm performance. Empirical evidence seems to support the claim that both incumbents and new entrants benefit from interfirm cooperation in their attempts to cooperatively commercialize a discontinuous innovation [2], [44], [45], [47], [52]. One question that remains is *who benefits more?* We suspect that incumbents benefit relatively more than new entrants, even though the incumbents help generate the available rents in the first place. Thus, interfirm cooperation between incumbents and new entrants in commercializing a discontinuous innovation creates a win–win situation, but the incumbents seem to win disproportionately more than the new entrants. This is an interesting proposition that should be taken up in further research.

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