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SIGNALS ACROSS MULTIPLE NETWORKS: HOW VENTURE CAPITAL AND ALLIANCE NETWORKS AFFECT INTERORGANIZATIONAL COLLABORATION

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In this article, we examine the contingent effects of signals generated by different types of networks on new ventures' formation of future strategic alliances. We argue that the signaling value of a given tie in reducing adverse selection is more pronounced when another type of tie is lacking. In particular, we suggest that signals associated with (i) a new venture's affiliations with venture capitalists (VCs) that have prominent positions in syndicate networks and (ii) a new venture's prominent position in alliance networks resulting from previous alliances offer redundant benefits. As a result, the positive effect of VC prominence in determining a new venture's future alliance formation diminishes as the new venture's prominence in alliance networks increases. Evidence from biotech alliances between new ventures and established companies provides support for our theory.

Despite the well-known benefits alliances confer on organizations (e.g., Gulati, 1998, 1999; Gulati & Gargiulo, 1999; Sampson, 2007; Stuart, 1998), organizations can face important obstacles in forming such relationships in the first place.[1] Among the many factors potentially impeding collaborations is the risk of adverse selection, which can arise between a new venture and its potential alliance partners when there is information asymmetry regarding the value of the new venture's resources and its future prospects (e.g., Gulati, 1999; Nicholson, Danzon, & McCullough, 2005; Shipilov, Rowley, & Aharanson, 2005). For its part, a new venture seeking alliances has incentives to misrepresent its intellectual capital, the commercialization potential of its technologies, or other resources in order to attract potential partners. At the same time, a potential partner faces difficulty evaluating the new venture before collaboration actually begins (e.g., Hsu, 2006). Left unresolved, these problems reduce the chances of alliances or other economic exchanges occurring (e.g., Garmaise & Moskowitz, 2004; Milgrom & Stokey, 1982). Such difficulties can be particularly severe for new ventures in high-tech industries such as biopharmaceuticals because of these companies' intangible assets and lack of track records in their early years, when they are aggressively seeking partnerships (e.g., Gulati & Higgins, 2003; Stuart, 1998; Stuart, Hoang, & Hybels, 1999). New ventures can engage in activities to signal their quality and thereby facilitate economic exchanges such as future alliances by overcoming these challenges (e.g., Pollock, Chen, Jackson, & Hambrick, 2010; Spence, 1974). Even though outsiders cannot readily observe the actual quality of a new venture, a higher-quality new venture may benefit from signals of quality that make it more attractive than other ventures to potential partners. Given that potential alliance partners face high adverse selection risk and uncertainty regarding the formation of alliances with new ventures, such signals can be especially crucial if new ventures are to access needed resources through alliances or other means (e.g., Gulati & Higgins, 2003; Stuart et al., 1999).

Although new ventures may benefit from many different types of signals (please see reviews by Riley [2001] and Connelly et al. [2011]), interorgan-

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[1] Gulati defined strategic alliances as "voluntary agreements between firms involving the exchange, sharing and codevelopment of products, technologies or services" (1998: 293).

izational relationships in particular can generate important signals about a new venture's resources and prospects. For instance, a new venture's prominent position in networks of interorganizational relationships can signal its quality and future prospects when it is costly to form and maintain such relationships (Gulati & Higgins, 2003; Podolny, 1993, 1994). As an example, a new venture's affiliations with prominent intermediaries such as venture capitalists (VCs) signal its quality, suggesting that the new venture has superior resources and capabilities as well as better market opportunities (Gulati & Gargiulo, 1999; Hsu, 2004; Stuart et al., 1999). Such new ventures therefore present lower adverse selection risk and uncertainty to potential alliance partners, such as established companies, thereby facilitating future alliances.

Given that new ventures are often simultaneously involved in different types of interorganizational networks, an important question arises as to whether the effects of these networks are contingent upon one another. Previous research has analyzed signaling or other benefits of different types of networks, yet this research has examined interorganizational relationships in isolation or has treated them independently (e.g., Brass et al., 2004; Gulati, 1998; Podolny, 2001), so it would be valuable to investigate whether and how the effects of different networks are contingent upon one another. Scholars have recently begun to examine the relative importance of interorganizational and interpersonal relationships (Barden & Mitchell, 2007; Dushnitsky & Lavie, 2010; Rosenkopf, Metiu, & George, 2001) as well as how the effects of these relationships are contingent upon certain factors such as external market conditions (Gulati & Higgins, 2003) or various organizational or exchange attributes (Dushnitsky & Lavie, 2010; Gulati, 1998; Stuart, 1998; Stuart et al., 1999). Nevertheless, there is less understanding of how the impact of a new venture's interorganizational relationships in one network (e.g., affiliations with prominent VCs in syndicate networks) might be influenced by the new venture's own prominence in other types of networks.

In addressing this core research question, this study contributes to prior research on alliances and other interorganizational relationships in several ways. Specifically, we use signaling theory to suggest that the effects of ties in one type of network (e.g., affiliations with prominent VCs) are indeed contingent upon the signals associated with ties in another network (e.g., prominence in alliance networks). Given the uncertainty that new ventures face, it might be reasonable to expect that different types of networks are mutually reinforcing in providing a start-up access to resources and market opportunities via future alliances. However, to the extent that both types of interorganizational relationships can bring about similar signaling benefits (e.g., Gulati & Gargiulo, 1999; Shipilov, Rowley, & Aharanson, 2005; Stuart et al., 1999) and are costly, we argue that signals generated by one type of network weaken the effects of the signals generated by another type of network. Our work also contributes to research on the efficiency of network ties (e.g., Baum et al., 2000) by suggesting that efficiency considerations span different types of networks to the extent that the signals generated within one network weaken the need for additional signals in another network.

THEORY

When there is information asymmetry between a new venture and potential exchange partners, the potential exchange partners face the risk of adverse selection in their exchanges with the new venture (e.g., Riley, 2001; Stiglitz, 2002). Therefore, in the presence of information asymmetry, a new venture's resources and prospects will be discounted by potential exchange partners who cannot differentiate high-quality new ventures from lower-quality ones (Akerlof, 1970). For example, when forming alliances with new ventures, it can be difficult for potential alliance partners to evaluate the new ventures' technological and other resources, so the risk of adverse selection can be significant, and worthwhile collaborations might not materialize as a consequence (Balakrishnan & Koza, 1993; Gulati, 1995b, 1998; Gulati & Gargiulo, 1999; Nicholson et al., 2005). Such problems can be especially acute for new ventures in high-tech industries because they lack track records and have substantial resource requirements.

As a remedy to the adverse selection problem, a new venture can signal the quality of its resources and future prospects by engaging in activities that are costly for others to imitate. Spence (1974) originally analyzed the implications of information asymmetry and signaling in the employee recruitment process. He showed that more productive candidates do not receive higher wages than less productive ones unless the more productive candidates engage in some activities that are positively related to unobserved quality and are costly to im-

itate. For instance, more productive candidates can use their educational achievement as a signal of their productivity and hence can differentiate themselves from the less productive ones.

In a similar vein, Hsu (2004) showed that new ventures are willing to sell their shares at discount to prominent VCs in order to signal their resources and prospects. New ventures might signal their quality in other ways as well, such as by engaging in a first alliance on less favorable terms (Nicholson et al., 2005) or underpricing their securities when going public (Heeley, Matusik, & Jain, 2007). Hence, by engaging in costly signaling, new ventures can differentiate themselves from others lacking attractive resources or prospects. In this way, new ventures can help mitigate the adverse selection risk that potential exchange partners face, thereby facilitating the new ventures' future economic exchanges (e.g., Dewally & Ederington, 2006; Hsu, 2004; Nicholson et al., 2005; Pollock et al., 2010). As we discuss below, different types of interorganizational relationships can convey important signals to a new venture's potential partners. We also extend signaling theory by analyzing how the effects of a new venture's ties in one type of interorganizational network are influenced by its ties in another network.

VC Syndicate Networks and Future Alliance Formation

For new ventures in high-tech industries, two critical types of networks are networks of prior alliances, or alliance networks (e.g., Baum et al., 2000), and VC syndicate networks, which are formed through VCs' joint investments in new ventures (Sorenson & Stuart, 2001). Even though previous research has extensively analyzed the impact of alliance networks on future alliance formation (e.g., Gulati, 1998, 1999; Gulati & Gargiulo, 1999), it has devoted far less attention to the impact of other important types of networks, such as VC syndicate networks. This represents an important omission since VCs are critical providers of resources (e.g., Bygrave & Timmons, 1992; Gompers & Lerner, 2000) and certify the quality of new ventures (e.g., Gulati & Higgins, 2003; Hsu, 2006). Therefore, to have a more complete understanding of the determinants of future alliance formation of new ventures, researchers need to investigate the implications of a new venture's affiliations with VCs.

Since VCs consider investing in new ventures that lack significant track records or established businesses, it is critical for the VCs to be able to access information regarding the quality of new ventures before investing in them. Given the high uncertainty that VCs face when investing in new ventures, VCs rarely make such investments alone. Instead, most of the time VCs form syndicates, in which multiple VCs jointly invest, or co-invest, in new ventures (Bygrave, 1988; Bygrave & Timmons, 1992; Echols & Tsai, 2005; Gompers & Lerner, 2000; Lerner, 1994). As a result of their joint investments, VCs form webs of relationships with each other, leading to VC syndicate networks that facilitate the exchange, pooling, and dissemination of information about new ventures. A particular VC's position in VC syndicate networks is based not only on its joint investments with other VCs in various new ventures, but also on the joint investment activities of those VCs with third-party VCs in other new ventures (Sorenson & Stuart, 2001). Thus, VCs that are well connected to other VCs through extensive direct and indirect co-investment ties achieve prominent positions in VC syndicate networks (e.g., Podolny, 2001; Shipilov et al., 2005) and are perceived to be of higher quality (e.g., Podolny, 2001).

Affiliating with a prominent VC can convey signals on a new venture's resources and prospects for several reasons. First, prominent VCs have extensive information channels thanks to their connections in the VC syndicate networks, enabling them to better conduct due diligence on a new venture before investing in it (Koka & Prescott, 2008). The fact that VCs having such information invest in a new venture conveys that the firm has attractive resources and prospects (Hsu, 2006).

Second, prominent VCs are also quite selective in investing in new ventures because investing in lower-quality new ventures would put a VC's own reputation at risk (Hsu, 2004; Podolny, 1994). Specifically, VCs with prominent positions are expected to be quite selective in choosing in which new ventures to invest because prominent VCs have achieved high visibility and have gained reputations as successful investors. Hence, affiliations with lower-quality new ventures can damage prominent VCs' reputations (Hsu, 2004, 2006; Podolny, 1994). Therefore, the investment decisions made by prominent VCs are highly trusted and valued (Gulati & Higgins, 2003).

Third, new ventures need to be able to accept a lower valuation to be associated with prominent VCs (Hsu, 2004). High-quality new ventures are more likely to be able to bear such a cost (Spence,

1974), and associations with prominent VCs can be too costly for lower-quality new ventures to imitate. Taken together, these three arguments suggest that a prominent VC's investment in a new venture signals potential alliance partners, such as established companies, that the new venture has high-quality resources and superior prospects in comparison with new ventures that lack such affiliations. This signal, therefore, reduces the adverse selection risk and uncertainty faced by potential alliance partners about the new venture's resources and prospects, thereby facilitating the new venture's future alliance formation (e.g., Gulati, 1999). Thus, we specify the following prediction:

Hypothesis 1. A new venture's affiliations with prominent VCs has a positive impact on the new venture's formation of alliances in the future.

Organizations themselves can achieve prominence in networks of prior alliances (i.e., alliance prominence), by forming extensive direct and indirect alliance ties to other organizations in alliance networks (Gulati & Gargiulo, 1999; Podolny, 2001). Alliance prominence likewise conveys signals on the new venture's resources and prospects, alleviating problems associated with adverse selection that can impede future alliance formation. Just as financial intermediaries such as venture capitalists, and particularly prominent VCs, carry out due diligence on new ventures, alliance partners also conduct such evaluations prior to the formation of alliances (Nicholson et al., 2005; Ozmel, Robinson, & Stuart, 2012). The fact that a particular new venture is able to form extensive direct and indirect ties in alliance networks and hence achieve a prominent position indicates that the new venture possesses valuable resources and capabilities that are in demand by other companies (e.g., Jensen, 2003; Nicholson et al., 2005).

This line of argument suggests that when there is information asymmetry and uncertainty about a new venture and its potential alliance partners, a prominent position achieved in alliance networks signals that the new venture has higher-quality resources and better prospects (e.g., Podolny, 2001; Shipilov et al., 2005). By signaling the new venture's resources and prospects, a prominent position in alliance networks mitigates the adverse selection risk that potential partners face (Gulati, 1999; Jensen, 2003). As a result, prominent positions in networks of prior alliances facilitate a new venture's future alliance formation. Thus, although our primary interest lies in understanding the contingent effects of signals associated with different types of networks (e.g., VC syndicate networks and alliance networks), we specify the following hypothesis as a baseline prediction for completeness:

Hypothesis 2. A new venture's prominence in networks of previous alliances has a positive impact on the new venture's formation of alliances in the future.

Contingent Effects of Different Types of Interorganizational Networks

Given that both having affiliations with prominent VCs (Hypothesis 1) and occupying prominent positions in alliance networks (Hypothesis 2) conveys signals on a new venture's resources and prospects and hence mitigates adverse selection risk, we anticipate that the positive impact of VC prominence on future alliance formation is also contingent upon the level of a new venture's own prominence in alliance networks. Networks might complement each other in certain ways, given the different types of resources and opportunities that are available through them, yet signaling theory would suggest that alliance prominence would diminish the positive impact of VC prominence on future alliance formation for several reasons.

First, the signaling value of an interorganizational relationship in determining a new venture's future alliance formation is a function of the level of adverse selection risk that the new venture's potential alliance partner faces. This, in turn, is influenced by the presence or absence of signals associated with the new venture's other types of interorganizational relationships. Holding everything else constant, if other signals are lacking, the risk of adverse selection is more severe, and the value of a particular signal will be greater in facilitating future alliance formation (e.g., Jensen, 2003; Nicholson et al., 2005).

In particular, if a new venture does not maintain a prominent position in alliance networks, potential partners confront greater adverse selection risk and uncertainty regarding the value of the alliance with this new venture. Therefore, the value of the signals associated with affiliations with prominent VCs will be greater when the new venture does not have a prominent position in an alliance network. If, on the other hand, the new venture has developed a prominent position in an alliance network and hence differentiated itself from others having

less attractive resources and prospects, the new venture's potential alliance partners face a lower risk of adverse selection. Therefore, the value of signals about the new venture generated by the new venture's affiliations with prominent VCs decreases.

Second, it can be costly for a new venture to simultaneously maintain different types of relationships to generate signals about its resources and prospects. Previous research examining the signals generated from interorganizational relationships in isolation implicitly argues each one of new venture's interorganizational relationships is sufficient in signaling a new venture's resources and prospects. For instance, prior research suggests that new ventures can effectively differentiate themselves from others with worse resources or prospects by associating with prominent VCs or occupying prominent positions in networks of interorganizational relationships (Gulati & Higgins, 2003; Koka & Prescott, 2008; Nicholson et al., 2005; Stuart et al., 1999). The sufficiency argument for a new venture's particular type of interorganizational relationship, such as its prominence in alliance networks, in differentiating a new venture from others indicates that sending additional signals through forming affiliations with prominent VCs can be inefficient, since a new venture already has borne this cost (Hsu, 2004; Nicholson et al., 2005) and has already distinguished itself from new ventures having worse resources and prospects. Therefore, signals about a new venture's resources and prospects generated by the new venture's prominence in alliance networks mitigate the positive effect of the signals generated by the prominence of the VCs that are investing in the new venture. We therefore posit:

Hypothesis 3. The positive effects of affiliations with prominent VCs on a new venture's future alliance formation diminish with the new venture's prominence in alliance networks.

METHODS

Data

To test our hypotheses, we formed a data set by combining information from various data sources, including Recombinant Capital, Thomson's VentureXpert, Corptech, and the patent databases provided by the National Bureau of Economic Research (NBER) and the US Patent and Trademark Office (USPTO). The biotech industry's alliance data were obtained from Deloitte Recombinant LLC (Recap), which is a company specialized in gathering various types of data in the US biotech industry. Data on the patent applications of biotech companies until the end of 1999 were obtained from NBER's database, and data on organizations' patent applications after 1999 were downloaded directly from the USPTO's website. We obtained data on VC investments between 1980 and 2004 from the VentureXpert database, which is part of Thomson Financial's Venture Economics database. As in previous studies, we excluded VC investments that were made prior to 1980 because VentureXpert's data pertaining to the pre-1980 period are less complete. In addition, when information was missing from VentureXpert, we conducted manual searches using Factiva and other online resources. Finally, we use Corptech data to obtain missing information on founding dates for several new ventures.

Our sample consists of all possible R&D alliances between new ventures and established companies during the 1980–2003 time period. If a new venture and an established company from among this set of all possible alliance pairs formed an R&D alliance in year *t*, we call them a "realized alliance pair." On the other hand, if they did not form an alliance in year *t*, they are an "unrealized alliance pair." For the purposes of our study, new ventures are defined as domestic, private companies that receive VC funding and that operate in the biotechnology industry. We define established companies as public companies that operate in the biotechnology or pharmaceutical industries in the United States. In our empirical analyses, these established companies serve as the potential alliance partners for new ventures. In R&D alliances between new ventures and established companies, established companies recruit new ventures to conduct R&D-related activities for them. Furthermore, in our sample, we made sure that the new ventures and established companies represent two completely different set of companies. This ensures that there is no overlap between the set of new ventures, which are primarily responsible for the R&D activities, and the established companies, which recruit and fund new ventures. For this purpose, we excluded any company that acted as a new venture, conducting R&D activities in an alliance when it was private, and later on took over the role of the established company. Finally, we included only alliances focused on research and development (R&D). Following these sampling criteria, we have 225 realized alliance pairs and 53,479 unrealized alliance pairs be-

tween 239 new ventures and 156 established companies.

In developing and testing our hypotheses, we formed independent variables from the perspective of new ventures, and this focus merits justification. As mentioned earlier, all of the new ventures in our sample were private, VC-backed companies with no access to public funding platforms such as stock exchanges. As a result such lack of access, new ventures obtain critical resources primarily from their alliance partners and VCs. Achieving prominent positions in alliance networks and affiliating with prominent VCs are especially critical for new ventures' ability to access much-needed resources. On the other hand, in our data set new ventures' partners are established companies, which are public firms that can access funding from equity markets. Furthermore, established companies already have a high level of visibility and can disseminate information to outsiders through financial statements and other documents required by the Securities and Exchange Commission (SEC). As an example, the set of biotech new ventures' alliance partners include Pfizer, Roche, and Merck, which are already very well-known companies that have established track records, are followed by many stock analysts, and appear continuously in the press. This suggests that established companies would not need prominent positions in alliance networks as much as the new ventures to signal their resources and prospects. Furthermore, VCs need to sell their equity positions in their portfolio companies within five to ten years. Hence, most VCs sell all of their equity shortly after a company completes an initial public offering, which suggests that associations with VCs are not as relevant for established companies. Therefore, we form our hypotheses and independent variables from the perspective of the new ventures.

Dependent Variable

Likelihood of future alliance formation. Our level of analysis is the dyad-year, and the dependent variable is whether or not a particular new venture (*i*) and established company (*j*) form an R&D alliance in a given year (*t*) (1 = "yes," 0 = "no"). Our data set therefore includes not only the realized alliances between the companies in these two sets, but also the nonrealized alliances. All of the independent and control variables discussed below enter the regressions with values lagged one year with respect to this dependent variable. Given the dichotomous nature of our dependent variable, we used logit models for estimation, and we estimated robust standard errors by clustering residuals at the dyad level to account for nonindependence of observations.

Independent Variables

VC prominence in syndicate networks (VC prominence). This measure represents the prominence of the VCs investing in a given new venture in VC syndicate networks. Previous research in strategy and organization theory uses the centrality measure of Bonacich (1987) as a standard measure for an organization's prominence in networks of social relationships (Podolny, 1993, 1994, 2001). Therefore, we first used this measure to calculate the centrality of *each VC* as of year *t*. The centrality measure of Bonacich (1987) incorporates not only an organization's direct ties, but also its indirect ties in its network, as discussed below. The centrality of VC firm *i* in year *t* is measured using all of the direct and indirect syndicate ties formed between *i* and all the other VC firms during the most recently past five years (between $t - 5$ and t), as shown below:

$$\text{VC firm centrality}_{i,t} = C_{i,t} = \sum_{j=1}^{N_t} (\alpha_t + \delta_t c_{j,t}) R_{i,j,t} \quad (1)$$

where $C_{j,t}$ is the centrality of the VC firm j in year t; $R_{i,j,t}$ is the relationship matrix entry indicating the number of co-investments between VC firm i and VC firm j during the last five years; δ_t is the weighting coefficient, which is set equal to three-quarters of the reciprocal of the largest eigenvalue of R (e.g., Podolny, 1993; Jensen, 2003); and α is the scaling factor, which assures that the maximum centrality for each year is equal to 1 across all the VCs.

Typically more than one VC has invested in a particular new venture as of time *t*. After calculating the centrality of each VC investing in a particular new venture as of time *t*, we took the *maximum* of the centralities of those VCs that had invested in the new venture by time *t*. Outsiders pay attention to the most prominent VCs investing in a new venture (Gompers & Lerner, 2000). Hence, to represent the extent of the signaling benefits the new venture receives from the investment of prominent VC firms, we used the maximum centrality

calculated across the VCs investing in the new venture as of time *t*. However, in unreported supplemental analyses we also calculated VC prominence as mean centrality and found that the results presented below are robust.

New venture's prominence in alliance networks (alliance prominence). As explained previously, centrality is a good indicator of an organization's prominence in a network of social relationships (Podolny, 1993, 1994, 2001). A new venture's alliance network centrality was calculated as its centrality (Bonacich, 1987) in networks of prior alliances using the new venture's alliance formation activity within the last five years, as follows:

$$\text{Centrality of the new venture}_{i,\,t} = C_{i,\,t} = \sum_{j=1}^{N_t} (\alpha_t + \delta_t c_{j,\,t}) R_{i,\,j,\,t} \quad (2)$$

where $C_{j,t}$ is the centrality of the new venture *i*'s alliance partner, established company *j*, in year *t*, and $R_{i,j,t}$ is the relationship matrix that shows the number of alliances formed between *i* and *j* during the last five years, up to year *t*. We normalized the centrality measure so that the maximum centrality in a particular year is equal to 1.

Control Variables

We included various covariates at the industry and dyad levels as well as at the levels of both established company and new venture to address other determinants of alliance formation that might also be related to the above theoretical variables of interest. To begin with, we included *IPO market conditions* for the biotechnology industry. When the biotech industry is faring well, investors are more optimistic about the quality and prospects of companies in general; this might increase the level of funding that established companies have for alliances. To capture the IPO (initial public offering) market conditions in the biotech industry, we measured the ratio of the number of biotech companies that went public during the past three months to the number of private biotech companies in the industry. We next controlled for the number of *prior ties* between a new venture and established company. Prior ties can facilitate future alliances by mitigating moral hazard and enhancing trust as well as cultivating interorganizational routines that enhance efficiency (Gulati, 1995a, 1998; Zollo et al., 2002). This variable was measured as the log of the number of prior alliances between the partners in a given pair during the past five years.

We also account for the number of patents an established company has applied for during the past five years (*patent count, established company*) and for its number of alliances (i.e., *alliance count, established compan*y). In addition, we controlled the prominence of the established company in alliance networks using its centrality in the alliance network (i.e., *alliance prominence, established company*). Furthermore, we controlled for *patent count*, a new venture's number of patents, to address its innovative capability and knowledge base (e.g., DeCarolis & Deeds, 1999; Stuart, 2000; Hagedoorn & Cloodt, 2003). We used as proxy the number of patents the new venture had applied for during the past five years. In high-tech industries, being innovative is a critical determinant of a new venture's quality and future prospects (e.g., DeCarolis & Deeds, 1999; Hagedoorn & Cloodt, 2003; Sorenson & Stuart, 2001; Stuart, 2000). Therefore, the number of patent applications during the last five years is a frequently used measures of a new venture's quality and innovative capability in high-tech industries. In addition, we controlled for the age of the new venture in months (i.e., *age*). New ventures are subject to the liability of newness because they lack sufficient track records as well as established relationships with prominent organizations, managers, and scientists in their environment (Carroll & Hannan, 2000; Stinchcombe, 1965). This liability might deter established companies from forming alliances with new ventures. On the other hand, older organizations might suffer from organizational inertia (Carroll & Hannan, 2000), which might reduce their ability to form new alliances. Controlling for the age of a sampled new venture allowed us to incorporate the impact of these factors in determining the new venture's future alliance formation.

We incorporated a variable for the deal size of the VCs investing in the new venture to control for the experience of these VCs. This variable, *VC deal size*, is measured as the number of a VCs' portfolio companies (Gompers & Lerner, 2000; Hsu, 2004). In addition, we controlled for the age of the VC funds investing in a new venture (*VC fund age*) to better incorporate the level of escalation of commitment, whereby VC firms might be less likely to terminate the investment of an older fund and thereby lead to further VC funding rounds (Guler, 2007). Similarly, to control for the size of the syndicates invested in

a new venture, we controlled for the number of VCs invested in the new venture as of time *t* (*size of the VC syndicate*) (Gompers & Lerner, 2000). We also controlled for a venture's *number of VC funding rounds*.

We also controlled for the amount of alliance funding a new venture received through royalty payments and milestone payments during the past five years (*amount of alliance funding*) as well as the amount of equity invested in the new venture through alliances during the past five years (*equity invested in alliance*) to control for the extent of funding the new venture received from its alliance partners (Stuart et al., 1999). Both of these variables are in logged millions of dollars, and both also help us capture new venture need to form alliances. In addition, we controlled for a new venture's *alliance count*, or the mere number of alliances the new venture had formed during the past five years (Gulati, 1998, 1999; Stuart et al., 1999).

In supplemental analyses, we also incorporated squared terms for VC prominence, alliance prominence, and new venture's accumulated VC funding rounds to determine if one more relationship of any type, rather than our hypothesized effects (e.g., in Hypothesis 3) might explain the diminishing benefits of signals from prominent VCs, but these variables were all insignificant (results are available upon request).

RESULTS

Table 1 shows descriptive statistics and correlation coefficients. New ventures that had affiliations with prominent VCs tend to have gone through more VC funding rounds, which is consistent with the quality of such new ventures. Descriptive statistics also document the stark differences between new ventures and established companies. The average prominence of a new venture in alliance networks, (alliance prominence) is 0.04, where the maximum can be 1. On the other hand, the average prominence of an established company in alliance networks (*alliance prominence, established company*), is 0.19 ($p < .001$). On average, each established company had formed 15 alliances during the past five years, whereas each new venture on average had formed 2 alliances during the past five years ($p < .001$). Similarly, the average patent count of the established companies is 31, whereas it is 2 for new ventures ($p < .001$). The mean number of the new venture accumulated funding rounds is two. Furthermore, the variable measuring size of the VC syndicate shows that on average a new venture receives investment from around five VCs.

Table 2 shows the results of the regression models. Model 1 shows the control variables. Model 2 shows the controls and the VC prominence variable. Model 3 adds alliance prominence to the control model. Model 4 includes both VC prominence and alliance prominence along with the control variables. Model 5 is the full model, in which we incorporate the interaction between VC and alliance prominence.

Table 2 shows that VC prominence has a positive and highly significant effect on future alliance formation by a new venture. Even after the interaction variable is included, the coefficient of VC prominence is still very significant ($p < .001$). This suggests that as a new venture becomes affiliated with more prominent VCs, its likelihood of future alliance formation increases significantly. These findings provide strong support for Hypothesis 1. Models 3–5 show that the main effect of alliance prominence on future alliance formation is positive and quite significant as well ($p < .001$), supporting Hypothesis 2. Model 5 reports the interaction of VC prominence and the new venture's prominence in alliance networks. The estimation results reported in these models provide strong support for Hypothesis 3, which suggests that the signaling benefits of affiliations with prominent VCs on a new venture's future alliance formation is contingent upon the new venture's own prominence in alliance network. In particular, model 5 suggests that the positive effect of signals generated by VC prominence diminishes as a new venture itself achieves a more prominent position in its alliance network ($p < .001$) (see also Figure 1).

It is difficult to interpret the interaction coefficients in logit models. To assess how alliance prominence shapes the positive effect of VC prominence on future alliance formation, in Figure 1 we have plotted the likelihood of future alliance formation at different levels of alliance prominence. Figure 1 therefore depicts the economic effect of VC prominence on future alliance formation at different levels of alliance prominence, when other covariates are at their means. To summarize our findings, we found that at the median level of alliance prominence, when VC prominence increases by one standard deviation from its mean, future alliance formation likelihood increases by 60 percent. However, when the alliance prominence variable is at the median plus one standard deviation, an in-

TABLE 1
Descriptive Statistics and Correlations[a]

	Variable	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Future alliance formation	0.004	0.04																
2.	IPO market condition	1.82	2.10	.01															
3.	Prior ties	0.001	0.02	.06	.01														
4.	Patent count, established company	30.77	89.57	.01	.06	.01													
5.	Alliance count, established company	14.90	18.58	.03	−.13	.01	.16												
6.	Alliance prominence, established company	0.19	0.19	.03	.06	.01	.28	.80											
7.	Patent count	2.24	4.02	.00	.01	.01	.00	.00	.00										
8.	Age	86.87	65.10	−.03	−.09	.00	−.02	.04	−.02	.14									
9.	VC deal size	82.95	94.62	−.01	−.10	−.01	−.02	.04	−.02	−.02	.06								
10.	VC fund age	53.40	157.91	−.01	−.10	.00	−.02	.04	−.02	.07	.44	−.13							
11.	Size of VC syndicate	5.06	4.88	−.01	−.06	.02	−.01	.02	.00	.26	.23	−.07	.19						
12.	Number VC funding rounds	2.14	2.43	.00	−.01	.01	.00	−.01	.01	.20	−.04	−.01	−.27	.45					
13.	Amount of alliance funding	1.29	11.47	.00	−.01	.01	.00	.00	.00	−.01	−.05	−.01	−.03	.06	.03				
14.	Equity invested in alliance	0.29	0.74	.00	.03	.02	.01	−.02	.01	.21	.06	.06	.03	.14	.14	.14			
15.	Alliance count	2.21	2.85	−.01	−.01	.03	.00	.00	.00	.22	.19	.02	.15	.42	.13	.08	.31		
16.	Alliance prominence	0.04	0.05	.02	.14	.04	.03	−.06	.04	.08	.24	−.08	.15	.36	.11	.09	.24	.67	
17.	VC prominence	0.33	0.38	.02	.08	.02	.02	−.03	.02	.15	.05	−.04	.16	.42	.20	.07	.03	.15	.18

[a] n = 53,704. IPO market condition is in thousands; age and VC fund age are given in months. Correlations equal to or higher than .01 in absolute value are significant at the 5 percent level or better.

TABLE 2
Results of Logit Regressions for Future Alliance Formation[a]

Variable	Model 1		Model 2		Model 3		Model 4		Model 5	
IPO market condition	0.09**	(0.03)	0.08**	(0.03)	0.07**	(0.03)	0.07*	(0.03)	0.09**	(0.03)
Prior ties	5.67***	(0.77)	5.46***	(0.79)	5.65***	(0.74)	5.44***	(0.77)	5.58***	(0.82)
Patent count, established company	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Alliance count, established company	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)
Alliance prominence, established company	2.12***	(0.60)	2.06**	(0.60)	1.99**	(0.59)	1.94**	(0.60)	2.14**	(0.60)
Patent count	0.04	(0.02)	0.04	(0.02)	0.04	(0.02)	0.04†	(0.02)	0.05†	(0.03)
Age	−0.01**	(0.01)	−0.01**	(0.00)	−0.01**	(0.00)	−0.01**	(0.00)	−0.01*	(0.00)
VC deal size	−0.00*	(0.00)	−0.00*	(0.00)	−0.00*	(0.00)	−0.00*	(0.00)	−0.0**	(0.00)
VC fund age	0.06*	(0.03)	0.06†	(0.03)	0.05†	(0.03)	0.04	(0.03)	0.05†	(0.03)
Size of VC syndicate	0.00	(0.04)	−0.03	(0.04)	−0.01	(0.03)	−0.05	(0.04)	−0.02	(0.05)
Number of VC funding rounds	−0.21*	(0.08)	−0.22*	(0.09)	−0.19*	(0.08)	−0.20*	(0.09)	−0.18*	(0.09)
Amount of alliance funding	0.00	(0.00)	−0.00	(0.00)	0.00	(0.00)	−0.00	(0.00)	0.00	(0.00)
Equity invested in alliance	0.01	(0.14)	0.06	(0.15)	−0.02	(0.14)	0.03	(0.14)	0.08	(0.15)
Alliance count	−0.06	(0.05)	−0.07	(0.05)	−0.12*	(0.05)	−0.13*	(0.06)	−0.06	(0.05)
VC prominence			0.87**	(0.31)			0.95**	(0.31)	1.71**	(0.35)
Alliance prominence				(0.02)	5.14***	(1.09)	5.42***	(1.04)	8.49***	(0.97)
VC prominence × alliance prominence									−27.77***	(6.31)
Log-likelihood	−939		−786		−775		−769		757	

[a] IPO market condition is in thousands; age is given in months.
† $p < .10$
* $p < .05$
** $p < .01$
*** $p < .001$

crease of VC prominence by one standard deviation increases the likelihood of future alliance formation by less than 1 percent. These numbers suggest that the economic impact of alliance prominence in weakening the positive effect of VC prominence on future alliance formation is substantial. In robustness tests, we repeated our analyses using rare event logit models and received similar results.

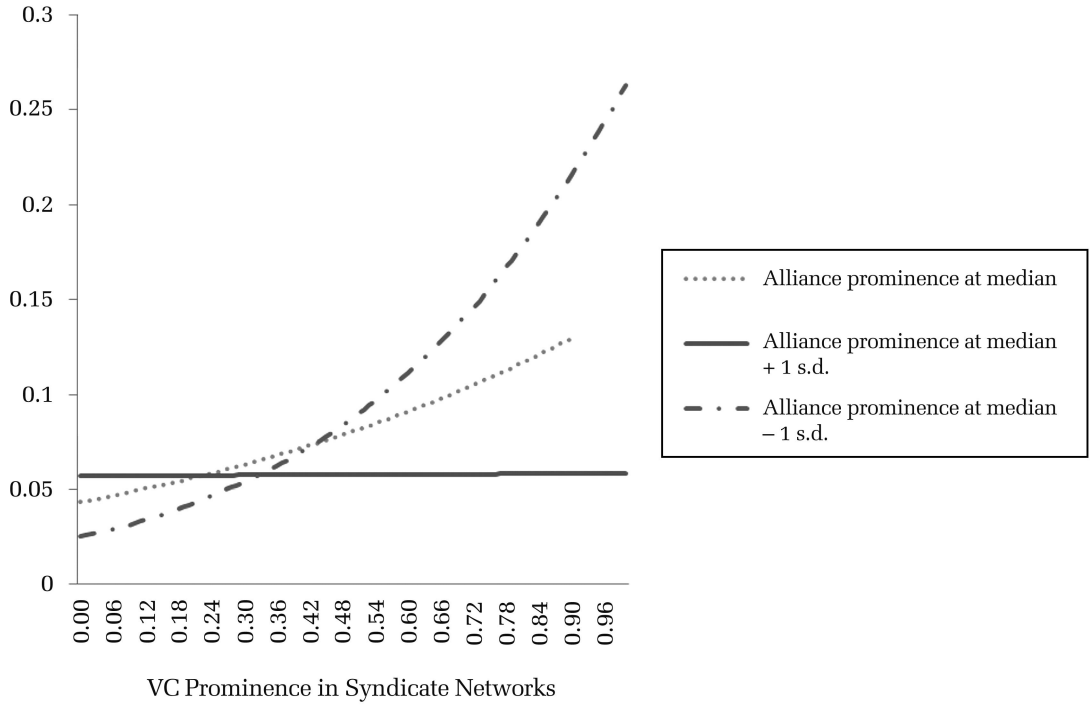
DISCUSSION

In this study, we extend signaling theory to argue that a new venture's own prominent position in alliance networks mitigates the positive impact of the new venture's affiliations with prominent VCs in determining the new venture's future alliance formation. We first suggest that a new venture's affiliations with prominent VCs in syndicate networks signal the quality of the new venture's resources and prospects, thereby facilitating future alliance formation. We also suggest that signals generated by the prominence of the affiliated VCs are more important when potential alliance partners face higher adverse selection risk due to the new venture's lack of prominence in networks of prior alliances. Our findings provide strong evidence for our overall proposition derived from signaling theory that the effects of a new venture's affiliations in a particular type of network of interorganizational relationships, such as VC syndicate networks, are contingent on the new venture's position in other types of networks such as alliance networks.

Our theory and evidence therefore advance prior research that has investigated different types of interorganizational relationships in isolation or has treated them independently from one another. Our theoretical arguments and empirical evidence also contribute to recent studies on other contingencies affecting the value of interorganizational relationships, including external market conditions and various organizational or exchange attributes operating at different levels of analysis (Dushnitsky & Lavie, 2010; Gulati & Higgins, 2003; Rothaermel & Boeker, 2008).

Beyond offering a signaling theory of how the effects of multiple networks are contingent upon one another, our study also contributes to recent research on social networks and interorganizational relationships in several ways. For research

FIGURE 1
Moderating Effect of Alliance Prominence on the Relationship between VC Prominence and Future Alliance Formation Likelihood



that has examined particular types of networks and their value to organizations (e.g., Gulati & Gargiulo, 1999; Shipilov et al., 2005), our study suggests that organizations can derive similar benefits from different types of networks; these two associations have not been investigated together within a given study. This suggests that both scholars and managers need to account for affiliations in networks other than a focal one to consider the broader benefits or costs of interorganizational relationships of a particular type. Moreover, prior research has suggested that organizations need to configure their networks efficiently. Forming affiliations can be costly, and our study suggests that efficiency considerations span networks, because different types of interorganizational relationships may confer redundant benefits in the signals they provide about an organization's resources and prospects.

Our study is limited in not focusing on the coevolution of different network structures, but our findings carry potential implications for future research on the evolution of different types of networks and how they influence each another. Specifically, the literature has focused on path dependency in particular interorganizational relationships such as strategic alliances (Gulati, 1995b, 1998; Powell et al., 1996). It would be interesting to examine how relationships of organizations might simultaneously or sequentially develop in various types of networks. As one illustration, our study would suggest that path dependency is a multidimensional rather than a unidimensional phenomenon, wherein each dimension is a different type of network, such as a VC syndicate network or alliance network. This suggests that studies analyzing the evolution of social networks need to consider the changes in not only in an organization's environment or in the structure of a particular network, but also in an organization's positions in other types of networks at the same time. For example, path dependencies in alliance networks might be altered by changes in a new venture's relationships with VCs or the new venture's prominence in other networks to the extent that the latter relationships provide signals on the new venture's resources and prospects. Given our focus on the behavioral consequences of this network contingency and signals for future alliance formation, the performance consequences of the evolution of multiple networks also merit future inquiry.

Our study also advances upon influential research on the value of interorganizational endorsements (e.g., Podolny, 1994; Podolny et al., 1996; Stuart et al., 1999) by arguing and showing that the value of such endorsements hinges on a new venture's position, especially its prominence, in other types of networks. Specifically, the value of endorsements by financial intermediaries such as prominent VCs will be greater when the new venture does not already occupy a prominent position in alliance networks. We have focused on endorsements by prominent VCs, so opportunities exist to examine whether network interdependencies similarly shape the value of endorsements by other types of financial intermediaries (e.g., investment banks) or other types of organizations (Podolny, 1993).

In developing and testing a signaling theory of network contingencies, we focused on the ways in which different types of networks of interorganizational relationships might decrease the effects of the others in facilitating a new venture's future alliance formation. Interesting research opportunities exist to extend this research in several ways as well as address several additional limitations of this study. First, the empirical context of this study concerns the alliances between domestic, private, VC-backed biotech companies and established companies in the biotechnology/pharmaceuticals industry. In this industry, knowledge is dispersed across various organizations (Powell et al., 1996), so interorganizational relationships are quite important for accessing information. Furthermore, a biotech company's product development life cycle is rather long. As a result, uncertainty regarding the capabilities and future prospects of biotech companies is very high. Future research could examine the contingent effects of different types of networks in other contexts to explore the generalizability of our findings to different types of collaborative agreements.

Second, it would be valuable to examine other consequences of network contingencies besides future alliance formation, including financial performance or exiting through an initial public offering or an acquisition. Signaling theory emphasizes that significant information asymmetry and uncertainty exist regarding the resources and prospects of new ventures in these and other high-tech industries. Therefore, it would be interesting to determine if the signals we study have consequences for new ventures' ability to acquire resources in other ways and hence achieve higher performance.

Third, we analyze VC syndicate networks and the networks of prior alliances as these two are particularly important networks for new ventures operating in high-tech industries. However, we believe that our arguments might be generalized to other contexts as long as (i) potential partners face adverse selection risk and (ii) companies can signal their quality through their positions in different types of networks. When these two conditions hold, our hypotheses can be applied to other types of interorganizational and interpersonal relationships. It would be interesting and worthwhile for future research to examine these contingencies in other types of networks. For instance, board interlocks of another type of network that might affect an established organization's performance and strategy (e.g., Gulati & Westphal, 1999; Haunschild & Beckman, 1998; Mizruchi, 1996). As another example, in emerging markets governmental ties might be particularly important, particularly for firms without ready access to other endorsement institutions (e.g., Ahuja & Yayavaram, 2011).

In addition, there are other ways that new ventures or established organizations can signal their value without relying on endorsements or prominent positions in networks (e.g., patenting, warrantees, financial choices, etc.), so it would also be valuable to examine whether such factors also weaken the effect of alliance, VC syndicate, board interlock, or other types of networks and potentially have an impact on network contingency. Finally, our hypotheses can also be extended to analysis of the formation of other types of interorganizational exchange relationships than strategic alliances.

Furthermore, in future research it would be valuable to study network contingencies using alternative theoretical perspectives. In particular, it would be interesting to identify conditions under which networks might complement each other in facilitating economic activities, such as when rivals' imitation costs are lower. Research in directions such as these could be very valuable in further investigating the extent and nature of contingent effects of different types of networks.

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