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The Impact of Early Imprinting on Evolution of New Venture Networks

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Abstract

Given the argued importance of networks to new ventures, this paper is intended to fill a noted gap in the literature pertaining to the factors that influence the evolution of new ventures' alliance networks. Drawing on the imprinting literature, we propose that one has to look beyond the first partner per se, and instead focus on the extant relationships the initial partner has with other firms. More specifically, we argue and find that the network size and centrality of a new venture's initial alliance partner influence the subsequent size of the new venture's network.

Keywords: Networks; New ventures; Imprinting; Panel Data

1. Executive summary

Entrepreneurship scholars have increasingly investigated the consequences of new venture networks (Hoang and Antoncic, 2003). Having a larger alliance network has been shown to lead to a shorter time between a company's founding and undergoing an IPO (Chang, 2004), increased venture capitalist investment (Baum and Silverman, 2004), a higher rate of new product development (Deeds and Hill, 1996), increased absorptive capacity (George et al., 2001), the pursuit of larger scale strategies such as internationalization (Coviello, 2006) and ultimately higher levels of new venture performance (Baum et al., 2000).

Given the benefits realized by ventures with larger alliance networks, it is surprising to note that relatively few studies have examined how a new venture's network grows and becomes larger. Also referred to as interorganizational networks, networks are here defined as a set of firms and the alliances between them (Gulati and Gargiulo, 1999). The literature describes the evolution of alliance networks as an iterative process, in which “new partnerships modify the previous alliance network, which then shapes the formation of future cooperative ties” (Gulati and Gargiulo, 1999: 1441). However, new ventures do not have an existing alliance network to rely on, and must instead start with a clear slate.

In building our theoretical model we draw on the imprinting literature, which argues that new ventures' early conditions have a lasting influence on their future outcomes (Stinchcombe, 1965). While prior literature demonstrated that new ventures' development trajectories are imprinted based on various circumstances surrounding their early age (e.g. [Bamford et al., 2000] and [Boeker, 1989]), we build on Gulati and Gargiulo's (1999) argument and posit that the initial alliance partner may in itself serve as an important predictor of the new venture's network trajectory.

We first hypothesize that the network size of a new venture's initial alliance partner is positively associated with new venture's subsequent network size. Having an initial partner with a greater network size may aid a new venture in accessing more information on potential alliance partners, and also increase the venture's attractiveness as a prospective partner. Additionally, partnering with a “well-networked” firm may increase the new venture's legitimacy in the eyes of potential partners.

Our second hypothesis proposes that the network centrality of a new venture's initial alliance partner is positively associated with the new venture's subsequent network size. A firm's network centrality reflects its capability to access or control the various resources in the network through both direct and indirect ties (Hoang and Antoncic, 2003). We expect the initial partner's network centrality to have a positive effect because a central firm receives a wider scope of information in the network, and is in the better position to identify potential partners for the new venture. Additionally, the new venture's visibility may be further enhanced as the information emitted by central organizations may travel extensively through the network (Robinson and Stuart, 2002).

To test the hypotheses, we constructed a panel dataset of 209 biotechnology new ventures, which were observed from the year in which the venture's initial alliance was formed through 2000 — the end year of our study (a total of 947 observations). In our analyses we utilized a random-effects Poisson model. The results support both hypotheses, confirming that both the network size and the centrality of the initial alliance partner do matter to the subsequent development of a new venture's network.

Due to the criticality of networking noted in the literature for new ventures, it is argued that networking skills are among the most important entrepreneurial skills that can be developed. We support this view but, guided by our results, additionally warrant that development of collaborative skills and recognition of good alliance partners are crucial already in the early stages of new venture development as the choice of the first partner may set the new venture on its networking trajectory, which is likely to be important for its future success.

2. Introduction

In recent years, research on networks has surfaced as an important new area of interest within the field of entrepreneurship (Hoang and Antoncic, 2003). For new ventures, alliance networks prove to be especially valuable in overcoming constraints commonly associated with the liability of newness (Stinchcombe, 1965). This is corroborated by multiple studies supporting a positive association between the number of alliance network partners and a shorter time between founding and undergoing an IPO (Chang, 2004), gaining more venture capitalist investment (Baum and Silverman, 2004), increasing the rate of new product development (Deeds and Hill, 1996), enhancing absorptive capacity (George et al., 2001), pursuing larger scale strategies such as internationalization (Coviello, 2006) and ultimately benefiting new venture performance (Baum et al., 2000). Together, these studies imply that a new venture's ability to build alliance networks is critical, as it can be considered a method for building competitive advantage. In contrast, lack of an alliance network has been described as the new venture's additional liability and a “catalyst for organizational death” (Oliver, 2001:473).

Given the benefits realized by ventures with larger alliance networks, it is surprising to note that relatively few studies have examined how new ventures build and grow their networks. The literature essentially describes the evolution of alliance networks as an endogenous and iterative process, in which “new partnerships modify the previous alliance network, which then shapes the formation of future cooperative ties” (Gulati and Gargiulo, 1999: 1441). However, new ventures do not have an existing alliance network upon which to rely, but must instead start with a clear slate when establishing foundations to initiate and grow their network.

The imprinting literature highlights the enduring impact of prior history on subsequent organizational outcomes (Stinchcombe, 1965). In researching new ventures, scholars have applied the imprinting lens to demonstrate the lasting impact of initial conditions such as a new venture's initial financial capital and environmental munificence (Bamford et al., 2000), competitive intensity (Swaminathan, 1996) and strategy (Boeker, 1989) on subsequent new venture behavior (Boeker, 1989), growth (Eisenhardt and Schoonhoven, 1990), profitability (Bamford et al., 2000) and mortality (Swaminathan, 1996). Yet, to our knowledge, the current literature neglects to inspect the effect of the initial alliance formed by a new venture. Due to the strategic importance that developing a larger alliance network carries for new ventures, in this study we focus on the new venture's initial alliance partner as one neglected, yet important, imprinting factor. More specifically, we develop theoretical arguments to explain how the growth trajectory of the new venture's network size is in part influenced by the network size and position of its initial alliance partner.

In developing and testing our model we make a number of contributions to the literature. First, our work contributes to the field of entrepreneurship as it extends the literature that notes the short-term benefits of alliances in mitigating liabilities of newness (e.g. Baum et al., 2000), to include insights on their enduring consequences in shaping a firm's trajectory in the network. Moreover, accounting for the initial alliance extends the research that has examined resource-based imprinting on one hand, or environmental imprinting on the other, to add a new network perspective to the body of work on imprinting and initial conditions.

Second, while social network research gives important insights on the endogenous and path-dependent dynamics of network evolution in studying the reproduction of the network ([Baum et al., 2003], [Baum and Ingram, 2002], [Gulati and Gargiulo, 1999] and [Walker et al., 1997]), it often neglects to differentiate between new entrants to the network and incumbent firms already in the network (Walker et al., 1997). Compared to network incumbents, new entrants suffer from the liabilities of newness, resource constraints and lack of a history of partnerships within the network (Bae and Gargiulo, 2003), which makes them a natural starting point to refine our understanding of the rules and dynamics of network evolution. Similarly, accounting for the initial conditions contributes to social network research (Kim, Oh and Swaminathan, 2006) by adding the understanding of path-setting factors which precede the noted dependency in network evolution.

Third, alliance and network literatures are often criticized as being too static. We respond to recent calls for more dynamic network research (Parkhe et al., 2006) and offer a dynamic model of new ventures' network evolution where we aim to better understand the endurance of effects

of initial alliances in order to give better advice to aspiring entrepreneurs. Finally, the results of this work encourage entrepreneurs to look beyond the explicit value of the initial dyadic collaborative effort and realize the hidden value of future network resources which lurks from the structural pattern of relationships surrounding their first alliance partner (Gulati, 1999).

3. Theory and hypotheses

3.1. Imprinting and new venture networks

The notion of imprinting can be traced back to Stinchcombe (1965: 153) who argued that "organizational forms and types have a history, and this history determines some aspects of the present structure of organizations of that type." In applying the concept of imprinting to new venture interorganizational networks, we focus on the initial alliance partnership made by a new venture and how this partnership imprints the subsequent development of the new venture's interorganizational network. New ventures are imprinted, or otherwise started on development trajectories, based on circumstances surrounding their early years ([Boeker, 1989], [Baum et al., 2000] and [Kelley and Rice, 2001]). Because alliances can carry benefits for a new venture that extend beyond the particular exchange designated in the formal agreement ([Powell et al., 1996] and [Stuart et al., 1999]), the initial alliance partner may, itself, serve as an important predictor of the new venture's network trajectory. For example, studies of entrepreneurial networks suggest that a new venture's partners provide the "conduits, bridges and pathways through which the firm can find and access external opportunities and resources" (Hite, 2005: 113). This implies that the benefits the initial partner brings to a new venture are inextricably related to the characteristics of the broader network in which the partner is embedded (Duysters et al., 1999) as well as to the partner's position in the network.

Formation of an initial alliance is an important event for a new venture, as it symbolizes the new venture's formal "entrance" into the industry's extant network. It has been noted that an organization's existing partners create a path-dependent network environment that shapes the formation of subsequent partnerships and, thus, the evolution of the network ([Gulati, 1999] and [Hite and Hesterly, 2001]). Accordingly, we argue that the initial alliance may imprint the new venture in terms of the structural location, or entrance into the industry network, as well as through more subtle dimensions related to the development of its collaborative capabilities, recognition of partnering opportunities, its legitimacy and, correspondingly, its attractiveness as a partner.

In developing the theoretical model of imprinting in social networks, we draw on the structural homophily principle recognized by Gulati and Gargiulo (1999). In short, this principle posits that interorganizational networks tend to reproduce themselves over the course of time, giving support to the path-dependent pattern of network evolution (Walker et al., 1997). Following this logic, research has shown that highly embedded firms in the network tend to form alliances in a way that further enhances and secures their future centrality and position, whereas the not-well-connected firms tend to remain on the periphery of the network (Gulati and Gargiulo, 1999). Although, according to this principle, the central organizations in the network would exhibit low tendency to partner with peripheral organizations (e.g. new ventures), exceptions arise when new ventures control something that a central firm might need, such as new technologies

(Shane and Stuart, 2002). For the extant firm, this increases the value that the new venture carries as a potential partner, and a new venture gains a good entry point into the network. Drawing on the principle of homophily, the position of the initial alliance partner may imprint the new venture's future position in the network, and determine the path-dependent network context within which the new venture grows and forms its own future partnerships.

In addition to determining the new venture's network entry point, we posit that the initial alliance partner may also imprint a new venture's network size via more subtle mechanisms. For example, formation of new partnerships can be a frustrating experience (Gulati and Gargiulo, 1999) that requires time, resources and skills (Tsai, 2000). To reduce the search costs associated with finding new partners, organizations tied to a common partner often utilize reliable information about each other from that partner, which in turn serves as a context for subsequent decisions on interaction (Powell et al., 1996). Kogut (2000) has shown that, in the process of network formation, ties between firms develop informational properties that drive a matching process between firms. In this regard, the initial partner may imprint the development of a new venture's visibility and future alliance opportunities as the information on the new venture will spread through the partner's network. This is all the more important as, due to liabilities of smallness and newness, new ventures suffer from restricted visibility among existing firms (Elfring and Hulsink, 2003), which can limit their initial pool of potential direct alliance partners. Therefore, the initial alliance partner is likely to determine the extent to which the participants in the network are aware of a new venture's capabilities, indirectly influencing new venture's opportunities to form relationships (Ahuja, 2000). As Eisenhardt and Schoonhoven (1996:138) posit: “Evolution of awareness…is central to the creation of cooperative relationships”.

The new venture's initial alliance partner may also act as a source of information regarding the new venture's capabilities and values it brings as a partner. In the search for new potential partners, firms turn to existing networks not only to reduce the search costs, but likewise alleviate the risk of opportunism (Williamson, 1985). This is especially pertinent in uncertain environments, where attractiveness of potential partners can be gauged from organizations already tied to that partner (Podolny, 1994). Sharing the same ties means that both indirect partners and new venture are regarded as trustworthy by the same organization (Gulati and Gargiulo 1999). In the context of this paper, this implies that the initial alliance partner is likely to determine the extent to which a new venture is perceived as more legitimate (Oliver, 1990) to the pool of firms connected to their initial alliance partner, influencing the chances of forming alliances with them.

Path dependency effect of the initial partner may finally be reinforced by the new venture's limited scope of available resources and opportunities (Hite and Hesterly, 2001), since finding and evaluating potential partners involves experience (Gulati et al., 2000), time (Tsai, 2000) and collaborative know how (Simonin, 1997) that new ventures typically do not possess. Since learning from prior experience is an important basis for the accumulation of alliance-formation capabilities (Gulati, 1999), the first alliance is consequently likely to imprint the path of learning about the collaborative process and the new venture's network experience (Powell et al., 1996).

This is important, as the extent of a firm's opportunities increases as its opportunity-recognition skills increase (Davidsson, 1991).

In summary, we believe that the initial alliance partner is likely to play a critical imprinting role in new venture's network evolution, as it is through this relationship that the new venture will be introduced into the network, determining the nature of the iterative process of network evolution through the subsequent formation of alliances. Subsequently, we propose that this imprinting effect is likely to be inextricably related to the initial partner's extant connections to other firms in a network. In order to understand just how the initial alliance partner impacts the development of a new venture's network, we next take an in-depth look at two aspects of the initial alliance partner's network: size and centrality.

3.2. Initial partner's network size

There are many ways to assess the extant network of the new venture's initial alliance partner. One of the most common methods is to examine the network size or number of firms to which the initial alliance partner is connected. The larger the network of a firm, the more the firm is said to be in the “thick of things” or the more involved the firm is in the network, reflecting visibility, information access and potential communication activity of the firm (Freeman, 1979). To quote Freeman (1979:219), “an organization that is in a position that permits direct contact with many others should begin to see itself and be seen by those others as a major channel of information”. Since direct partners serve as both sources and resources of information (Ahuja, 2000), having an initial partner with a greater network size implies that a new venture is likely to have access to more information about potential alliance partners and, likewise, may gain visibility and attractiveness in the partner's network. In addition to gaining access to a larger number of new potential partners, partnering with a “well-networked” firm may yield legitimacy for the new venture. Since a firm's value and collaborative capabilities are related to its internal assets and, in turn, internal assets are further enhanced by collaboration (Powell et al., 1996), companies with large extant networks often enjoy a reputation of being a strong actor in the network. Becoming a partner of such a company may consequently result in spillover effects of the partner's legitimacy to the new venture. To use Stuart's (2000) metaphor of endorsement, obtaining a well known and prominent initial alliance partner represents a strategic advantage to a new venture that is similar to obtaining a certification from a well known investor, enhancing its legitimacy in the network. In contrast, companies having small extant networks are not considered as active in the relational process (Wasserman and Faust, 1994). Thus, such an initial partner is likely to limit the new venture's access to potential partners in the network. Accordingly, we propose that the network size of the initial alliance partner is an important imprinting factor:

H1

The network size of a new venture's initial alliance partner will be positively associated with the subsequent network size of the new venture.

3.3. Initial partner's network centrality

While network size tends to measure the firm's quantity of network partners, it does not consider where the firm is positioned among the other players in the industry. In other words, one cannot infer the structural advantages that the firm enjoys in a network by merely focusing on its network size. One of the key concepts reflecting a firm's position and importance in the network is centrality ([Madhavan et al., 1998] and [Wasserman and Faust, 1994]). Defined in the simplest way, a firm's network centrality considers how centrally positioned a firm is in the network, thereby explicitly including the firm's capability to access or control the various resources in the network through both direct and indirect ties (Hoang and Antoncic, 2003). To the extent that an organization's role and status are based on its patterns of interaction, they should be gauged from the position that the organization occupies in the network (Gulati and Gargiulo, 1999). Thus, centrality can be interpreted as reflecting the extent of the organization's influence over other members of the network, but one that is gained by the position in the network structure rather than the organization's internal attributes (Rowley, 1997).

A highly central initial partner is likely to benefit a new venture's subsequent network size because of its facilitative role in the network. Centrality makes firms an obligatory passage point for the information flowing through network structure (Owen-Smith and Powell, 2004). Additionally, if many organizations in the network must go through a new venture's initial partner in order to access other organizations for the purpose of communication or resource exchange, then the initial partner can be considered a “gatekeeper” since it facilitates exchanges between other actors (Freeman, 1979). As a result, a centrally positioned initial partner is better “plugged in” to different information and resource exchange flows in the network and enjoys stronger strategic advantages (Madhavan et al., 1998) as well as rapid access to critical information (Powell et al., 1996).

Building on our arguments of networks as information conduits, a central partner is likely to receive a wider scope of information in the network and may be in a better position to identify potential partners for the new venture. At the same time, the new venture's visibility is likely to be further enhanced as the information emitted by central organizations travels extensively through the network (Robinson and Stuart, 2002 Robinson, K.C., Stuart, T.E., 2002. Just how incomplete are incomplete markets? Evidence from biotech strategic alliances. Working paper, Columbia University.Robinson and Stuart, 2002), again increasing access to a wide pool of potential partners. Centrality is often interpreted as reflecting power and status (Podolny, 1993), and having an alliance with a powerful initial partner that is highly regarded in the network may further legitimize the new venture. Finally, Madhavan et al. (1998) presume that when firms realize the value of occupying central positions, they are likely to engage in efforts to improve their centrality by forming alliances with more and more central firms, which Gulati (1999) later confirmed in developing his argument on structural homophily. In the context of this paper, this implies that network centrality of the initial alliance partner is also likely to be an important imprinting factor. Therefore, we posit:

H2

The network centrality of a new venture's initial alliance partner will be positively associated with the subsequent network size of the new venture.

4. Methodology

4.1. Biotechnology industry

The empirical setting for this study is the biotechnology industry. Biotechnology is an attractive empirical context because the youth and impressive recent growth of this industry resulted in the entrance of many new ventures (Owen-Smith and Powell, 2006). Additionally, the biotechnology industry is characterized by a high reliance on interorganizational relationships (Powell and Brantley, 1992), making it an ideal setting to examine the evolution of new venture networks (Walker et al., 1997). Finally, the contractual nature of partnerships is typically announced to the public, enabling us to obtain reliable data for our study.

4.2. Data sources

The main data source for this study was Recombinant Data (Recap). Recap is one of the largest and most detailed biotech business intelligence databases in the world and has previously been used in other academic research (Gulati and Higgins, 2003; Orsenigo et al., 2001). A great advantage of this dataset is that it comprises alliances of both public and private companies, enabling us to include both in testing the hypothesized relationships. The ability to include private companies helps to reduce a common sample selection bias often found in strategic alliance research — a sole reliance on public company data (Gulati, 1999). Other supplementary data sources included Corptech, Biomedical Industry Analyzer and Bioscan. We relied on the United States Patent and Trademark Office database to compile the data on new venture patents, and used the Science Citation Index to compile the data necessary to construct the variable reflecting the new venture's scientific capability, which we describe in more detail below.

4.3. Sample

We tested our hypotheses using data describing the alliance activity of new ventures in the biotechnology industry and documented in Recap during the time period between 1991 and 2000. Additionally, because our dependent variable is collected in year t + 1 to allow for a one-year time lag between control and dependent variables, we collected network data for 2001. We chose 1991 as a starting year for our sample, due to the institutionalization of the industry. Following the turbulent 1980s, which saw founding of hundreds of small science-based firms, the industry started to mature in the 1990s with the release of dozens of new medicines and stabilization of relational contracting practices (Powell et al., 2005). We limited our study to the time period from 1991 to 2000 due to our primary interest in the imprinting effects of new ventures, which are defined as those firms that are ten years old or less. As other noteworthy imprinting studies have examined shorter periods of time (e.g. [Bamford et al., 2000] and [Baron et al., 1999]), the time period of our study allows for a more stringent test of the imprinting hypotheses.

To be included in the sample, a biotechnology firm had to be ten years old or less as of the year 2000. Within the entrepreneurship literature, a firm has been considered to be a new venture through either six (Robinson, 1999), eight (Biggadike, 1976) or ten years of age (e.g. [Carpenter

et al., 2003] and [Certo et al., 2001]). In this study, we have followed the latter definition in order to allow time to more fully examine the imprinting effects of the initial alliance partner.

Given our interest in the imprinting effect of the initial alliance partner on the subsequent size of a new venture's network, we limited the sample to only include new ventures that have entered into an alliance within their first three years of operation. Theoretically, the imprinting argument pertains to a firm's sensitive years, when the firm is still suffering from the liability of newness (Stinchcombe, 1965). Due to resource constraints, biotech ventures use alliances to get access to needed capabilities and the money necessary to grow while, in turn, they offer partners their R&D-specific knowledge (Deeds and Hill, 1999). The “thirst” for partners is particularly pronounced within the first few years following founding, while after this period the biotech ventures internalize accessed resources, which reduces their dependence on partnerships (Oliver, 2001). Consequently, we believe that the three-year period satisfies the theoretical definition and the industry-related notion of “sensitive” years when new ventures are most prone to be imprinted. In order to determine whether the new venture meets this sample criterion, we used the Recap database which, among other data, includes the date of formation for each alliance. We compared the date of the earliest alliance reported for each firm with the firm's respective founding date to determine whether the formation of the first alliance occurred within the first three years upon founding. If the firm met this criterion and remained in the sample, the earliest alliance reported was then used to identify the first partner and obtain measures of its network to test our hypotheses.

Similar to other studies of new ventures ([Carpenter et al., 2003] and [Robinson and McDougall, 2001]), we eliminated all new ventures from our sample that were corporately held or a result of a corporate spin-off. Thus, only independently-owned and operated new ventures entered our sample. To the extent that a new venture was not independent, rather being a subsidiary or a spin-off, it could have been “imprinted” in other ways than by the first alliance it makes. For example, the venture might have an advantage due to its parent's legitimacy or parent's existing contacts in the network, confounding the effects of the importance of the first alliance on the size and centrality of its future network. The final sample consisted of 209 new ventures and 947 venture-year observations. The first observation for each venture is recorded in the year in which the new venture formed its initial alliance and the last observation for the sample firms is in 2000 — the end year of our study (with the last observation of the dependent variable recorded in 2001). Thus, a new venture entering into its initial alliance in 1995 would be represented by six observations from 1995 to 2000. The number of observations per new venture ranges from 1 to 10, with an average of 4.6.

4.4. Variables

To compute the necessary network measures, we constructed industry adjacency matrices, utilizing the data comprising all alliance relationships between all the firms in the industry network for each year in the observed timeframe. Following prior network literature in biotechnology (e.g. Robinson and Stuart, 2002) and other industries ([Ahuja, 2000], [Gulati and Gargiulo, 1999], [Soda et al., 2004] and [Stuart, 2000]), we considered alliances as active links over the period of five years and constructed industry networks as five-year moving windows.

For illustration purposes, our first five-year moving window – necessary to construct the measures for the ventures that had their first alliance in 1991 – starts in 1986 and ends in 1991, the first year of the study. Naturally, since companies sometimes renew alliances with previous partners, these were duly updated in the database. All adjacency matrices have dichotomous data, with 1 marking the existence of an alliance between two companies, and 0 representing an absence of partnership. Ucinet 6.81 (Borgatti et al., 2002) was used to construct all network-related measures.

Before introducing each of the variables, it is important to clarify that, in constructing our model, we measured the new venture's network size (the dependent variable) in year t + 1 to allow for a one-year time-lag in the analysis (c.f. Podolny, 2001) whereas all of the control variables, described in detail below, were measured in year t, denoting the year of observation in the study that can range from 1991 until 2000. While both dependent and control variables are updated on a yearly basis, the independent variables of interest (initial partner's network size and centrality) are time-invariant (having an equal value for a specific firm across all firm-year observations) because the measures are observed at the year of the new venture's first alliance (t1st alliance), and hypothesized to imprint the new venture's network size in the future.

4.4.1. Dependent variable (t + 1)

4.4.1.1. New venture network size

Consistent with prior studies ([Ahuja, 2000] and [Deeds et al., 1999]), the network size for each new venture was measured as a count of the total number of alliance partners. As for all other network-related measures, we utilized the five-year moving window industry network matrices to calculate our dependent variable. Hence, a new venture's network size in year t + 1 would count all of the alliance partners that the new venture formed alliances with in the 5-year period preceding year t + 1. Our operationalization of network size is synonymous with degree centrality, calculated on a dichotomized ego-network (Wasserman and Faust, 1994). The measure is updated yearly for each new venture.

4.4.2. Independent variables (t1st alliance)

4.4.2.1. Initial partner network size

Similar to the network size of the new venture, we operationalized the network size of the initial alliance partner as the count of the number of alliance partners that a new venture's first partner had in the year of their alliance. In order to take into account a growing network and to be able to compare measures across years (Wasserman and Faust, 1994), the network size of the initial partner was normalized by dividing the number of partners by the total number of firms in the entire network as of the respective year (Borgatti et al., 2002). Given the lack of linearity, the variable was then transformed by taking its natural logarithm (Cohen et al., 2003). As described above, this imprinting variable enters the analyses as a time-invariant covariate.

4.4.2.2. Initial partner network centrality

To capture the network centrality of the initial alliance partner, we used the betweenness centrality measure (Freeman, 1979). Betweenness refers to the number of times a player is located on the shortest geodesic path between two other players (Wasserman and Faust, 1994), where the expression “geodesic path” is used to denote the shortest path between two points in the network. If a certain player is directly linked to two other players who are not directly linked to each other, then the first actor is said to be “between” the other players (Hagedoorn and Duysters, 2002). In this way, the higher the betweenness score of an actor, the greater the extent to which that actor serves as a structural conduit connecting others in the network. To make the measure comparable across years, betweenness centrality was normalized by dividing each betweenness score by the maximum possible betweenness score. The variable was also transformed by taking the natural logarithm in order to address a lack of linearity (Cohen et al., 2003). Being likewise an “imprinting” variable, this measure is time-invariant, i.e. constant over all firm-year observations.

4.4.3. Control variables (time t)

4.4.3.1. New venture network size (lagged)

Because this study tries to tease out the short-term and long-term effects of initial alliance for the evolution of a new venture's network size, we include a lagged value of the dependent variable (or new venture's network size in time t) as an explanatory variable to the model (Kennedy, 2003) which is consistent with prior research on the evolution of a new venture's networks (e.g. Baum et al., 2000). The lagged dependent variable is intended to capture any alliance capabilities and relational history that the new venture accumulated owing to its current alliance experience (at time t), and which may have helped it in forming new alliances and finding new partners in the following year (t + 1). Accordingly, all of the analyses include a time varying score of the new venture's network size, observed simultaneously with other control variables (in the year t preceding the score of the dependent variable in t + 1).

4.4.3.2. Time since initial alliance

Given our interest in the imprinting effects of the initial alliance partner, it was necessary to control for the time since the initial alliance. Older new ventures have had a longer time period to build up their network size and reflect a longer assessment of the imprinting effects. The time since the initial alliance was updated yearly and measured as the number of years from the initial alliance until the respective year in the study.

4.4.3.3. New venture patents

Of the various resources available to the firm, knowledge is arguably the most important (Spender, 1996), which is particularly the case for young high-technology ventures (Yli-Renko et al., 2001). Patents are generally considered as an indicator of a firm's technological capability (Brusoni et al., 2001) and technological knowledge (Rosenkopf et al., 2001). Therefore, patents may enhance a new venture's visibility and attractiveness as a partner in the network by signaling its innovativeness and knowledge to potential partners ([Ahuja, 2000] and [Powell et al., 1996]). We hope to isolate these by controlling for the cumulative number of patents issued

to a new venture from the date of their founding though the respective year in the study. Due to a lack of linearity, this variable was transformed by taking the natural logarithm (Cohen et al., 2003).

4.4.3.4. New venture scientific capability

To ensure that we completely capture the new venture's internal capabilities, we additionally control for the quality of a new venture's scientific output using citation data from the Science Citation Index (SCI). The basic premise behind citation data as reflecting a firm's scientific quality is that the number of times a paper is cited is an indication of the paper's quality and its importance to the field ([Cockburn and Henderson, 1998] and [Deeds et al., 1999]). Accordingly, to construct a measure of the new venture's scientific capability, we searched the SCI for all papers listing the names of our sample firms (and likely variations of their names). We then used the SCI to gather the total number of citations for each paper affiliated with the sample firm during the sample observation window. These citations were cumulated by year to create a dynamic and yearly-updated measure of the new venture's scientific capability. To address lack of linearity, the final scientific capability measure was transformed by taking the natural logarithm (Cohen et al., 2003).

4.4.3.5. New venture firm type

Alliances can serve as a significant source of capital for biotech firms, and different types of biotechnology firms may need varying amounts of capital investment (Baum et al., 2000). Hence, based on the types of products being developed, biotech firms may differ in their need to develop alliances to finance their startup. Therefore, we first classified the new ventures as agricultural biotech, diagnostic firms or human therapeutic firms and then constructed two dummy variables, one capturing whether the firm was agricultural biotech and the other identifying diagnostic firms.

4.4.3.6. New venture ownership status

In our sample, some of the companies underwent an initial public offering (IPO) during the observation period, while others remained private. Going public can signal a firm's legitimacy (increasing the future network size) or, conversely, signal reduced dependence on external resources through decreasing the need for cooperation and network size (Walker et al., 1997). Thus, we introduce a time-variant dummy variable where 1 represents that a firm is publicly held and 0 otherwise.2

4.4.3.7. New venture location

The new venture's location could potentially influence its network size because alliance partners may be attracted to a biotech firm's location ([Coombs et al., 2006] and [Rothaermel, 2002]), presumably to tap into locally-developed knowledge. To control for geographic location effects, we followed Deeds et al. (1999) and first coded the new ventures in our sample into geographic territories according to zip codes and metropolitan statistical areas. A dummy variable was then created to indicate whether or not the new venture's headquartered location was in one of the eight areas identified by Burrill and Lee (1993) as concentrations of biotechnology activity (a

firm is assigned 1 if the headquarters location is in a concentrated biotech area and 0 otherwise).

4.4.3.8. Industry network density

The frequency of alliance activity in an industry may influence a firm's propensity to form alliances because partnering may increasingly be perceived as the norm within the industry. Following prior literature (Gulati and Gargiulo, 1999), we use industry network density to control for such possibility. The industry network density was calculated by taking the total number of partnerships in a given year divided by the total number of possible partnerships among all organizations within the industry. The variable was then scaled by 1000 to make its regression coefficient comparable to the other variables in the model.

5. Analysis and results

Table 1 presents the descriptive statistics and correlations for all variables used. The average age of the new venture was 3.6 and ranged from 1 to 10. As evident from the correlation table, the network size and centrality of the initial alliance partner are significantly correlated at 0.86 ($p < 0.01$). The high level of correlation is somewhat expected ([Bonacich et al., 1998] and [Mehra et al., 2001]) as both measures evaluate the initial partner's position in the network (Powell et al., 1996). Yet, the measures are also distinctly theoretically different as network centrality goes beyond the simple count of firm's direct partners and also considers where the firm is positioned within the entire industry network, thus taking both direct and indirect ties into account ([Brass, 1984], [Brass and Burkhardt, 1993] and [Krackhardt, 1990]).

Table 1. Means, standard deviations and correlations

Variables	1	2	3	4	5	6	7	8	9	10	11	12
Mean	5.71	4.56	2.62	− 4.50	− 2.75	0.05	0.22	0.20	0.74	1.49	− 0.84	− 1.53
s.d.	6.86	5.87	2.31	3.69	5.39	0.22	0.42	0.40	0.44	0.50	1.11	3.11
1 New venture network size	1.00											
2 New venture network size (lagged)	** 0.95	1.00										
3 Time since initial alliance	** 0.38	** 0.46	1.00									

Variables	1	2	3	4	5	6	7	8	9	10	11	12
Mean	5.71	4.56	2.62	− 4.50	− 2.75	0.05	0.22	0.20	0.74	1.49	− 0.84	− 1.53
s.d.	6.86	5.87	2.31	3.69	5.39	0.22	0.42	0.40	0.44	0.50	1.11	3.11
4 New venture patentsa	∗∗0.25	∗∗0.31	∗∗0.52	1.00								
5 New venture scientific capabilitya	∗∗0.30	∗∗0.34	∗∗0.55	∗∗0.45	1.00							
6 New venture firm type: Ag/Bio	†− 0.05	†− 0.05	∗− 0.07	0.02	∗− 0.07	1.00						
7 New venture firm type: diagnostics	∗∗− 0.14	∗∗− 0.13	†− 0.06	0.00	∗∗− 0.13	∗∗− 0.13	1.00					
8 New venture ownership status	∗∗0.40	∗∗0.45	∗∗0.51	∗∗0.31	∗∗0.33	∗∗− 0.09	0.03	1.00				
9 New venture location	∗∗0.15	∗∗0.14	∗0.08	− 0.05	0.03	− 0.01	− 0.03	− 0.03	1.00			
10 Industry network densityb	∗∗− 0.17	∗∗− 0.20	∗∗− 0.39	∗∗− 0.31	∗∗− 0.27	∗− 0.07	†− 0.06	∗∗− 0.27	∗0.08	1.00		
11 Initial partner's network sizea	†0.06	0.05	0.02	0.03	0.05	0.00	∗0.08	†0.06	∗∗0.13	†0.06	1.00	
12 Initial partner's network centralitya	0.05	0.04	0.02	0.05	∗0.08	0.04	0.03	0.04	∗∗0.13	0.03	∗∗0.86	1.00

Full-size table

†p < 0.10; ∗p < 0.05; ∗∗p < 0.01 (n = 947).

a Variables have been transformed.
b Variable has been scaled by 1000.

We used a longitudinal research design for testing the new venture's network size resulting from the imprinting effects of the initial partner's network size and centrality. Since our data traces

209 new ventures over the span of 10 years, we employed a panel data method. Because our key independent variables are time-invariant, we model our data using the random-effects model (Castilla, 2005), implemented in Stata 9.1. Random effects allow one to examine both within- and between-organization variance on independent and dependent measures, and are recommended for data in which the average number of year-records per firm is not very large (c.f. Gulati, 1995). The dependent variable in this study (new venture's network size) is a non-negative count variable, which records the number of alliance partners for each venture over time on a yearly basis. When a dependent variable is a count, using a simple regression is not advised because we could end up with nonsensical negative estimates of the number of alliances. A natural baseline for such data is the Poisson model (Gardner et al., 1995).3

In Table 2, we present the results of our analyses. In the first model, we entered the control variables. The second model introduces the initial partner's network size, followed by the third model where the initial partner's network centrality was introduced. Both models report the results for the dependent variable new venture network size measured at time t + 1. Each row in the table contains the effects of the control variables measured at time t, or in the case of the imprinting variables, at the year of the first alliance. Given the high correlation between the initial partner network size and network centrality variables (0.86), multicollinearity posed a threat to estimating the two variables in the same model. Therefore, we chose to analyze and report the results separately.

Table 2. Random–effects Poisson regression results (dependent variable: new venture network size)

	Model 1		Model 2		Model 3	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Control variables						
New venture network sized (lagged)	0.036∗∗∗	(0.003)	0.036∗∗∗	(0.003)	0.036∗∗∗	(0.003)
Time since initial alliance	0.033†	(0.018)	0.033†	(0.018)	0.034†	(0.018)
New venture patentsa	− 0.005	(0.006)	− 0.005	(0.006)	− 0.006	(0.006)
New venture scientific capabilitya	0.031∗∗∗	(0.005)	0.031∗∗∗	(0.005)	0.031∗∗∗	(0.005)

	Model 1		Model 2		Model 3	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
New venture firm type: Ag/Bio	− 0.230	(0.189)	− 0.233	(0.190)	− 0.244	(0.190)
New venture firm type: diagnostics	− 0.190†	(0.108)	− 0.205†	(0.108)	− 0.206†	(0.108)
New venture ownership status	0.043	(0.047)	0.042	(0.047)	0.041	(0.047)
New venture location	0.227∗	(0.101)	0.213∗	(0.101)	0.206∗	(0.101)
Industry network densityb	− 0.135†	(0.076)	− 0.136†	(0.077)	− 0.134†	(0.077)
Independent variables						
Initial partner's network sizea			0.044∗	(0.022)		
Initial partner's network centralitya					0.022∗∗	(0.008)
Constant	1.378∗∗∗	(0.163)	1.430∗∗∗	(0.165)	1.425∗∗∗	(0.164)
Log likelihood	− 2089.591		− 2087.521		− 2086.068	
Likelihood-ratio chi-square	1008.819		1012.957		1015.864	
Change in likelihood-ratio chi-square			4.139∗		7.046∗∗	

Full-size table

†$p < 0.10$; ∗$p < 0.05$; ∗∗$p < 0.01$; ∗∗∗$p < 0.001$. Unstandardized estimates are reported. Standard errors are in parenthesis. (n = 947).

a Variables have been transformed.
b Variable has been scaled by 1000.

Overall, the directionality and significance of the coefficients support our hypotheses. Hypothesis 1 states that the network size of the new venture's initial partner will be positively associated with the size of a new venture's network. As evidenced in Model 2, the network size of the initial partner significantly increased the likelihood-ratio chi-square ($\Delta\chi 2 = 4.14$, $p < 0.05$), improving the overall fit of the model. Because the coefficient is significant and in the expected direction, support is found for this relationship ($\beta = 0.044$, $p < 0.05$). Hypothesis 2 considers the

possibility that the network centrality of the new venture's initial partner is positively linked to the subsequent size of the new venture's network. Upon introducing this variable, the model fit for Model 3 is significantly improved compared to Model 1 ($\Delta\chi 2 = 7.05$, $p < 0.01$). As shown in Model 3, the results provide support for this hypothesis ($\beta = 0.022$, $p < 0.01$).

To further validate our findings, we followed recent studies ([Pollock and Rindova, 2003], [Rhee and Haunschild, 2006], [Sine et al., 2005] and [Sine et al., 2006]) and conducted a supplementary analysis using a modified Gram–Schmidt procedure ([Cohen and Cohen, 1983] and [Saville and Wood, 1991]) to orthogonalize the two highly correlated independent variables of interest: initial partner network size and initial partner network centrality. When two variables are orthogonalized, the “effect” of the first variable is removed from the second variable. In this way, orthogonalization offers a way to address multicollinearity concerns and simultaneously test both variables in the same model. Applying this procedure to our data helped us to tease out the unique aspects of each variable's contribution to the new venture's network size by extracting from the initial partner network centrality variable any part of the power and information flow that may have been captured by the pure initial partner's network size effect. When both orthogonalized variables were included in the same model, the results remained consistent with the reported findings from separate models — both the initial partner's network size and network centrality had a positive and significant coefficient.4

6. Discussion

The motivation for this study arose from a growing body of literature in entrepreneurship that increasingly recognizes the importance of strategic alliances for new ventures' various outcomes ([Baum et al., 2000] and [Oliver, 2001]). In particular, prior research suggests that – due to liabilities of smallness and newness, lack of legitimacy and higher uncertainty – new ventures are heavily reliant on, and affected by, key alliances they make in their early years ([Eisenhardt and Schoonhoven, 1996] and [Yli-Renko et al., 2001]). However, despite the major contributions from these studies, prior literature has failed to consider whether these early partner choices also carry long-term repercussions for the evolution of new ventures' networks.

To pursue this line of inquiry, in this study we examined the imprinting effects of a new venture's initial alliance partner on the subsequent development of the new venture's network size. Although a very basic measure of network, size is important as it reflects the extent to which resources can be accessed at the level of the organization (Baum et al., 2000) and ultimately benefits a range of organizational outcomes ([Baum and Silverman, 2004], [Chang, 2004], [Coviello, 2006], [Deeds and Hill, 1996] and [George et al., 2001]). Our findings largely confirm the important role of initial partners in imprinting the new venture's network size. Specifically, we found that the size of a new venture's network was impacted by both the size of the initial partner's network as well as the initial partner's centrality in the overall industry network.

Taken together, our results seem to voice one common message: the initial partner's network structure matters in imprinting the new venture's network size. To this end, our results demonstrate how the inclusion of the network perspective can enrich our understanding of the new venture's early conditions, long studied through the lens of economic resources and environmental factors (Marquis, 2003). Additionally, the results of this study reveal that the

effect of early alliances stretches beyond influencing the venture's immediate performance (Baum et al., 2000) into determining the extent of network resources available through alliances in the years following the first alliance. Hence, we believe that our study primarily contributes to the entrepreneurship literature on imprinting by highlighting the unrecognized importance of the new venture's initial alliance partner for the evolution of its network.

Studied independently, the fact that each of the observed aspects of the initial partner's network – its network size and centrality – has individual explanatory power in imprinting the new venture's network size points to a richness of various structural factors early in a venture's life that may be important in understanding why some ventures manage to grow their network and others less so. To this end, our results imply that both the “local” and more “global” network reach of initial partners are important in understanding the new venture's network evolution. A positive coefficient for the initial partner's network size, which captures the firm's direct ties, speaks to the importance of studying the initial partner's ego-network characteristics ([Borgatti and Foster, 2003] and [Parkhe et al., 2006]) or understanding the initial partner's “local” relational strategy ([Hanneman, 2001], [Powell et al., 1996] and [Scott, 1991]) in imprinting the new venture's network size. Following our theoretical arguments, new ventures can learn from such partners' rich collaborative experiences, and benefit from partnering with relationally active actors in the network, which ultimately legitimize the new venture (Stuart, 2000). The initial partner's centrality, which captures the initial partner's position in the overall industry network, is a more “global” network position measure, as it takes into account both direct and indirect ties of the initial partner. A positive coefficient of this variable speaks to the importance of having initial partners whose position is of strategic significance in the overall structure of the industry network (Scott, 1991). Among other things, the centrality of these firms in the industry's overall information flow aids in positively imprinting the new venture's visibility in the network.

The specific implications that emerged from our findings complement, and contribute to, the existing theory in entrepreneurship and network literature in multiple ways. First, by adopting a network perspective in this study we support prior research evoking the need to move beyond a sole focus on the dyadic relationship to the entire network in which they are embedded (Duysters et al., 1999). This is of special importance for new ventures, which often enter their first alliances unadvised, lacking collaborative experience (Alvarez and Barney, 2001) and seeking to satisfy immediate resource needs, rather than thinking about the long-term development of the network resources that the alliances cumulatively bring (Gulati, 1999). In that respect, this study shows that the choice of the initial partner has implications for a new venture's network evolution to the degree that one looks beyond the initial partner per se, but extends the view into the initial partner's extant network.

Second, by applying a longitudinal approach, we also provide insight to the entrepreneurship literature. Alliances are frequently argued to be a way for new ventures to overcome their lack of operating history and limited resources ([Deeds and Hill, 1996] and [Lu and Beamish, 2001]). Yet, although partners do provide many short-term benefits, our results highlight the enduring impact of the initial alliance partner in developing a new venture's alliance network. Moreover, we respond to calls to examine intermediate steps linking network formation and firm performance, as the linkages between these two variables, especially over time, could be

interpreted through different intervening variables (Zaheer and Usai, 2004). While prior studies in the biotechnology industry (e.g. Baum et al., 2000) established that a new venture's initial alliance network size influences its subsequent performance, our study adds to these findings by demonstrating one way in which this process might occur — through the development of a new venture's alliance network over time.

Finally, new entrants to a network differ from incumbent members. In examining the path-dependent nature of alliance networks, Gulati (1999) demonstrates that the likelihood of a new alliance between two organizations increases with prior mutual alliances, common third parties, and joint centrality in the alliance network. Yet, in addition to lacking any operating history (liability of newness) upon the initial entry into the network, new ventures likewise suffer from lack of partnerships or relational liability (Oliver, 2001). Therefore, a firm cannot rely on a history of relationships to use as leverage in building its network. In this paper, we posited and tested that a new network entrant relies heavily on the network characteristics of their initial partner in the process of becoming a member of the broader industry network structure. Thus, at least in the case of new ventures which have no history of relationships, our results supplement Gulati's (1999) model to take into account where the firm's "network history" begins, which is ultimately contingent on the initial partner's embeddedness.

Moreover, our findings carry interesting implications for practitioners. Due to the criticality of networking noted in the literature for new ventures, it is argued that the skills involved in making networking succeed are among the most important entrepreneurial skills that can be taught and developed. Although typically applied to personal networks (Ostgaard and Birley, 1994), we support and extend this view to alliance networks. However, guided by our results, we additionally warrant that development of collaborative skills and recognition of good alliance partners are crucial already in the early stages of new venture development as the choice of the first partner will set the new venture on its networking trajectory which may be critical for its future success. We add to this observation that young new ventures have one advantage in the face of the path dependencies in network evolution, (Walker et al., 1997), which is just building their paths in the network. Contrary to established incumbents who may end up "trapped in their own net" (c.f. Uzzi, 1996), starting with a clean slate when entering the network structure may give the new ventures more discretion in forging their first alliances, as they have no prior structural constraints imposed. Therefore, entrepreneurs would be well advised to devote significant time and efforts to their initial networking activities (Dubini and Aldrich, 1991), which may ultimately result in extending the reachability of their network and aid in better responsiveness to change.

7. Limitations and future directions

Despite the suggested importance of network imprinting, our findings should not be interpreted without some caution. First, our hypotheses were tested on a relatively narrow sample of biotechnology new ventures. Thus, it is unclear whether the results are generalizable to other industries. Second, we admit that limiting our sample to young new ventures leaves open the question — are the results generalizable to firms which form their first alliance at a later age? While this is an important question for future research to answer, we believe that compromising

on this type of generalizability was important in this study because, to our knowledge, it is the first one to examine the phenomenon of network imprinting. With young companies, the “logical distance” in arguing for new propositions is shorter and clearer, whereas using older organizations could introduce noise into the data, inviting different intervening mechanisms linking network variables to organizational outcomes (Zaheer and Usai, 2004). Still, because interorganizational networks are an important social context for organizations of any size or age (e.g. [Baum et al., 2000] and [Goerzen and Beamish, 2005]), such research could enrich our theory. Third, we limited the study period to ventures forming their first alliances between 1991 and 2000 with the intent of capturing a more homogenous period following turbulent industry emergence (Powell et al., 2005). Still, we believe future studies should extend our findings to probe their generalizability in the earlier stages of industry formation as well as in its most recent years.

In addition, we note that the existing imprinting literature typically investigates the imprinting effects of early conditions for firm performance. While our model does not relate the initial alliance partnership and venture's performance, we believe that our study's findings may represent a step in this direction — given the established link between the first alliance and future network size which enables the venture to tap into the network resources. Providing that a positive link between a new venture's network size and its performance holds true (e.g. Soh, 2003), our study offers a complementary perspective to current imprinting literature towards explaining a venture's future performance.

Finally, while we believe that our findings are exciting to the extent that they emphasize the value of studying both the “local” and “global” aspects of the initial partner's network for new venture's network size, there is a multitude of other structural and relational network factors (Wasserman and Faust, 1994) which may yield further insights into imprinting of the new venture's network evolution. Therefore, we invite future research to first consider other forms of structural imprinting that may carry consequences for a new venture's long-term position in the network. Similarly, there is much to be gained in studying a relational perspective that pays attention to the intensity and content of these ties ([Granovetter, 1985] and [Shane and Stuart, 2002]). Strategic alliances can vary in their contractual form or governance structure (Gulati, 1999) from looser license agreements to strongly involved joint ventures; which is likely to influence their relational depth. Also, the extent of initial financial investment (equity) in alliances may influence the strength of these relationships. How these relational factors interplay with the structural level of analysis is a fruitful area for future research endeavors.

8. Conclusion

Drawing on the imprinting literature, this study addressed the noted gap in the literature pertaining to factors that influence the evolution of new venture alliance networks. We focused on the new venture's initial entry to the network, which corresponds to the formation of its first alliance. In brief, we theorized and found that both the initial partner's network size and centrality positively influence the new venture's network size. Hence, the strongest message of this study is perhaps in highlighting the potent role that the new venture's initial partnerships have in their ability to access network resources in the long term. For entrepreneurship

scholars, the findings of this study extend the established short-term benefits of initial partnerships in mitigating liabilities of newness (e.g. [Baum et al., 2000] and [Stuart et al., 1999]), to include insights on their enduring consequences for the ability to build one's network. At the same time, the findings of this study inform practitioners to look beyond the explicit value of their initial dyadic collaborative efforts and realize the hidden value of future network resources which evolve from the socio-structural pattern of their first relationships. Indeed, in light of the prior literature's findings on the importance of building one's network size, such initial efforts will be well-justified in setting the venture on the trajectory of future success.

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