Research on Strategic Alliances in Biotechnology: An Assessment and Review

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1. Introduction

Since the late 1980s, the rate of interorganizational alliances, or voluntary agreements between firms involving exchange, sharing, or co-development of products, technologies, or services, has accelerated in multiple industries (Gulati 2007). Subsequently, scholars have grown interested in issues around formation of strategic alliances and selection of partners (e.g., Chung et al. 2000; Gulati 1995b; Hagedoorn 1993; Walker et al. 1997), governance of alliances (e.g., Casciaro 2003; Reuer et al. 2002), as well as understanding the implications of strategic alliances for firms' behavior and performance (e.g., Ahuja 2000a; Chan et al. 1997; Doz 1996). These issues have been examined both in more traditional industries, such as global airline industry (Gimeno 2004), automotive (Dyer 1996), steel (Koka and Prescott 2002; Rowley et al. 2000), chemical (Ahuja 2000b), and packaging machine manufacturing (Lorenzoni and Lipparini 1999), as well as in more technology-oriented fields such as cellular services (Rosenkopf et al. 2001), computers (Gulati et al. 2007), semiconductors (Rowley et al. 2000; Stuart 1998), software (Lavie and Rosenkopf 2006; Singh and Mitchell 1996), and biotechnology (Powell et al. 1996; Rothaermel and Deeds 2004).

Among these industries, biotechnology[1] stands out because interorganizational collaborations have played a crucial role in the industry since its inception. In fact,

[1] The biotechnology industry comprises various sectors, such as healthcare, agricultural and industrial biotechnology (Burrill 2007). Alliances have mostly, if not exclusively, been studied within the healthcare sector, since the other sectors are characterized by a smaller number of firms with comparatively little alliance activity. Within the healthcare sector, only a handful of studies have distinguished among its different subfields, such as therapeutics and diagnostics, in order to ac-

the first true biotechnology firms, Genentech and Biogen, founded in 1976 and 1978, respectively,[2] realized initial successes largely through ties with organizations including research labs and pharmaceutical incumbents. Other newly founded biotechnology companies followed suit: One decade later, more than 70% of U.S. biotechnology companies were engaged in strategic alliances, with an average of 10 alliances per firm (Ernst&Young 1988). Since then, alliance formation in biotechnology has grown steadily, with more than 650 new alliances in 2006 alone, with related financial commitments of over $90 billion (Edwards 2007). These trends position biotechnology among the industries with the highest alliance formation rates (Hagedoorn 1993, 2002).

This proliferation of alliances in biotechnology is in part due to their tremendous importance for biotechnology firms' survival and performance. Emerging from the confluence of many disciplines, biotechnology has evolved to represent a complex value chain. In the therapeutics area of biotechnology, for example, early discovery research platforms generate product candidates, which move through preclinical stages of development, testing in human trials, the FDA approval process, commercial-scale manufacturing and, ultimately, marketing and distribution to consumers. Many biotechnology firms lack the knowledge, resources, and required legitimacy in the eyes of other market constituents to effectively go through this value chain on their own. Thus biotechnology firms form alliances at each stage of the value creation cycle: Research and development partnerships, formed in the early stages of the value chain, typically focus on discovery research and co-development of technologies or products, comprising collaborations with universities, government research labs, hospitals, and peer biotechnology firms. Such alliances usually focus on exploration of new knowledge and technology and entail identification and validation of new molecular targets and new chemical and biological entities, as well as screening compounds for commercially viable drug candidates. Biotechnology firms also enter alliances in the later stages of the value chain, that aim at exploitation of existing technology, by partnering with organizations that are closer to the market, such as pharmaceutical companies, clinical research organizations, or large-scale manufacturers. These alliances often focus on ensuring the safety and efficacy of the product through complex clinical trials, gaining FDA approval for it, and marketing it to customers (Baum et al. 2000; Higgins and Gulati 2006; Rothaermel and Deeds 2004).

Considering the criticality of these alliances for biotechnology firms' success, it becomes of paramount importance to understand biotech enterprises' as well as their partners' motivations for entering these partnerships, the determinants of

count for their respective differences (e.g., Folta 1998; Santoro and McGill 2006). In accordance with the existing studies, our discussion remains inclusive of different healthcare subfields when developing theoretical arguments.

[2] Cetus Corp. was founded earlier, in 1971, but its original technology could be characterized as biological engineering rather than recombinant genetic engineering, which formed the basis of the biotechnology industry.

these partnerships' efficient governance, and the precise benefits and costs for biotechnology firms of participating in strategic alliances. This article reviews the research evidence accumulated over the last 20 years on the alliances involving biotechnology firms and the networks which they create. We demonstrate the importance of considering a biotechnology firm's individual alliances as well as its position in the broader social structure of the industry, a structure created by the interconnectedness of firms through strategic partnerships.

Although our primary focus is on the drivers and implications of strategic alliances for biotechnology firms, we also highlight some concomitant ramifications for other types of organizations which partner with biotech firms. We first discuss the motives underlying alliance formation in biotechnology; in this discussion we highlight firms' pursuit of knowledge and other complementary resources, as well as their quest for legitimacy. In addressing these motives, we also consider factors that determine how biotechnology firms choose alliance partners. Next we review the factors and conditions determining the initial governance form of biotechnology alliances, as well as their ongoing governance dynamics. Third, we highlight the performance consequences of strategic alliances and biotechnology firms' resulting positions in the industry's social structure, outlining both the benefits and the constraints associated with these. Finally, we draw attention to some of the lacunae in extant research in this area, and suggest promising avenues for future studies.

2. Why and with Whom Do Biotechnology Firms Form Alliances?

The high frequency of alliance formation in biotechnology has drawn significant scholarly interest (e.g., Powell 1996; Powell et al. 2005). Many of the motives underlying alliance formation in biotechnology mirror those observed in other industries. For instance, given that product development in biotechnology is costly and associated with highly uncertain returns,[3] firms seek to share their costs and risks of innovation through strategic partnerships. Developing a product jointly with an alliance partner may ease the resource burden on the firm and grant it a certain degree of flexibility to alter its resource commitments should environmental conditions change (cf. Eisenhardt and Schoonhoven 1996). Additionally, biotechnology firms may seek strategic alliances with established rivals so that they can avoid direct competition with them in the product market (Gans et al. 2002).

[3] In therapeutics, by some estimates, it may take more than 15 years for an experimental drug to progress from the laboratory to market. Further, for every 10,000 compounds screened, only five will enter clinical testing and only one will receive FDA approval, representing the likelihood of 0.01 for turning a newly discovered molecule into a revenue-generating product (Rothaermel and Deeds, 2004: 208-209).

Though it would be difficult to present a comprehensive inventory of the motives underlying biotechnology alliances, we suggest that there are two key drivers of alliance formation that are particularly characteristic of this industry: (1) the pursuit of knowledge and other complementary resources and (2) the quest for legitimacy.

2.1 Access to Knowledge and Other Complementary Resources

Scholars have long proposed that firms are best described as open-system structures, whose survival depends on the effective exchange of resources with multiple elements of their environments, such as suppliers, buyers, and competitors, (Pfeffer and Salancik 1978; Thompson 1967). In biotechnology, a biotech's pursuit of knowledge and complementary resources stems largely from the monumental challenge of new product development and commercialization process, which is highly resource-intensive. Many biotechnology firms lack the resources to execute a full product development cycle, and their existing resources are further squeezed by intense competition (Gambardella 1995: 146-161; Shan 1990). Thus accessing much-needed resources through strategic alliances is crucial to boosting the firm's viability. Research shows that firms often seek contractual partners when they perceive their resource base as either fully utilized or inferior to that of the partner (Odagiri 2003). By partnering with pharmaceutical companies, for example, biotechnology firms gain access to production facilities, distribution channels, and expertise regarding clinical development and government approval of new products (Dalpe 2003; Kogut et al. 1992). Biotechnology companies in general lack these downstream resources and capabilities and therefore have to reach out to potential partners (Rothaermel and Boeker 2007).

Of the resources that biotechnology companies seek, knowledge deserves special attention. Because many of the firms in this field have no product sales for years, proprietary knowledge often constitutes their core competitive advantage and becomes central to their survival. Further, the knowledge required to develop a new chemical or biological molecular entity is complex and multifaceted, spanning disciplines including molecular biology, immunology, genetics, physiology, analytical and medicinal chemistry, and bioinformatics (Henderson and Cockburn 1994; Sorensen and Stuart 2000). Adequately developing this broad and deep knowledge base exceeds the capacity of a single firm. As a result, the locus of innovation in biotechnology has moved beyond a single firm's boundaries and into the network of collaborations, spanning the entire industry to access a widely dispersed pool of knowledge (Liebeskind et al. 1996; Powell and Brantley 1992; Powell et al. 1996). The resulting knowledge-driven collaborations typically target upstream segments of the value chain, or the research and development components of the product development cycle, and include partnerships with research labs, universities, and peer biotech firms, among others. For instance, biotech firms' reliance on knowledge contributed by university molecular biology departments has been particularly strong (Argyres and Liebeskind 1998; Kenney 1986).

Thus, through partnerships, firms strive to gain access to the wide pool of knowledge of the biotechnology industrial and scientific community. Some may simply seek membership in a biotech community to access knowledge spillovers (Owen-Smith and Powell 2004). But because the complex knowledge typical of this field requires rich and deep interactions for successful transfer and absorption (Rothaermel 2001; Zucker et al. 1998), many firms aim for a central position in the network of partnerships, which would position them on the intersection of knowledge flows (Powell et al. 1996).This is further reflected in how biotech firms pursue network expansion, connecting to one another through multiple independent paths, thereby increasing the number and diversity of accessible actors (Powell et al. 2005). Evidence confirms that many biotech firms pursue a diverse network, spanning different types of partners (e.g., pharmaceutical firms, hospitals, research labs), to access a broader knowledge base and ultimately position themselves for higher innovation rates (Baum et al. 2000).

In sum, many biotechnology firms enter strategic alliances in pursuit of knowledge and other complementary resources for research and development or commercialization purposes. As further support for these general motives, studies show that alliance formation patterns for firms in biotechnology are age-dependent and non-linear, peaking around four years post-founding, then declining until the ten-year mark, after which they rise again (Oliver 2001). This non-linear trend roughly corresponds to the needs associated with the biotech product development process, which requires access to research and development expertise early on, followed by commercialization capabilities later in a firm's life. Companies can obtain some complementary resources through dyadic relationships with more resourceful partners. The choice of partners, therefore, is atomistic and is largely made in the narrow context of the potential relationship. The pursuit of knowledge, however, especially as related to early stages of the drug development process, requires a biotechnology firm to seek a central position in the broader network structure of the market, to better access industry-wide knowledge flows and pool of innovations (Powell et al. 1996).

2.2 Pursuit of Legitimacy

In addition to being embedded in a technical environment, where a firm's survival is largely driven by access to resources and its reliance on the related production efficiencies, firms are also situated in normative environments where their survival hinges on conforming to the social standards of the market (Dacin et al. 2007; DiMaggio and Powell 1983; Scott 1995). While nimble and innovation-driven, many new biotechnology firms lack the necessary underpinnings of legitimacy, which can be defined as social justification or public endorsement (Dacin et al. 2007). Because of their relative newness, most biotechnology firms do not have the validation associated with stable exchange relations with important market constituencies and with significant experience delivering a product or service to

market (cf. Stinchcombe 1965). In fact, many biotech companies lack a product to show, owning instead the rights to a set of ideas with ambiguous commercial viability. Building legitimacy, therefore, is critical for biotechnology ventures, particularly young ones, because market participants – on whom they depend for physical, financial, and reputational capital – face extremely high levels of uncertainty with respect to the quality of the biotech product or service. Securing public validation and reducing the level of uncertainty associated with the biotech firm can subsequently yield significant economic and competitive benefits (Dacin et al. 2007; Higgins and Gulati 2006; Kim and Higgins Forthcoming).

Strategic alliances with prominent partners is one of the most promising routes to legitimacy for biotech firms (Baum and Silverman 2004; Stuart et al. 1999). Indeed, one of the fundamental precepts of sociological theory is that interorganizational relations and the resulting networks of connections are not merely pipes carrying resources and information, but also prisms of the market, reflecting and inducing differentiation among market participants (Podolny 2001). Thus, forging alliances with prominent market participants may confer an aura of legitimacy to a biotechnology firm, which in turn facilitates the acquisition of other resources. Note that the legitimacy enhancement effect could be bidirectional: not only do biotechnology firms benefit from endorsements, but so do some of their endorsing partners. Nichols-Nixon and Woo (2003), for instance, demonstrate that by forming more R&D contracts and licensing agreements in biotechnology, pharmaceutical companies enhance their expertise in biotech, as perceived by peer firms.

2.3 Choosing Partners

Given the importance of accessing knowledge, complementary resources, and legitimacy for biotechnology firms, they would be expected to favor alliance partners who can offer better resource and knowledge endowments, as well as superior legitimacy benefits (Baum et al. 2000; Powell et al. 2005; Rothaermel and Boeker, 2007). These rather calculative motives, however, represent only a subset of those underlying biotech firms' choices of alliance partners. Many studies point to the strong influence of homophily, wherein similarities among firms foster mutual trust and co-identification (cf., Gulati and Sytch Forthcoming; Lazarsfeld and Merton 1954; McPherson and Smith-Lovin 1987), increasing the likelihood of their partnership. In a study of the formation of research and development partnerships in biotechnology, Baldi, Stern, and Dukerich (2007) find that firms are more likely to collaborate if their founders have graduated from the same educational institution. This effect does not necessarily reflect a direct social tie between scientists (e.g., they often have graduated from different professional schools and in different years), but rather their sense of shared identity. Along similar lines, Powell et al. (2005) show that biotech firms, particularly new entrants, tend to choose partners based on the allies' similarity to previous partners; Kim and Higgins (Forthcoming) find additional evidence for the influential role of homophily, such that firms occupying similar positions in the market's social structure inherit

similar obligations and expectations, which draw them toward each other. More specifically, they find that firms gravitate toward potential partners that employ upper echelon members with matching affiliations. The presence of a downstream affiliation, one example of which would be having a biotech executive previously employed at a firm like Pfizer, increases the chance of attracting a downstream alliance partner by 40%. While biotechnology firms generally gravitate to similar partners, studies also find that it is largely the firms that are underperforming with respect to their historical performance aspirations and their peer reference group, that venture outside of their comfort zone and search for foreign partners (Ener and Hoang, 2007).

Note that any episode of alliance formation requires a bilateral choice, wherein both the focal biotechnology firm and the partner must be motivated to enter the alliance. The extant research often overlooks this seemingly intuitive concept (for a thoughtful discussion of this issue see Ahuja 2000b). The ability to attract a partner is critical, since biotech firms face vigorous competition for the attention of prominent and valuable potential allies. Several factors are instrumental in this respect. Kim and Higgins (Forthcoming) find that a firm's upper echelon affiliations with prominent players facilitate partnerships with such allies. The affiliations grant biotech firms an aura of legitimacy, thus mitigating prominent partner's concerns regarding loss of status over allying with a lower-status firm. Stern and Dukerich (2007) further demonstrate that firms founded by more prominent scientists with stronger publication records are more likely than others to attract commercial partners early in the product development cycle, when uncertainty regarding a start-up's commercial potential is particularly high. The legitimacy stemming from higher academic reputation of a founding scientist helps deflect possible reservations of financing entities over partnering with the biotech firm holding unclear commercial promise.

Overall, while it is difficult to explicate all the factors firms may consider when choosing alliance partners, the multifaceted nature of this choice is clear. Motives include those of a more or less calculative nature and address both the needs of biotech firms as well as their ability to attract desirable partners.

3. Governance of Alliances

Representing a hybrid governance form of market and hierarchy, strategic alliances are associated with a variety of governance forms, ranging from more market-like contractual arrangements to more hierarchical equity-based alliances and joint ventures. Several studies have investigated the antecedents of variations in alliance governance.[4] Many of these investigations have approached this issue

[4] Another intriguing line of inquiry has looked at factors driving the choice of alliance governance form versus arm's length and fully internalized transactions,

through the lens of transaction cost economics (e.g., Williamson 1975; Williamson 1985), highlighting the role of transaction costs in the choice of governance form. At the heart of this theoretical perspective is the idea of discriminatory alignment or the belief that certain governance structures are better suited for certain transactions. The preferred governance mode of a transaction, in turn, is the one the minimizes transaction costs, which may be loosely classified into the ex ante costs of search and contracting and ex post costs of monitoring and enforcement (Williamson 1985). The ex post transaction costs can be particularly high, as humans are viewed as inherently prone to opportunistic behavior (Simon 1985; Williamson 1975: 26-37; 1985: 46-52) and limited in their rationality (Simon 1957: xxiv).[5] Such bounded rationality, in turn, prevents organizational agents from writing complete contracts that would cover all possible contingencies and therefore diminish opportunistic pursuits in the form of ex post haggling. The expected costs of such post-contractual haggling are especially high at increased levels of behavioral and task uncertainty. While behavioral uncertainty refers to the unpredictability of a partner's behavior, task uncertainty relates to highly complex tasks where monitoring and evaluating a partner's behavior and contributions is not easy and hence costly. When uncertainty is high, firms tend to prefer more hierarchically organized exchanges, since common ownership may decrease partners' opportunistic advances and managerial fiat could provide tighter control and speed the resolution of conflicts (Williamson 1981).

Some evidence derived from studies of biotechnology alliances supports the key propositions of transaction cost economics. Higher partner and task uncertainty lead biotech firms to adopt a more hierarchical governance form for their alliances (Santoro and McGill 2005). Further attesting to the firms' desire to avoid the hazard of opportunistic haggling in their alliances, Pisano (1989) finds that if there are fewer partners available with a specific expertise, pharmaceutical firms are more likely to have equity participation in the biotechnology alliance rather than develop it through a contractual partnering agreement. A more hierarchical governance arrangement in this instance may help alleviate the risk of an opportunistic contract renegotiation, which could be provoked by the small-numbers hazard.[6]

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as well as the performance of alliances relative to these alternative forms of governance (Dyer 1996; Gulati et al. 2005). See also Schweizer and Knyphausen (this volume) for the discussion of why pharmaceutical companies may choose to internalize the product development capabilities of a biotech company.

[5] Some of these assumptions are debated in the literature (Ghoshal and Moran 1996). This debate, though an important discourse in organizational science, is beyond the scope of this article.

[6] Competitive considerations also may drive taking a major equity stake in the partner. For instance, by taking significant ownership in a biotechnology company, a pharmaceutical firm may attempt to prevent competitors from accessing the resources and capabilities of the biotech firm. Pharmaceutical firms' willingness to lock out competitors from valuable biotechnology expertise is particularly high

It is further essential to note that collaborations in biotechnology, particularly those including an R&D component, are filled with behavioral and task uncertainty. Many biotechnology firms enter partnerships with no meaningful organizational history and no prior collaborative experience, bringing extreme levels of behavioral uncertainty to the arrangements. High task uncertainty emanates from extreme complexity of biotechnological knowledge, which spans a wide array of disciplines and thus transcends the capabilities of a single firm (Powell et al. 1996; Sorensen and Stuart 2000). Moreover, many biotechnology collaborations include a broad scope of activities, further increasing the concomitant task uncertainty (Pisano 1990). Complicating matters further for R&D collaborations, there are usually few substitute partners available for a particular line of business, creating an increased risk of self-seeking haggling. Beyond that, the nature of many R&D activities in biotechnology is significantly complex and entails high levels of asset-specific investments, which are tailored to the current relationship and thus cannot be redeployed to other transactions without a significant loss in value.[7] Taken together, these conditions – particularly when applied to R&D collaborations in biotechnology – should create high expectations of opportunistic behavior and thus motivate firms to adopt a more hierarchical governance form for partnerships,[8] as manifested in the distinct preference for equity-based alliances over simple contractual arrangements. So it is remarkable that the tendency to use less hierarchical contractual R&D collaborations is exceptionally strong in biotechnology and pharmaceuticals compared to other industries (Hagedoorn 2002).

One way to shed some light on this empirical conundrum is to consider an additional factor that shapes alliance governance choice: firms' desire to maintain strategic flexibility. The pursuit of strategic flexibility – often invoked under the rubric of "real options" – suggests that firms frequently form alliances with a strong expectation that these partnerships will evolve in response to the shifting strategic and environmental demands and that their inherent value to the firm may change. Maintaining initial flexibility becomes particularly crucial in situations marked by high technological uncertainty, when the value of many technological developments is unclear. Specifically, when operating under these conditions, firms may

when there are few biotechnology firms with comparable capabilities. As an example, consider Roche's pursuing Genentech's unique expertise and product pipeline in monoclonal antibodies by taking a 60% stake in the company in 1990, subsequently securing exclusive non-U.S. marketing rights for all of Genentech's products through a licensing deal in 1995.

[7] In the reasoning of transaction cost economics, the condition of asset-specificity is critical for the uncertainty argument to hold: Uncertainty increases costs associated with ex post haggling only at non-trivial levels of asset-specificity (David and Han 2004; Williamson 1985).

[8] This expectation is in line with extant research, which generally suggests that R&D transactions will entail higher transactions costs and, subsequently, will have more hierarchical forms of governance (Gulati 1995a).

opt for more flexible and less hierarchical governance arrangements to avoid making irreversible commitments to a lost cause (e.g., Folta 1998; Santoro and McGill 2005).

Evidence from biotechnology partnerships supports the importance of maintaining strategic flexibility as related to the choice of alliance governance form. For instance, partnerships involving technological applications in the field of therapeutics are considered highly technologically uncertain and tend to involve more flexible governance arrangements (Santoro and McGill 2005). This initial flexibility gives firms the opportunity to alter the governance form later and ramp up their commitment to more promising partnerships as their potential becomes more fulfilled. Folta and Miller (2002) report that biotechnology firms tend to purchase additional equity stakes in their partners when the partners' market valuations are increasing, which lends further supports to this hypothesis[9].

Scholars of strategy and organizations also have gained valuable insights by investigating post-formation changes in alliance governance structures. Reuer, Zollo, and Singh (2002) found that roughly 44 percent of alliances in their sample experienced a governance change as the alliance evolved. These changes included contractual alterations, major changes in the committee or board overseeing the alliance, and the introduction or formalization of monitoring mechanisms. Taking a deeper look into why such post-formation governance changes may transpire, they found that prior partner-specific experience facilitates ex post adjustments in alliances by fostering inter-organizational routines specific to the collaboration. These routines equip partners to better understand shifts in the partnership, discuss possible courses of actions more openly, and eventually implement governance change more smoothly.

In a related line of inquiry Lerner, Shane, and Tsai (2003) explore the initial allocation of control rights in an alliance, as well as subsequent changes in this allocation. The authors suggest that the imbalance of bargaining power between larger pharmaceutical companies and smaller biotech firms may lead to the initially skewed allocation of control rights in the alliance (see also Lerner and Merges 1998).[10] Such skewed allocation manifests in the pharmaceutical firm's obtaining

[9] Evidence also suggests that a rather strict, when compared to other industries, intellectual property protection regime in biotechnology may further contribute to the formation of less hierarchical contractual alliances by stimulating licensing agreements. In the presence of strong intellectual property protection, firms are generally more open to licensing partnerships as there is less threat that the licensee will invent around the licensed innovation and renege on the terms of the agreement (Anand and Khanna, 2000b).

[10] This study provides further evidence that relative bargaining power of the partners matters in gaining control rights in R&D agreements. Using a sample of 200 research and product development agreements in biotechnology, Lerner and Merges (1998) find that the financial status of R&D firms affects their ability to

a lion's share of control over management of clinical trials, the manufacturing process before and after product approval, choice of sales categories (by region and indication), and even issues related to marketing exclusivity. The bargaining imbalance and the resulting skewed allocation of control rights is particularly acute when the public financial markets are unavailable to a given biotech firm, depriving it of alternative sources of financing and, ultimately, some measure of bargaining power. However, Lerner et al. (2003) also show that agreements that are disadvantageous to R&D firms are significantly more likely to be renegotiated as the firms' public financing potential improves and their bargaining power in the alliance increases.

In sum, existing research clearly identifies a set of predictors of governance choice in biotechnology alliances. While behavioral and task uncertainty in biotechnology alliances motivates firms to adopt more hierarchical governance forms, the need to maintain strategic flexibility due to high technological uncertainty promotes looser, quasi-market alliance structures. Building on early research that focused on the choice of initial governance form, a promising stream of work has sought to unpack factors driving changes in the governance form of the alliance as the partnership evolves.

4. Consequences of Alliances

As highlighted above, biotechnology firms pursue alliances to secure access to knowledge and other complementary resources, and to gain legitimacy. Therefore, upon entering alliances, firms can be expected to develop a more effective resource base, as well as to show more promise to potential partners and to the market in general. These consequences can manifest in several positive organizational outcomes. Specifically, firms that engage more actively in alliance formation have been shown to have higher rates of innovation (Shan et al. 1994), product development and commercialization (Rothaermel and Deeds 2004), growth (Baum et al. 2000; Niosi 2003; Powell and Brantley 1992; Powell et al. 1996), IPO success (Stuart et al. 1999), and survival (Oliver 2001).

In reviewing studies of the consequences of alliances for biotechnology firms, we first focus on those that have explicated firms' access to knowledge and other complementary resources, along with the benefits stemming from that access. These benefits emanate from individual alliance linkages and access to the resources of current alliance partners, as well as from the firm's position in the broader network of alliances. Next we examine how alliance formation leads to tangible benefits by reducing uncertainty with respect to a biotech firm's overall

retain control rights in R&D agreements. More specifically, a one standard deviation increase in shareholders' equity leads to an 11% drop in the predicted number of control rights assigned to the financing firm.

quality. Finally, we illuminate a promising yet underdeveloped line of inquiry: the costs and constraints associated with alliances. Specifically, we discuss evidence that alliances do not generate uniformly positive effects across all types of partners and relationships, and the resulting structural positions of the firm in the web of alliance linkages. In some instances, the effects of alliances can be neutral, hinting at less effective use of a firm's resources or the existence of factors that cause performance trade-offs; in others, the effects of alliances and the concomitant structural position of the firm can be outright detrimental, possibly reducing the entire enterprise's viability. We thus review and conceptualize extant research on the possible role of alliances as a "relational liability," suggesting that the pursuit of complementary resources, knowledge, and legitimacy may come at a price.

4.1 Consequences of Accessing Knowledge and Other Complementary Resources

From its outset, research on the role and impact of strategic alliances in biotechnology focused on the benefits of a firm's assembling portfolios of complementary resources through access to partners' resource endowments. In an early study, Shan et al. (1994) argued that forming commercial ties allows a biotechnology company to reduce its resource and attention inputs into commercialization, freeing it to focus more effectively on innovation, especially new product discovery and development. Analyzing alliance formation patterns in the first decade of the industry, Shan et al. (1994) show that the number of commercial agreements a biotechnology start-up holds is positively related to its innovation rate, as measured by granted patents. Subsequent research shed further light on how alliances also can contribute to a firm's commercialization rates by bringing it complementary resources. Using a sample of 325 biotech firms and their 2,565 alliances from 1973 to 1997, Rothaermel and Deeds (2004) show that a firm's downstream alliances – those focused on clinical trials, the FDA regulatory process, or marketing and sales – afford it access to pharmaceutical companies' expertise in regulatory compliance, large-scale product manufacturing, marketing and sales, and, certainly not least of all, their capital reserves. These complementary resources and expertise boost the biotech's commercialization rates, increasing the number of products it has on the market.

Downstream alliances, as suggested above, are certainly important, but the ability of a firm to access biotechnology-specific knowledge through upstream or exploration-focused alliances is no less critical (Rothaermel 2001). Evidence suggests that a firm's upstream alliances, which are focused on early discovery research and preclinical development, are associated with greater levels of knowledge creation and internalization for the firm. This effect may be stronger for more similar partners, since they can avail themselves of smoother knowledge transfer and absorption. Specifically, having basic knowledge pools, compensation practices, and commercial objectives comparable to those of a partner increases a firm's ability to value, assimilate, and commercialize the partner's knowledge

(Lane and Lubatkin 1998). While both downstream and upstream alliances can benefit the firm directly by channeling knowledge and other resources, they also can offer indirect benefits by limiting access to these resources for the firm's rivals. Silverman and Baum (2002) find that firms' upstream partnerships with government labs and research institutes, as well as their downstream marketing partnerships, can deprive rivals of comparable access and thus threaten competitors' survival.

In the process of pursuing knowledge and other complementary resources through alliances, firms tend to develop a relational capability, or an ability to transfer and internalize knowledge adeptly, as well as to effectively manage alliance relationships (cf. Dyer and Singh 1998; Kale et al. 2002). Greater relational capability can lead to superior performance outcomes for firms participating in alliances for several reasons.[11] First and foremost, as a firm's experience in alliance formation and its resulting relational capability grow, it gains an edge in regard to its level of receptivity toward and ability to absorb knowledge generated in the alliance and to the exclusive knowledge brought to the alliance by its partner (Cohen and Levinthal 1990; Hamel 1991). Externally acquired knowledge often entails an unfamiliar set of heuristics; thus a firm's relational capability, which represents an accumulation of experience dealing with various heuristics, positions it to better process, interpret, and understand the information this knowledge carries (Zahra and George 2002). Second, having a formal support structure in place and informal organizational processes for expediting knowledge transfer is likely to amplify the firm's intent to learn and acquire knowledge (Hamel 1991). The resulting high motivation and effort regarding knowledge internalization is likely to enhance a firm's already superior capacity to absorb knowledge. A similar boost is likely to be demonstrated for alliance management skills. As firms go through alliance formation repeatedly, they develop organizational routines that enable them to select the most effective type of agreement for a particular alliance. As firms gain experience with alliances and develop relational capability, they also improve their ability to respond to contingencies that could not be specified in formal contracts and to manage collaboration activities in general (Anand and Khanna 2000a; Mayer and Argyres 2004; Vanneste and Puranam 2007).

The development of biotechnology firms' relational capability and its resulting performance benefits have been thoroughly documented. For instance, in one of the earlier studies on the subject, Zollo, Reuer, and Singh (2002) showed that familiarity through prior partnership experience leads to improved alliance performance when biotech and pharmaceutical firms partner. Along similar lines, Katila and Mang (2003) show that biotechnology firms that have prior collaborative experience with a focal partner as well as with other firms strike deals earlier in the

[11] See Wang and Zajac (forthcoming) for the exploration of how experiential learning from alliance formation may transfer to mergers and acquisitions as well as how experience with mergers and acquisitions may translate into benefits in the alliance formation arena.

technology development process. This timing carries tremendous performance implications for biotechnology firms, since it enables them to capitalize on a technological opportunity early, before others move in or before the opportunity loses its appeal in a high-velocity technological environment. Finally, in a comprehensive study of 292 drug development projects between biotechnology and pharmaceutical firms between 1980 and 2000, Hoang and Rothaermel (2005) find a positive association between a biotech firm's level of general collaborative experience – accumulated through prior alliances with firms other than the focal alliance partner – and the alliance's performance. This manifests in the higher probability of FDA and European Medicines Evaluation Agency approval for a jointly developed drug. This effect is curvilinear, and thus exhibits diminishing marginal returns of collaborative experience, which is possibly due to companies' exploiting their most promising opportunities first or relying excessively on certain technological competencies.

The discussion thus far has focused on the benefits firms extract from individual alliance linkages by effectively accessing the knowledge and other resources of immediate partners. The numerous alliance linkages among firms also cumulate into the broader social structure of the market; this network, in turn, serves as a conduit of knowledge and other valuable information. For example, a firm's position in the larger social structure shapes the quality of its leads and referrals regarding alliance and technological opportunities, as well as its access to the industry-wide pool of knowledge (Gulati 2007). Thus, the implications of alliances transcend a given relationship, with their magnitude dependent on a firm's position with regard to the industry's pipes of knowledge and information flows. This is particularly important in biotechnology, a field marked by sophisticated and increasingly complex technologies. As such, the innovative efforts of individual firms have clear limits, and the locus of innovation has shifted to the broader network of relationships (Powell and Brantley 1992; Powell et al. 1996). Preferential access to this network enables firms to garner timely knowledge about available partners and their resource endowments, developmental trends in the industry, and the most promising technological opportunities. Specifically, a biotechnology firm's position on the high-traffic intersection of R&D-related knowledge flows enables it to develop a portfolio of diverse relationships, move toward an even more central and advantageous network position, and ultimately enjoy greater rates of growth (Powell et al., 1996).

Contributing to the research into a firm's access to knowledge through its superior position in the network structure, subsequent work involved structural and geographical mapping of firms and their partners in the web of alliance linkages. Specifically, this research looked into the different ways by which alliances with collocated partners generate value, relative to those in which partners belong to different geographical clusters. For instance, Zaheer and George (2004) suggest that while alliances with both collocated and non-collocated partners create value for firms, resulting in their higher market valuations, they do so in different ways. Alliances within a geographical cluster due to a firm's proximity to the sources of

knowledge, contribute to the firm's ability to transfer complex and tacit knowledge and to access information spillovers. In contrast, alliances that span different clusters allow a firm to access a more diverse pool of knowledge and hence create value by fostering heterogeneity in its knowledge base.

In the setting of biotechnology, the potential ability of a firm to use alliances as an entrée to the research community and to subsequently access knowledge spillovers within that community constitutes a particularly intriguing research question. This is because knowledge in biotechnology is viewed as so complex and difficult to transfer that it guarantees its "natural excludability" (Zucker et al. 1998). Such natural excludability makes knowledge in biotechnology relatively immune to absorption from spillovers. Accordingly, Zaheer and George (2004) find that merely belonging to an alliance cluster or a geographic cluster through a single alliance linkage does not benefit a firm's performance. In other words, spillovers are not of much consequence, and in order to benefit from industry-wide knowledge a firm has to link more strongly to knowledge pools through the information-transferring pipes of alliance ties (cf., Podolny 2001).

Other studies extend this debate, suggesting that understanding the role of a firm's structural position in benefiting from spillovers should not be limited to considering how well firms can absorb those spillovers. In addition to looking at absorption efficiency, these studies concentrate on spillover availability, the key predecessor to benefits associated with spillovers (Owen-Smith and Powell 2004). The availability of spillovers, in turn, may be contingent on the nature of the specific organizations that anchor the network of the geographical cluster. Based on these ideas, Owen-Smith and Powell (2004) established the presence of knowledge spillovers in the Boston biotechnology community, demonstrating that a simple alliance membership in the Boston cluster boosts a firm's innovation rates. The key to this effect is that the Boston biotechnology network is anchored by public research organizations, which are more committed to open information-sharing and public disclosure. Because of these norms, significant knowledge leaks through organizational boundaries, allowing biotechnology firms to internalize some of it.[12] This internalization is attained simply through membership in the research community or having at least one tie to an existing member.[13] If, however, a firm is situated in a more diverse network of firms – one outside the Boston cluster, for example – where attitudes toward open knowledge-sharing may vary,

[12] While not focusing on the issue of collocation or industry-wide norms of knowledge sharing, Silverman and Baum (2002) provide additional evidence that spillovers matter. They show that rivals' upstream alliances with universities can benefit the focal firm by generating a larger pool of knowledge, of which at least a part becomes available to the firm.

[13] More precisely, Owen-Smith and Powell (2004: 13) look at the presence of at least one connection to the largest weakly connected component within the network, which indicates the largest segment of the overall network, where each firm is connected to every other firm by least one path.

the effect of simple membership subsides. Thus of more importance is not a firm's simple access to the knowledge community through a peripheral alliance tie, but rather the centrality of its position in the network of alliances, which places the firm at the intersection of different network ties and the knowledge flows they represent (Owen-Smith and Powell 2004). The importance of the central position in the industry knowledge network further manifests in that biotechnology firms may pursue and benefit from alliances with their rivals, by securing advantages from rivals' structural positions in the industry network (Silverman and Baum, 2002).

4.2 Consequences of Enhancing Legitimacy

In addition to enabling a firm to access the complementary resources and knowledge of its partners and those of the broader network community, the firm's alliances play a crucial role in enhancing its legitimacy. By providing a firm with the endorsements of established partners, alliances send a strong signal with respect to the firm's reputation, reliability, and commercial promise, thereby alleviating the uncertainty various market stakeholders may perceive regarding the firm. Reduced uncertainty may in turn lead to the increased support of the firm by venture capitalists, underwriters, and public investors, as well as prominent alliance partners. While venture capitalists, for instance, sometimes invest in biotech firms with less obvious potential, they are generally keen on investing in clear winners with tangible market potential (Baum and Silverman 2004). Thus Baum and Silverman (2004) suggest that signaling a clear capacity for success to the VC community through the alliance capital of downstream and horizontal alliances is critically important. Specifically, they find that start-ups with greater alliance capital obtain significantly more VC financing than those without it. Along similar lines, Higgins and Gulati (2003) provide some evidence that companies with a larger alliance portfolio can secure a more prestigious underwriter because the ties reduce uncertainty regarding their commercial potential. The benefits stemming from a biotech firm's enhanced legitimacy are particularly important in situations when uncertainty about the biotech firm's commercial promise is high, such as in earlier stages of the firm's life.[14]

[14] It is essential to note one methodological difficulty in exploring the role of alliances as legitimizing endorsements and their subsequent impact on firm's performance. It is possible that the unobserved dimension of the firm quality both attracts the more prestigious alliance partners and triggers the observed performance outcomes. Thus, the observed performance outcomes may be independent of and have only a spurious correlation with endorsement. In the absence of a controlled experiment, scholars need to employ a rigorous set of controls for the quality of the firm, try to instrument out the omitted-variable endogeneity, and invoke qualitative research to shed additional light on the nature of the observed relationship.

By focusing on the impact of a firm's alliances with commercially and technologically prominent partners, other extant research suggests that such prestigious affiliations are even more instrumental than general ties in alleviating uncertainty regarding a firm. Here, market participants rely not only on the ability of prominent partners to discern the quality of the firm, but also consider the established partners' reputational concerns over affiliating themselves with low-quality firms (Stuart et al. 1999). Indeed, a partnership with a "lemon" can certainly damage the social standing of a prominent firm, motivating it to conduct especially thorough due diligence of potential allies. The expectation of this strict scrutiny, in turn, endows market participants with greater confidence in the signaling quality of the endorsement, and legitimizes the firm even further. These outcomes, with time, translate into tangible financial gains by helping young biotech firms make their IPOs more quickly and ensuring superior IPO returns (Stuart et al. 1999).

4.3 Taking Off the Rose-Colored Glasses: Alliances as Relational Liability

It is fair to say that existing research on alliances in biotechnology, much like work in other industrial settings, has approached inter-firm linkages with strong positive predispositions. In other words, the primary focus has been on the benefits companies can reap through strategic partnerships. There is evidence, however, that under certain conditions alliances may generate neutral or even negative consequences for participating firms (e.g., Deeds and Hill, 1996; Baum, Calabrese, and Silverman, 2000; Baum and Silverman, 2004). In other words, the resources and social capital emanating from the firm's alliance linkages and its position in the structure of network ties may turn into liabilities. An interesting and yet underdeveloped line of inquiry, then, involves the analysis of possible costs and other constraining effects of alliances and firms' positions in the network of strategic partnerships.

We identify several sources of such constraining effects. First, with respect to alliances providing access to knowledge and complementary resources, some partners and types of relationships may severely constrain firms' performance by triggering resource misallocations and by bringing out competitive rather than cooperative motivations in some partners. We also show that a firm's structural position in the network may trigger relational and structural lock-in, preventing a firm from pursuing a more efficient set of relations by confining it to a disadvantageous competitive pool, where it may be mismatched on its ability to create and internalize knowledge. Second, regarding alliances that legitimize a firm, we highlight that access to well-established partners is not cost-free and that the costs of entering and maintaining such partnerships may outweigh the benefits.

Some alliances may lead biotech firms to over-allocate resources to some activities at the expense of important other ones. For instance, in contrast to studies suggesting that a firm's commercial ties may free significant resources for innova-

tive research and development projects (Shan et al., 1994), some research indicates that such alliances may in fact slow down a biotech's innovation rate by diverting its resources exclusively into commercialization (Baum and Silverman 2004). There is also evidence that a start-up biotech firm's alliances with government labs significantly slow its revenue growth (Baum et al. 2000). While, as Baum and colleagues suggest, this effect may reflect a selection bias, due to the higher commercial uncertainty of projects brought to government labs, it may also indicate an inefficient resource lock-in in a relatively unproductive relationship. Furthermore, upstream alliances of biotechnology firms with universities frequently involve flows of scientists into commerce and therefore pose a high risk of legal disputes over the ownership of intellectual property, which can further consume valuable resources of a biotechnology firm (Rothaermel and Deeds, 2004). One influential example includes the dispute between the University of California and Genentech over misappropriation of intellectual property rights on genetically engineered human growth hormones,[15] which later triggered a patent infringement lawsuit,[16] leading Genentech to settle the case for $200 million in 1999. Finally, evidence also suggests that – regardless of the kind of partnerships – excessive alliance formation may result in diminishing returns to accessing and leveraging complementary resources as well as stretch the managerial capacity of the firm. The resulting burden can outweigh the benefits generated by alliances and put a strain on the firm's product development and innovation efforts (Deeds and Hill 1996).

Of critical importance, some alliance partners may have their competitive or value appropriation motivations dominate their cooperative or value creation motives (Amburgey et al. 1996). Take, for example, a typical downstream alliance situation in which a cash-starved biotechnology firm cannot afford to divert its management's attention for the several months often required to raise additional venture financing. In this circumstance, a financially strong pharmaceutical partner can use its relative bargaining power to demand control rights far beyond what the biotechnology firm would be prepared to cede under less pressing conditions. Studies suggest that such situations do occur and that they often lead to an inefficient allocation of control rights, lowering the success rate of the project (Lerner and Merges 1998; Lerner et al. 2003).

Horizontal alliances among peer biotech firms, which are aimed at joint product development, also may entail such motivation imbalance. The problem's source is that while peer biotechnology firms may be willing to cooperate on a particular project, they may be competing fiercely in other lines of business. That is why when it comes to research-driven collaborations, biotech firms have to balance their aspirations of access to new knowledge with their need to guard against mi-

[15] The case was settled in 1980 with Genentech's agreeing to pay up to $2 million in royalties.

[16] *Genentech Inc. v Regents of University of California*, 939 F. Supp. 639 (S.D. Ind. 1996).

sappropriation of that knowledge (Liebeskind et al. 1996). A possible negative outcome of such competitive tension is the unwillingness of biotech firm partners to share information. In partnering with competitors, biotech firms can thus be overly protective with respect to knowledge-sharing, hurting joint knowledge creation and decreasing the total value generated by the alliance. Alternatively, partnerships with competitors may be characterized by learning races wherein each firms strives to maximize its own learning and the application of that learning outside the scope of the alliance – without regard for the partner's learning (Amburgey et al. 2000; Khanna et al. 1998). It is not surprising, then, that a biotech firm's participation in horizontal alliances, which often entails partnering with competing firms, has been linked to decreased revenues and reduced innovation levels (Baum et al. 2000; Baum and Silverman 2004).

Pursuits of relational capability through repeat partnering with the same set of partners may lead to another peril for biotechnology firms: the relational lock-in. The relational lock-in denotes parties' attempts to perfect a suboptimal exchange relationship or, at the extreme, their unwillingness and inability to disengage from clearly dysfunctional partnerships. Maurer and Ebers (2006) suggest that the desire to honor the norms of reciprocal exchange may lock biotech allies into such dysfunctional ties. Additional evidence comes from Hoang and Rothaermel (2005) who find that prior partner-specific collaborative experience has no positive impact on alliance performance with the partner and, at high levels, can even be detrimental. These findings hint at the presence of inertia or relational lock-in in interorganizational partnering, wherein firms engage in repeated alliance formation due to the comfort partnering with familiar firms, rather than clear performance benefits (Li and Rowley 2002). Such relational lock-ins are particularly hazardous in light of evidence that more successful biotech firms reshape and restructure their alliance portfolios as the firms mature and face new objectives. For biotechnology firms, in particular, while many young start-ups embed themselves into cohesive partnership networks early on (Walker et al., 1997), successful companies evolve to develop a diverse portfolio of links to other players in the market, gaining access to the information and other resources these partners hold (Maurer and Ebers, 2006). This evidence resonates with a larger body of literature suggesting that, particularly in high-velocity and uncertain technological environments, firms' performance could be substantially impeded by maintaining alliance linkages to a set of familiar partners because it limits the firms' ability to access novel and nonredundant information (e.g., Goerzen 2007; Rowley et al. 2000).

Just as with individual ties, a firm's network position may be a source of both opportunity and constraint. Owen-Smith and Powell (2004), for instance, find that a weak connection or a simple membership in the non-collocated network has either neutral or negative implications for a firm's innovation levels. They suggest that, given the unavailability of localized knowledge spillovers, a weak structural network position would be akin to "a competent minor leaguer attempting to play in the majors while lacking the necessary skills" (Owen-Smith and Powell, 2004: 16). In other words, a firm's structural position locks it into the disadvantageous

competitive pool where it is likely grossly mismatched on its ability to generate and internalize knowledge.

As discussed above, the detriments of alliances and a firm's structural position in the web of partnerships have to do with the access to knowledge and other complementary resources alliances provide. It appears, however, that the legitimizing effect of alliances is also not uniformly positive. Some research, for instance, finds no impact of downstream alliances with prominent pharmaceutical and healthcare organizations on the IPO success of biotechnology firms (Gulati and Higgins 2003). Thus the key to unpacking these observed relationships is scrutinizing not only the benefits but also the costs of such endorsements. It is no secret that affiliations with highly prestigious partners generally entail asymmetric terms of exchange (Hsu 2004; Podolny 1993). A young biotech firm unknown to the market community may be forced to pay a hefty premium for an affiliation with a prestigious alliance partner. This premium may manifest, for instance, in the biotech's having to transfer to the partner a disproportionate share of control rights to intellectual property or to revenue streams from commercialized products (Lerner and Merges 1998). In other instances, to gain access to a prestigious pharmaceutical firm, a biotech firm may have to compromise its learning and business development objectives, tailoring the alliance exclusively to the needs of the partner. But when and under what circumstances the benefits of endorsement by prestigious partners may outweigh related costs remain to be explored.

5. Future Research

Over the past twenty years management scholars have collected illuminating insights on the motives underlying alliance formation and choice of partners by biotechnology firms, the governance structure of these alliances, and the implications of partnerships for firms' performance. In addition to enhancing the current state of the art, extant research also reveals several promising avenues for future research. We outline three intriguing directions: (a) detailed investigations of firms' dual cooperative and competitive motivation in biotechnology alliances; this naturally extends to the multifaceted effects of the firm's position in the networks of alliances, which could influence both cooperative and competitive behaviors; (b) studies of dynamics of power and dependence in strategic alliances and their effects on the processes of value creation and appropriation; and (c) the application of a richer, multi-level lens of analysis spanning individual relationships, portfolios of alliances, and entire networks of interorganizational linkages.

First, scholars can pay closer attention to the symbiosis of cooperative and competitive aspects of strategic alliances among biotechnology firms. We need further insights into when biotechnology firms tend to maximize their individual learning in the alliance at the expense of joint value creation. Another fruitful line of inquiry could unpack when firms' concerns about knowledge misappropriation

thwart knowledge-sharing in alliances. Additionally, scholars have to take a deeper look at certain kinds of partnerships with respect to the underlying motivations of the firms involved. For instance, licensing deals, which many scholars classify as cooperative ties, sometimes result from settlements of intellectual property disputes, and thus may have strong underpinnings of conflict and rivalry. There is also a sizable opportunity to use insights from studies of the structure of cooperative relations in biotechnology to gain a deeper understanding of competitive trends in the industry. Indeed, cooperative ties provide differential access to resources, information flows, and status, and may therefore impact firms' ability and motivation to engage in competitive behavior (Gnyawali and Madhavan 2001).

Second, based on the need to consider both cooperative and competitive aspects of strategic alliances in biotechnology, research could delve more deeply into dynamics of power and dependence in interorganizational alliances, especially as related to value creation and value appropriation. Gulati and Sytch (2007), for instance, reveal that value-capturing advances of partners may destroy value-creation trends in an alliance. Other work suggests that biotech firms often exchange knowledge with pharmaceutical firms for money on disadvantageously asymmetric terms (Barley et al. 1992; Lerner and Merges 1998), and that when allocation of control rights is skewed toward a funding company, it may be detrimental to biotech alliances (Lerner et al. 2003). Scholars could take a more detailed look at the behavioral dynamics of such partnerships and unpack their implications for the performance of the ventures.

Finally, while existing research has examined strategic alliances in biotechnology using several distinct units of analysis, ranging from individual alliance linkages to the networks of alliances, there are more opportunities to cut across different levels of analysis (cf. Rothaermel and Hess, 2007). We will identify three of these. First, it is essential to consider that while many aspects of interorganizational relations become institutionalized at the level of an organization, they are still largely based on interpersonal interactions (cf. Gulati and Sytch Forthcoming). Alliance research would benefit from taking a more fine-grained look at the interpersonal dynamics between boundary-spanning organizational agents and other employees involved in managing strategic partnerships. The implications could be informative and valuable. For instance, positive implications of inter-partner familiarity and prior partnerships can be downplayed by frequent personnel turnover or tender relationships between organizational boundary-spanners. Also, much existing research on the development and implications of relational capabilities has implicitly assumed that organizational experience with alliances smoothly diffuses throughout the firm, making it a better overall partner. Studying interpersonal networks within organizations with respect to alliance formation activity could shed light on organizational knowledge diffusion, accumulation, and internalization, leading to more precise inferences with respect to organization-level outcomes.

Second, while there is quite a bit of research focused on individual alliances, there is ample room to consider the origins and implications of a firm's entire alliance portfolio. There is evidence, for example, suggesting that firms in different stages of an evolutionary cycle and facing different market demands may require distinct alliance portfolio configurations (Maurer and Ebers, 2006). Future research can unpack this in greater detail, looking at behavioral and performance implications of alliance portfolios that differ on the dimensions of partner diversity, relationship scope, strength, duration, and others. Finally, recent theoretical and methodological advances in studies of complex systems (e.g., Guimera and Amaral 2005; Gulati et al. 2007; Newman 2004) offer a tremendous opportunity for analyzing networks of biotechnology alliances in a new light. For example, new, more robust clustering techniques help unveil a more accurate picture of industries' community structures. Building on these insights, Gulati et al. (2007) suggest that the global network topology can display dramatic variations over time, which carries major consequences for individual firms' behavior. Taken together, these advances, in turn, could offer promising avenues into understanding global network evolutionary patterns and their interrelationships with individual firms' behavior and performance.

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