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and the Spatial Distribution
of Venture Capital Investments



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Abstract

Sociological investigations of economic exchange highlight the role of institutions and social structures in shaping transaction patterns among economic actors. Extending this line of inquiry, we explore how interfirm networks in the U.S. venture capital (VC) market affect spatial patterns of exchange.

We present evidence suggesting that information about potential investment opportunities for the most part circulates within geographic and industry spaces. In turn, the circumscribed flow of information within these spaces contributes to the geographic—and industry—localization of venture capital investments. After establishing this finding, our empirical analyses demonstrate that the social networks in the venture capital community—built up through the industry’s extensive use of syndicated investing—diffuse information across geographic and industry boundaries and therefore expand the spatial radius of exchange. We show that VCs that build axial positions in the industry’s co-investment network invest more frequently in spatially distant companies. Thus, variation in actors’ positioning within the structure of the market appears to differentiate market participants’ ability to overcome boundaries that otherwise would curtail exchange.

1. Introduction

The role played by geography and social topography in structuring interaction has long interested sociologists. Beginning with Bossard (1932), many studies have investigated the importance of propinquity in determining the likelihood of friendship and marriage. These studies consistently find that the probability of a relationship increases sharply when two individuals live near one another. A parallel line of research establishes that the likelihood of forming a social relationship declines as a function of distance in social space (Lazarsfeld and Merton 1954; Blau 1977; Blau and Schwartz 1984). The similar findings relating social and physical distance to the likelihood of a relationship reflect the fact that both operate by influencing the probability of random interaction. To form a relation, two individuals typically must meet in space and time. Because both physical and social locations strongly influence people's activities, proximity on these dimensions increases the likelihood of a chance encounter (Blau 1977). Although the research on geographic propinquity and homophily has focused primarily on the formation of friendships and marriages, the same processes that localize these forms of interaction also may structure economic exchange relations in physical and social space.

The literature documents the decline in interpersonal interaction with an increase in geographic and social distance, but it has offered few explanations for heterogeneity in the salience of these dimensions over time and across actors. The effect of geographic distance on the likelihood of interaction varies from actor to actor. Similarly, demographic characteristics differ in the degree to which they structure interaction (Blau and Schwartz 1984; McPherson, Popielarz and Drobnic 1992). In the latter case, two factors might explain this variation. First, individuals' preferences for interacting with similar others might produce homophily (Lazarsfeld and Merton 1954; Rogers and Kincaid 1981). According to this view, differences in the extent to which we observe homophily on sociodemographic characteristics derive from the underlying preference distribution for similarity. Alternatively, others argue that homophily stems primarily from the structure of opportunity (Blau 1977). In this perspective, sociodemographic dimensions vary in the degree to which they generate homophilous interactions based on the salience of these dimensions in the arrangement of daily activities.

Consistent with the second view, we argue that differences in the influence of propinquity and homophily in economic exchange systems stem from variation across actors in their opportunities to trade. We explore this idea in a market context by investigating empirically patterns of exchange in the U.S. venture capital industry from 1986 to 1998. Our analyses first demonstrate the prevalence of localized exchange by showing that the likelihood that a VC invests in a new venture ("target") declines sharply with the distance between VC and target. The data will

reveal strong evidence of localized exchange in terms of both the physical and the “industry” distance between the venture capital organization and the potential investment target, where the latter quantity represents the level of dissimilarity between the venture capital firm’s previous investment experiences and the industry classification of a given target company. We then show that certain characteristics of a VC’s position in the industry’s information network influence the degree of localization in its exchange patterns. Thus, we investigate the social structural factors that determine variation in the extent to which VC investments are “homophilous” (i.e., localized) with respect to geography and industry.

We contend that the structure of relationships in the VC community contours the movement of venture capital for at least two reasons. First, investors must be aware of investment opportunities to capitalize on them. In the public financial markets, many organizations disseminate information about potential investments; however, young, private entrepreneurial ventures typically fall outside the scope of these organizations’ activities. In the absence of public information about early-stage companies, personal and professional relationships provide one of the primary vehicles for disseminating timely and reliable information about promising new ventures. Second, investors carefully evaluate the quality of an investment opportunity before determining whether to support it. New ventures typically represent risky organizational propositions (Stinchcombe 1965). Not only do they face liabilities of newness and smallness, but also they often operate under unproven business models and in inchoate markets. In turn, the lack of a performance history upon which to base quality assessments tremendously increases the importance of trust—which we know to be built through repeated interaction—in the VC investment relation. Both information and trust require social interaction, yet the likelihood of this interaction varies across actors. The sociological literature on patterns of affiliation consistently finds that two factors, propinquity and homophily, influence the likelihood of interaction.

Because useful information regarding exchange opportunities travels across private networks, geographic and industrial spaces—areas within which interpersonal ties concentrate—represent spatial dimensions that contain the transmission of information about potential investments. We conjecture that the relatively more modest flow of information across geographic and industrial spaces deters geographically and industrially distant investments. Nevertheless, we argue that interfirm relationships in the venture capital community effectively reduce spatial limitations on the flow of information. Our empirical analyses focus on how the network connecting the members of the venture capital community—built up through the industry’s widespread use of syndicated investing—facilitates the diffusion of information across spatial boundaries, thereby decreasing the space-based constraints on economic exchange. Investors that build central positions

in the syndication network concomitantly extend their access to information about spatially distant targets and expand the radius of their investment activity. Therefore, consistent with the sociologist's general view of economic transactions, the social structure of the market determines the ability of participants to overcome the informational constraints that would otherwise restrict market exchange.

The analyses presented in this paper establish a series of findings that contribute to the literature in economic sociology. First, the paper represents the beginning of a sociological explanation of the spatial organization of economic activity. Economic geographers studying the spatial concentration of industry frequently call attention to the conundrum that production activity often concentrates in high-technology industries even though the primary production input—knowledge—can be inexpensively transported across large distances. In the absence of physical or economic constraints on the mobilization of resources through space, contemporary economic explanations of spatial concentration generally emphasize positive feedback processes that, for example, result from the geographic spillover of knowledge across firm boundaries but within small areas (Arthur 1990; Krugman 1991). According to this view, a sequential entry process leads new firms to locate near existing firms of the same type to establish local markets for scarce inputs (such as skilled labor) or to gain early exposure to knowledge produced by nearby firms. As we discuss in the conclusion, we believe that the spatial clustering of social and professional relations offers an alternative explanation for the spatial concentration of industry.

We also believe that the paper's findings have implications for regional economic development policies. Venture capital firms now play an important role in the U.S. economy. In the first half of 1999 alone, VC funds invested more than \$12.5 billion in early-stage companies. As the industry amasses ever-larger pools of capital to dispense, venture capitalists expand their influence in determining who receives funding to pursue their entrepreneurial visions. To the extent that these spells of entrepreneurship affect socioeconomic trajectories, venture capitalists become agents for social stratification. Similarly, VC firms have been critical catalysts in the development of many new high-technology industries. Because young companies in these areas make large investments in technology development significantly in advance of their ability to generate the cash flows to finance these investments, they must rely on capital infusions from venture capitalists and other investors. As these industries become important engines for economic growth and wealth creation, access to venture capital funding might significantly affect the macroeconomic health of regions and nations.

2. The Pattern of Exchange in the Venture Capital Market

In the last three decades, a new organizational form, the venture capital firm, has emerged as a substantial contributor to the financing of fledgling commercial enterprises. VC firms broker the relationship between investors and entrepreneurs. Using funds raised primarily from institutional investors and wealthy individuals, they search out promising, yet risky, investment opportunities. In this search, one might expect that VC firms would benefit by evaluating the broadest possible set of potential investments; on average, the best five investments from a set of one thousand possibilities should outperform the top five investments from a set of ten candidates. Despite the incentives for choosing from a broad array of opportunities, however, venture capitalists exhibit highly localized investment patterns in both physical and industry space (Gupta and Sapienza 1992; Norton and Tenenbaum 1993).

Two types of explanations can account for these insular investing strategies. One set focuses on the preinvestment activities of the venture capitalist, in particular the conditions that favor opportunity identification and evaluation. The second set of explanations addresses the postinvestment role of the VC firm, specifically the ease of monitoring the new venture and the facility with which the VC can provide value-added services.

2.1 The Preinvestment Role: Opportunity Identification and Appraisal

Finding investment targets entails two important tasks. First, VCs must acquire information about the existence and characteristics of investment opportunities. Second, they must assess the quality of these opportunities. Because each of these tasks becomes increasingly difficult at a distance, we believe that even passive investors—those who invest without intending to play an active role in managing the new venture—will likely invest locally.

Interpersonal relations act as primary pathways structuring the transmission of information within communities of actors. This observation underpins diverse sociological literatures; for example, the network-based explanations of the diffusion of innovations (Coleman, Katz, and Menzel 1966) and the more general sociological research on interpersonal influence processes (e.g., Friedkin 1998) reflect this fact. The capacity of networks to disseminate reliable information also underlies sociological investigations of economic markets. For example, Granovetter's (1973) seminal paper on the strength of weak ties motivated a number of studies of how network shapes determine the transmission of transaction-relevant information across the participants in a market. Many subsequent studies

specifically elaborate the mechanisms through which interactor ties affect both the patterns and governance of economic exchanges (e.g., Raub and Weesie 1990; Granovetter 1985).

Following this rationale, the structure of social and professional relations likely influences which actors become aware of promising, early-stage investment opportunities in the venture capital business. The majority of investment targets are small, inchoate entities. Timely information regarding high-quality investment opportunities in this domain often reaches a venture capitalist through his or her network. Thus, as economic sociologists have noted in other market contexts, the circumscribed diffusion of reliable information across networks plays a central role in the formation of exchange relations in venture capital.

The importance of networks in generating investment leads affects the spatial distribution of investment activity because social relations tend to cluster in both geographic and social spaces. Since the writings of Park (1926), studies have found that social actors form ties more frequently when they occupy proximate positions in physical space. In human ecology, the Law of Distance-Interaction states that the probability of interaction between social elements declines as a multiplicative function of the distance between them (Hawley 1971). Sociologists believe this "law" arises in large part because the costs of interacting—including finding and screening exchange partners and maintaining relationships—increase with distance (Zipf 1949). The seminal studies of Festinger, Schacter, and Back (1950) and the work of the human ecologists have refined these insights by showing an increased interaction frequency when actors meet in "functional" space (e.g., when the tenants in an apartment complex meet in the laundry room).

Although only a small body of literature examines how location affects the functioning of markets and the organization of economic activity, these studies reveal strong spatial effects (cf. Bothner 2000). In an analysis of the geographic diffusion of labor unions in Sweden, Hedstrom (1994) demonstrates that the geographic configuration of communication networks in the Swedish population can explain the spatial contagion in the establishment of these organizations. Research on interlocks among corporate boards created by overlapping memberships shows that spatially proximate companies are more likely to share directors (Mintz and Schwartz 1985; Kono, Palmer, Friedland, and Zafonte 1998). Studies of communication patterns within organizations observe that employees interact more frequently with co-workers in nearby offices (Allen 1977). Baker's (1984) study of price volatility in an options exchange importantly shows that the structure of interaction influences the transmission of information in a market context even in a very small physical space: the trading floor of a commodities exchange. Quoting an options trader, Baker (1984, 783) states, "Noise, static. The errors increase as an inverse square of the distance between brokers.... You trade with people in close

proximity to reduce this risk....” A growing empirical literature therefore establishes that individuals activate geographically localized social networks when they engage in economic exchange. Assuming this holds in the VC industry, geographic propinquity should facilitate the first task of the venture capitalist: learning about private investment opportunities.

A parallel line of research, beginning with Lazarsfeld and Merton (1954) but most extensively developed by Blau (1977), shows that social space also structures the likelihood of interaction. In social space, differentiation along sociodemographic dimensions operates as the equivalent to distance in geographic space (Milgram 1967). Relations cluster among similar people because individuals’ sociodemographic attributes determine what they do and where they do it. Sociodemographic dimensions act so strongly on the structure of interaction that homophily explains most of the social structural variation in the 1985 General Social Survey (Marsden 1988; Yamaguchi 1990). Many other studies also find proximity in social space a salient factor in explaining who interacts with whom (for a review, see McPherson and Smith-Lovin 1987). In our analysis of relationships and the spatial pattern of economic exchange in venture capital, the social space argument suggests that a VC’s prior experience in a particular industry should affect the extensiveness of the VC’s personal contact network among entrepreneurs and other investors in that industry. Having many contacts in turn facilitates the identification of new investment opportunities. Thus, experience in an industry may lead to specialization among venture capitalists along this dimension.¹

In addition to identifying investment opportunities, venture capitalists with deep contact networks in an industry or a geographic area can often better assess the veracity of the information they receive about the quality of an investment opportunity. As the economics and practitioner literatures on venture capital often note, information asymmetries make opportunity appraisal essential in this context. Information asymmetries exist because entrepreneurs know more than VCs do about the opportunities they seek funding to pursue. Moreover, VCs cannot simply rely upon entrepreneurs for accurate information about the quality of their business plans; this information may be tainted because entrepreneurs sometimes overstate the attractiveness of their proposals to secure funding and to obtain high valuations for their incipient companies. Thus, venture capitalists must guard against the hazard that entrepreneurs might try to sell them a “lemon” (Amit, Glosten, and Muller 1990).²

At least two dimensions of a venture capitalist’s contact network contribute to the localization of investments by influencing the VC’s ability to appraise investment opportunities under asymmetric information. First, individuals have greater confidence in information collected from trusted parties. Consistent with this disposition, reports on the venture capital industry indicate that VCs

¹The value of industry-specific knowledge in evaluating investment opportunities offers an obvious alternative explanation for industry specialization among venture capital firms. Because our primary interest lies in the factors that differentiate the degree of industrial specialization across firms, we make no attempt to discriminate among competing explanations for the “main effect” of industry specialization.

²Akerlof (1970) first posed the lemons problem using the used car market as an example. Amit, Glosten, and Muller (1990) extend this logic to venture capital investing.

repeatedly finance investments that they learn about through referrals from close contacts, including entrepreneurs that the VC has previously financed, fellow venture capitalists, family members, or friends (Fried and Hisrich 1994). These individuals have an interest in conveying accurate information and bringing high-quality investment opportunities to the attention of the venture capitalist because they typically wish to maintain an ongoing relationship with the VC.³ Second, lacking a strong tie, multiple and corresponding sources of information might offer the venture capitalist some assurance regarding the quality of a potential investment.

The density of strong and redundant ties likely declines particularly sharply in distance. Almost by definition, maintaining strong ties requires frequent interaction. The likelihood of this interaction decreases rapidly with distance—indeed, much more rapidly than the dissipation of weak ties that require less time and energy to maintain. Similarly, redundant ties imply the existence of multiple and duplicate information sources. Assuming, as we do, spatial constraints on tie formation and maintenance, the likelihood of receiving information about a potential entrepreneur from two or more sources will decrease even more rapidly in distance than will the likelihood of having a single information path.

2.2 The Postinvestment Role: Monitoring and Advising New Ventures

After investing in a start-up, venture capitalists perform two important functions. First, they monitor their investments. Because VCs make substantial investments in young companies with managers whose interests may conflict with the VCs' objectives, venture capitalists actively monitor their investments to mitigate agency problems. Meanwhile, the survey-based and ethnographic accounts of entrepreneurship scholars, as well as the business press and writings of practitioners, emphasize the value that venture capitalists add to early-stage companies by providing expertise and social capital.

A substantial body of (primarily theoretical) work in corporate finance concerns the optimal design of contracts between VCs and target companies to attenuate the agency problems inherent in providing capital to new ventures (for a review, see Kaplan and Strömberg 1999). Venture capitalists must contend with the possibility that entrepreneurs might pursue their own interests or reduce effort once they receive cash from their financiers (Jensen 1986). Several aspects of the contracts between venture capitalists and the entrepreneurs they fund, such as staged financing (Amit, Glosten, and Muller 1990; Gompers 1995; Bergemann and Hege 1998) and the allocation of control rights⁴ (Hellman 1998), help mitigate this concern. Although these contracts reduce the need for monitoring, they do not

³Among others, Blau (1964), Coleman (1990), and Burt (1992) offer general discussions of the social structural underpinnings of referral processes. For example, Coleman (1990, 180–88) describes “intermediaries in trust” as individuals who certify the trustworthiness of one individual to another. According to Coleman (1990, 181), “The advisor’s only stock of trade is the credibility of his advice, and if his advice proves incorrect, his loss is in the trustworthiness of his judgment in the eyes of those he has advised.”

⁴Venture capitalists secure several contractually specified control rights when they invest in early-stage companies. For example, they typically receive board seats and the power to replace the venture’s management team if it fails to meet financial or other performance-based milestones.

eliminate it. Thus, monitoring the managers of their portfolio companies remains an important postinvestment activity for the venture capitalist.

Practitioner accounts tend to emphasize the services VCs provide to the companies they support. An oft-repeated adage in the industry states, "It isn't getting the money, it is who the money comes from." This statement refers to the value-added services that VCs offer and the endorsement value derived from having high-status financial backers. Obviously, venture capital firms provide financial expertise; they also routinely act as general management consultants, providing advice on strategic and operational issues (Bygrave and Timmons 1992). Many venture capitalists successfully started and ran their own companies before entering the industry. Thus, they have experience in many of the management and strategic issues confronting the entrepreneurs they back. In addition, because of their present and past financing activities and prior business experiences, VCs hold abundant social capital that they can make available to the companies in which they invest (Stuart, Hoang, and Hybels 1999).

Spatial proximity to the target facilitates the execution of both of the VC's postinvestment roles. Monitoring requires frequent visits to company operations. As Gorman and Sahlman (1989) report, VCs spend an average of four to five hours per month on site at each of the companies in which they play a lead role. Even when another VC firm leads the investing, a venture capitalist will still typically visit the company at least once per quarter. In total, monitoring and advising occupies about half of the venture capitalist's time (Gorman and Sahlman 1989). Obviously, time spent in transit reduces the number of companies that an individual can monitor; thus, geographic proximity reduces the time costs of monitoring. VCs with limited past experience in the target's industry also find monitoring more challenging. Knowledge regarding the target company's industry allows the VC to oversee its investments more efficiently and more effectively, in part because industry experience enhances the VC's ability to recognize signs of trouble at an early stage.

Similarly, the advisory function is more difficult, and may be less valuable, when venture capitalists are separated from targets by large physical or industry distances. VCs can offer more assistance to targets when they interact with start-ups' management frequently and in person. Familiarity with the business issues confronting new ventures requires continual interaction, so spatial propinquity also facilitates advising. Similarly, the more extensive the VC's past experience in the target firm's industry, the more industry-specific expertise and the greater the industry-specific social capital the VC can provide.

Because both the preinvestment activities (opportunity identification and appraisal) and the postinvestment roles (monitoring and the provision of value-added services) favor local investing, we anticipate finding this pattern in the data. Nevertheless, because most industry participants would expect to observe this

phenomenon and because of the range of potential explanations for it, the limited spatial reach of exchange in the venture capital investing relation does not, in and of itself, constitute a particularly significant finding. This pattern could result from boundaries around the flow of information about investment opportunities, from a rational response to the costs of monitoring even with perfect information, or simply from satisficing behavior that engenders local search. Given the obstacles to discriminating among the multiplicity of factors that all predict local investing patterns, we focus instead on the factors that influence the sensitivity of venture capitalists' investments to target company proximity. In other words, we investigate the factors that lead VCs to extend the reach of their investments beyond their surrounding geographic and industrial neighborhoods. Fortunately, the determinants of the spatial sensitivity of VCs also provide some purchase for discriminating between competing explanations for the localization of investments.

2.3 Determinants of the Spatial Reach of Venture Capital Investments

Having established the reasons to expect localized investment patterns, we now develop specific predictions relating attributes of VC firms, characteristics of their information network, and features of specific VC-target pairings to the probability that a VC will invest in a geographically distant target or one in an industry in which the VC has had little prior investment experience. Although our data provide strong evidence of local exchanges, VC firms vary significantly in their proclivity to invest in proximate targets. We begin by proposing VC age and investment experience as factors explaining this variance, but we intend to show that tenure in the industry and experience proxy for the expansion of a VC's contact network and the growth of its reputation, which develop through time and the accrual of an investment track record. If our conjecture holds, the effects of tenure and experience should attenuate when we account explicitly for this network development.

VC age

The age of a venture capital organization captures at least four dimensions of tenure in the industry. First, as firms age, their members probably extend their networks both within the venture capital community and among entrepreneurs in a range of industries. Second, even without forming new ties, the spatial reach of a VC's contact network likely increases over time as geographic and social mobility produce spatial dispersion among the contacts in their network. Third, as they age, venture capitalists also accumulate experience in evaluating business proposals and entrepreneurs that could improve the VC's ability to perform these tasks at a distance. Fourth, long-tenured firms in the industry often become widely known, increasing the likelihood that other venture capital firms will bring good investment opportu-

nities to them. As our argument develops, we hope to disentangle the effects of networks and experience captured by firm age, but age might pick up residual effects from these processes. Thus, we anticipate that *older venture capital firms will fund distant targets more frequently than will young venture capital firms.*

VC experience

As the discussion of VC age implies, age captures the combined effects of a number of processes that produce systematic changes in organizations as they mature (Hannan 1998). One accompaniment of age is the accumulation of experience. Over time, the experience that venture capitalists accrue can alter the influence of distance in the investment decision in at least three ways. First, experience might reduce the costs of monitoring at a distance as VCs become more adept at this task. Similarly, as they gain confidence in their ability to evaluate investment opportunities and entrepreneurs, they might grow less dependent on trustworthy or redundant information sources to appraise the quality of investment candidates. Finally and most relevant to our argument, in the course of their investments, venture capitalists develop relationships with other venture capital firms and with experts and entrepreneurs in the industries in which they repeatedly invest. These networks provide privileged access to information about promising investments. Let us consider each of these in detail.

A substantial literature on organizational learning suggests that past experience influences organizational behavior (March 1988). As VCs gain experience monitoring their investments, they develop competence in activities such as writing effective contracts to minimize agency problems and recognizing the signs that forewarn of problems at the companies in which they invest. Effective monitoring also requires insight into the link between effort and outcome, which practice cultivates. An improvement in the efficiency of performing these activities reduces the time that the venture capitalist must spend monitoring, which should in turn enable the venture capitalist to invest in more distant firms because of a reduction in the time costs of monitoring at a distance.

In addition to improving their monitoring ability, experience also hones venture capitalists' ability to appraise potential investments. As they evaluate more business plans and directly observe more early-stage companies, venture capitalists may gain a better understanding of the factors that lead to success and failure in general and within a particular industry. As VCs improve their acumen in evaluating investment opportunities, they might become more willing to invest based on information acquired from nonredundant and weak ties.⁵ Although weakly affiliated actors may lack the incentive to refer only high-quality investments (Fried and Hisrich 1994), VCs might compensate by relying more heavily on their ability to discern quality differences among entrepreneurs and their business plans. Since

⁵ The literature on decision making counsels that a change in the willingness to rely on one's own judgment does not necessarily constitute a rational shift in behavior. Research shows that individuals become more comfortable engaging in an activity simply by doing it (Bandura 1986), especially when the feedback regarding success lies chronologically distant from the activity. Thus, venture capitalists might judge themselves to be better investors, regardless of any real improvement in their selection ability.

VCs likely have only nonredundant and indirect ties to informants on the quality of geographically distant targets or those in industries in which they lack previous investment experience, this shift toward a reliance on internal (rather than network-based) evaluation techniques disproportionately favors the consideration of faraway targets. Therefore, venture capitalists may become less sensitive to distance as they accrue investment experience.

Beyond the changing character and quality of the information VCs will consider in evaluating potential investments, the accrual of prior experience also expands a venture capitalist's access to information. For many reasons, each investment extends the VC's information network. First, the employees of previously funded companies occasionally launch new start-ups, since entrepreneurs in a particular industry tend to emerge from the rosters of organizations already operating in that industry (Sorenson and Audia 2000). Also, the executives and employees at funded companies may forward potential investment opportunities that they learn about through friends, relatives, and co-workers. To the degree that entrepreneurial activity forms a salient dimension in structuring social interaction, entrepreneurs will know other entrepreneurs, and thus they will be fecund sources for referrals. The contacts emerging from the associations generated by past financing relationships also offer another potential information advantage to venture capitalists: When investing within the same industry, these contacts offer privileged access to expert advice. Hence, we expect that *prior investment experience in an industry increases the geographic reach of investments within the industry*.

Although we expect stronger experience effects when venture capitalists consider investments within the same industries as their prior investments, each of the aforementioned arguments could affect a VC firm's investments even outside of the industries in which it has accumulated experience. For example, some aspects of monitoring require knowledge specific to a particular industry, but others should apply generically to the monitoring of any business venture. Similarly, a portion of the evaluation of any entrepreneurial venture involves aspects of the business plan and the capabilities of the founding team not specific to any particular industry. Moreover, entrepreneurs at the target companies in which a VC invests may forward referrals that extend beyond the industries in which they work. Therefore, we anticipate that *VCs with extensive investment experience will more likely invest in both distant industries and distant locations*.

Target company stage

The difficulty of opportunity appraisal and the importance of monitoring vary with the target company's development stage. Evaluating extremely-early-stage companies proves difficult because they lack track records for making informed quality assessments. In contrast, VCs can judge the quality of the management

team in light of its performance on a number of different performance metrics in later-stage companies. In addition to offering more data to inform the due diligence process, later-stage companies might also require less intensive monitoring. As organizational routines and policies evolve and management becomes better established, new ventures typically operate with greater reliability (Stinchcombe 1965; Hannan and Freeman 1984). Both of these observations suggest that *more-developed target companies receive investments from geographically or industrially distant VC firms more often than do early-stage ventures.*

Syndicate networks in venture capital

New ventures frequently obtain funding from syndicates of investors, implying that they receive financing from more than one venture capital firm, and they often garner multiple investors even in the same financing round.⁶ Many factors justify this practice: Syndicates diversify risk by enabling VCs to invest smaller amounts in a greater number of companies (Wilson 1968), they mitigate the information asymmetries between the initial investor and later-round investors (Admati and Pfleiderer 1994), and they leverage investment evaluation skills across coalitions of firms (Sah and Stiglitz 1986; Lerner 1994). Lerner (1994) also suggests that syndication might allow venture capitalists to “window dress” the results they present to their investors, which they accomplish by gaining late-stage access to “hot” firms even though much of the capital appreciation in these companies has already occurred. This allows VCs to report that they funded star companies when they attempt to raise future pools of capital.

Regardless of the particular motives for syndicating investments, the frequent reliance on investment coalitions to fund target companies creates a dense inter-firm network that expands the distance that information travels through the venture capital community. Each time a venture capital firm enters a syndicate, it develops new associations with, or strengthens existing relations with, other venture capital organizations. Thus, the practice of syndication creates a network of relations within the VC community that structures the flow of information across market participants. Likewise, repeated transactions with previous syndicate partners build trust between the focal VC firm and other VC organizations. As the relations between the reference firm and other members of the VC community strengthen and broaden, so too does (1) the chance that the reference VC will be invited to join future syndicates, and (2) the trust that it places in the monitoring and due diligence capabilities of fellow syndicate members. Thus, these connections enable a focal VC to rely upon the opportunity recognition and monitoring capabilities of colleagues. We therefore expect that *venture capital firms will more likely fund a spatially distant target if they have previously co-invested with another firm that invested in the target company.*

⁶ Syndicates financed slightly more than two-thirds of the 7,590 VC-backed firms in the data we analyze. The average target received investments from 5.3 VCs. Thus, the typical investment leads to an association between a reference VC and 4.3 other venture capital firms.

From the venture capitalist's vantage point, having a previous exchange partner in an investment syndicate increases the reference VC's probability of investing over a significant distance most when the exchange partner lies in close spatial proximity to the target. If a VC trusts another member in a syndicate and this well-regarded colleague resides near the target, the VC can rely on the due diligence, monitoring, and advisory capabilities of its trusted partner.⁷ This suggests that *venture capital firms will more likely fund a spatially distant target when a previous co-investment partner belongs to the syndicate for the target and is located near the target in geographic or industrial space.*

Finally, the centrality of the VC's position in the industry's co-investment network could affect its sensitivity to target firm distance for several reasons. First, assuming that information about investment opportunities flows through the ties in the syndication network, VCs with large numbers of co-investment relations with other organizations will have access to a significant amount of information about investment opportunities, particularly if they associate with other central actors (Bonacich 1987). This implies that central venture capitalists will be most aware of investment opportunities outside of their immediate geographic region and industrial foci. Second, centrally positioned actors enjoy high status because they occupy prominent structural positions in the community's syndication network (Podolny 1993). High-status venture capitalists likely receive many invitations to join investment syndicates because of the legitimacy they confer on the VC firms and the targets with whom they associate (Freeman 1999). The visibility bestowed by high-status venture capitalists through the investment relation particularly benefits early-stage companies that lack a proven performance track record and a strong identity among potential investors (Stuart, Hoang, and Hybels 1999). Thus, we posit that *venture capital firms centrally positioned in the VC community's co-investment network will more likely fund spatially distant targets.*

To recapitulate, we begin our empirical analyses by establishing that venture capital firms typically invest locally. Then, we show that well-established and highly experienced venture capitalists exhibit more dispersed investment patterns. Finally, we examine how the position of VC firms in the industry's evolving co-investment network affects the proclivity to invest in spatially distant targets.

3. Empirical Strategy

Our analysis addresses the determinants of financing relations between venture capitalists and start-up companies. In essence, the empirical component is a network study of tie formation; we model the probability that a particular VC firm invests in a given target company. Many studies of tie formation analyze every

⁷ The frequent appearance of serial syndicate partners in the data (the same pairs of VC firms investing together in multiple transactions) suggests the operation of an active norm of reciprocity in the industry, in which VCs build relationships by sharing high-quality deals with established exchange partners. It also suggests the need for studies that compare network extension strategies against relationship-strengthening strategies.

possible dyad and use logistic regression to estimate the effects of a covariate vector on the likelihood of a tie (e.g., Podolny 1994; Gulati 1995; Stuart 1998). This strategy creates two problems. Methodologically, it does not correctly account for nonindependence across cases, as each firm enters the analysis many, many times.⁸ The large number of repeat occurrences of each firm can lead to systematic underestimation of the standard errors for firm attributes that do not change from dyad to dyad. Pragmatically, this strategy presents a second obstacle; the observation of all possible dyads can prove burdensome computationally, especially for large networks. For example, consideration of all potential dyads in our data would require us to create a matrix with more than six million cells. Since many of our variables require cell-by-cell calculation, this would result in a nearly hundred-fold increase in the time required for variable construction.

Sampling randomly from the set of potential VC-target dyads offers one potential solution to these issues. Nevertheless, this approach falls short of the ideal because it ignores the fact that the realized ties provide most of the information for the estimation of the factors that affect tie likelihood (Coslett 1981; Imbens 1992; Lancaster and Imbens 1996). Thus, we include all cases of funding relations that actually appear in the data. For comparison, we then create a matched sample of potential ties that did not occur. To control for temporal variation in the supply of and demand for venture capital, we create the matched sample by pairing each venture capital firm that funded a start-up in a given quarter of a calendar year with a start-up funded by a different venture capitalist in that same quarter.⁹ This approach substantially reduces the problems associated with multiple firm observations; the average VC firm now enters the analyzed data matrix 78 times, as opposed to more than 6,000 times in the matrix of all potential funding relations. To address the fact that venture capitalists enter the data more than once, we report robust standard errors estimated without the assumption of independence across observations on the same VC firm.

The use of a matched sample introduces one new problem. Logistic regression can yield biased estimates when the proportion of positive outcomes in the sample does not match the proportion of positive outcomes in the population. Because logistic regression is a multiplicative model, this bias does not simply affect the intercept term. Rather, bias can affect all coefficient estimates. In particular, uncorrected logistic regression using a matched sample tends to produce underestimates of the factors that predict a positive outcome (King and Zeng 2000). Large samples do not necessarily alleviate this problem. To correct for this potential bias, we adjust the coefficient estimates using the method proposed by King and Zeng (2000) for the logistic regression of rare events.

⁸ Doreian (1981), Lincoln (1984), Krackhardt (1988), and Mizuchi (1989) discuss various approaches for addressing the non-independence problem.

⁹ Using target firms that received funding from different venture capital organizations as the sampling frame for the comparison set eliminates the issue of potential quality differences between the funding relationships that exist and those that never materialize, as all target companies in the data (by definition of the sampling criterion) pass the quality threshold necessary to receive venture funding.

The traditional logistic regression model considers the dichotomous outcome variable to be a Bernoulli probability function that takes a value 1 with the probability π :

$$\pi_i = \frac{1}{1 + e^{-x_i \beta}}$$

where X is a vector of covariates and β is a vector of parameters. Researchers typically use maximum likelihood methods to estimate β . King and Zeng (2000) prove that the following weighted least squares expression estimates the bias in β generated by oversampling rare events:

$$\text{bias } \hat{\beta} \approx (X'WX)^{-1} X'Wj,$$

where $j = 0.5 Q_{ii}^{-1} \hat{\pi}_i$, $W = \text{diag} \{w_1, \dots, w_n\}$, the Q are the diagonal elements of $Q = X(X'WX)^{-1} X'$, $W = \text{diag} \{w_1, \dots, w_n\}$ and w_1 represents the fraction of

ones (events) in the sample relative to the fraction in the population. Essentially, one regresses the independent variables on the residuals using W as the weighting factor. Tomz (1999) implements this method in the `relogit` Stata procedure.

3.1 Data Sources

Using the Venture Economics database from Securities Data Corporation, we developed a comprehensive data set of venture capital investments from 1986 to 1998.¹⁰ This database purports to record all VC firm investments in domestic, private companies. Because each venture capitalist's investment in a target generates a unique record in the database, we know the full history of VC investments in each target. Using this information, we create a matched sample by randomly pairing each venture capital firm that made an investment in a particular quarter with a target company that it did not fund (i.e., we create a potential but unrealized dyad). The matched sample includes 80,406 cases involving 1,025 venture capital firms and 7,590 target companies. Although exactly 50 percent of the cases form investment ties, the population as a whole actually realizes ties in 0.72 percent of the potential dyads.

From these numbers, one can readily see that each target company enters the data more than once. Three factors explain this fact. First, the method used for creating the matched sample implies that, on average, a target enters the data twice for each VC investment it actually receives. Second, most target companies experience more than one financing event because venture-backed companies typically receive funding in a sequence of capital infusions, known as "rounds." Each time a company undergoes a financing round, venture capitalists subject it to a thorough evaluation. Typically, VCs provide small amounts of funding in early rounds because they prefer not to make large financial commitments to young companies

¹⁰ SDC's Venture Economics database reports venture capital investments dating back to the early 1970s. However, we must allow for the passage of time to observe the buildup of the syndication networks. Thus, we restrict the cases analyzed to the period from 1986 to 1998, though we use all information in the database to construct the independent variables.

Table 1: Descriptive statistics

| Variable | Mean | SD |
|--------------------------|--------|--------|
| VC density | 0.58 | 0.23 |
| Target density | 0.81 | 0.35 |
| VC industry density | 36.19 | 29.57 |
| Target industry density | 61.81 | 38.93 |
| Early stage | 0.15 | 0.35 |
| Prior | 0.28 | 0.45 |
| Ln (distance) | 5.75 | 2.06 |
| Industry distance | 0.77 | 0.24 |
| VC age | 12.64 | 9.21 |
| General exp. | 162.53 | 211.24 |
| Industry exp. | 34.77 | 63.36 |
| Mean affiliation | 4.89 | 6.35 |
| Bonacich power | 1.28 | 1.83 |
| Min (affiliate geo dist) | 0.37 | 0.42 |
| Min (affiliate ind dist) | 0.37 | 0.34 |
| Same state | 0.28 | 0.45 |
| Prior state exp. dummy | 0.75 | 0.44 |

about which they lack a sufficient understanding of quality (Gompers 1995). As they learn more about the company, VCs then decide to terminate, maintain, or increase their funding level. Finally, for the reasons noted above, many start-ups receive financing through syndicates. As a result, each target enters the data an average of 10.6 times.

3.2 Independent Variables

Geographic distance

We measure geographic distance by calculating the number of miles between the venture capitalist's main office¹¹ and the location of the target company. Practically, we calculate this measure by assigning the longitude and latitude at the center of the zip code in which they reside to both venture capitalists and targets. Using spherical geometry, we calculate the distance between the two points, i and j , as:

$$d_{ij} = C \arccos \left(\sin(\text{lat}_i) \sin(\text{lat}_j) + \cos(\text{lat}_i) \cos(\text{lat}_j) \cos(\text{long}_i - \text{long}_j) \right)$$

where latitude (lat) and longitude (long) are measured in radians and C represents a constant based on the radius of the sphere that converts the result into linear units of measure. To convert the result to miles on the surface of the Earth, we use $C = 3437$.¹²

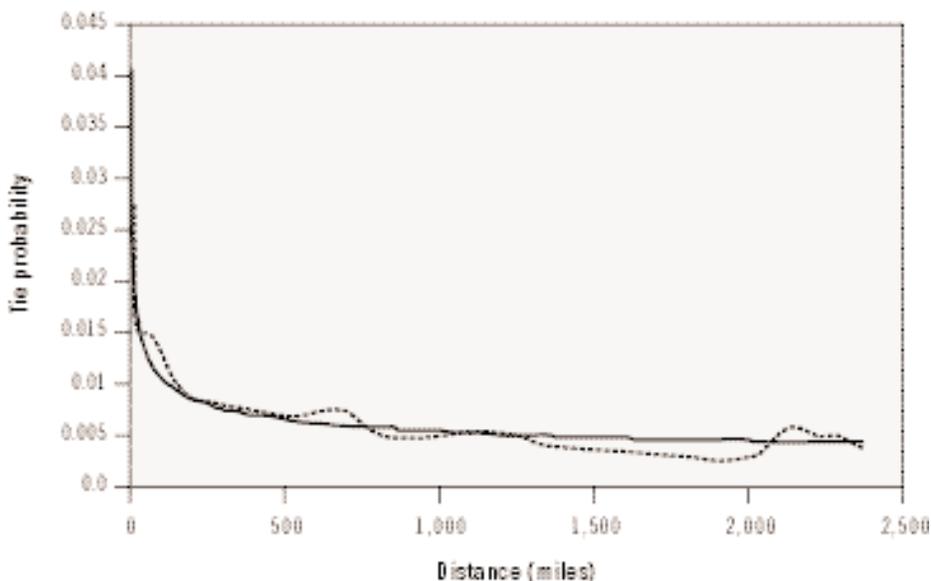
¹¹ Unfortunately, our data sources do not include information on when or if venture capital firms open satellite offices. Therefore, in some instances—when the VC firm has a second office that is nearer to the target than its head office is—the distance that we compute underestimates the actual distance between the VC firm and target. The exclusion of this information should add measurement error, making our tests of geographic effects less precise.

¹² The scaling (i.e., miles versus tens of miles versus kilometers) matters only to calibrate the relative importance of being located within the same zip code versus being located in a neighboring zip code (Sorenson and Audia 2000).

¹³ We split the data into 20 equal-proportion pieces. Thus, each of the 20 pieces represents 5 percent of the total cases.

Figure 1

Geographic distance spline. The dotted line shows a 20-piece linear spline of the likelihood of investment, while the solid line displays the implied relationship of the logged functional form.



In the models, we log geographic distance to account for the fact that transportation costs, both in terms of time and money, do not increase linearly over geographic space. Rather, as distance increases, actors substitute technologies to improve the efficiency of transportation and communication. For example, a person will drive to visit someone 30 miles away, but he or she will fly to see a contact 3,000 miles away. Since this specification imposes a strict functional form on the relationship between distance and tie formation, we fit a spline to the data to check the validity of this assumption. Figure 1 presents the predicted relationship between geographic distance and tie likelihood using both the natural log of distance and a 20-piece linear spline.¹³ The logged functional form fits the relationship between distance and investment likelihood quite well. Nevertheless, the graph appears to show two deviations between the parametric and nonparametric estimates. First, the logged functional form declines somewhat more rapidly over the first 60 miles than does the actual relationship between distance and financing. Presumably, at such short distances, little opportunity exists for technology substitution. Thus, transport costs should relate linearly to distance over this short span. Second, the data show a slight bicoastal effect. We believe that the distribution

¹⁴ An analysis of all firms with valid founding dates revealed that the first investment occurred 366 days after the founding of the venture capital firm, on average. We also ran all models excluding cases that lack valid founding dates. Excluding these cases does not qualitatively change the results.

of venture capital firms explains this effect; we will elaborate on this contention when discussing the results.

Industry distance

In addition to the factors that affect VC firms' investments in geographically distant targets, we also explore the determinants of the "industry distance" between VCs and targets. Because entrepreneurs at previously funded start-ups and contacts generated from working in an industry represent important sources for the identification of new investment opportunities, industry represents another dimension that delimits the flow of information. Moreover, VCs typically perform due diligence and monitoring more expeditiously and successfully when they have prior investment experience in the target's industry. To minimize assumptions, we define industry distance as the similarity between the industry profile of the venture capitalist's prior investments and industry of the target firm. Ideally, this measure would weight actual differences in the production processes and market dynamics of different industries to capture the transferability of knowledge across domains, but the construction of any such measure would require a host of arbitrary assumptions. To avoid such suppositions, we opt to define industry distance as the percentage of previous investments that the venture capitalist has made in industries other than the one in which the target firm operates:

$$\text{industry distance}_{ij} = \frac{\sum_{p \neq m} p}{\sum p},$$

where i indexes venture capital firms, m denotes the industry of the start-up j , and p represents an array of all prior investments in any industry. Thus, industry distance ranges from 0, when all of a venture capitalist's prior investments fall in the target's industry, to 1, when the VC has no previous investments in the target's industry. In assigning firms to industries, we use the Venture Economics one-digit industry taxonomy, an eight-category classification scheme that divides firms into the following "industries": biotechnology, computers, communication, consumer, energy, industrial, medical, and other.

VC firm age

To measure changes in investment patterns as venture capitalists mature, we calculate an age term based on the number of years from the VC firm's founding date to the quarter of the investment. The Venture Economics database lacks valid founding dates for venture capital firms in 6 percent of the cases. To avoid dropping these cases from the analysis, we assign a founding date to these firms of one year prior to the first investment recorded by SDC.¹⁴

¹⁵ This measure assumes the average strength of the relation between a reference VC and the other syndicate members to be important, but several reasonable variants of this measure exist. For example, the sum of prior co-investment events captures the degree to which having multiple trusted partners matters. Likewise, the maximum number of times the reference VC has co-invested with another member of the syndicate measures the degree to which the one most trusted partner influences investment patterns. We constructed these alternative specifications. Since the variables correlate highly and all produce the same pattern of effects in the models, we only report results using average relationship strength.

Experience

Two variables capture the effects of experience in financing. “General experience” counts the number of companies in which the venture capitalist has invested prior to the current quarter. “Industry experience” tallies the number of start-ups in the same industry as the target in which the venture capitalist has invested previously.

Network position

We compute three variables to capture different aspects of a firm’s position in the network linking venture capitalists through previous, joint (syndicated) investments in start-ups. One can construe this syndication network as an actor-event network; VCs intersect in the target “event” when more than one VC firm contributes funding to the same target. The syndicated investment thus provides the precipitating event leading to interaction among the venture capitalists that jointly finance a target.

The first variable gauges the degree to which the reference venture capital organization has an established relationship with the other VC firms that have also invested in the target. To construct this variable, we first create a count of the number of start-ups in which the focal venture capital firm has co-invested with each of the other VC investors in the target. Then, we average this score across all other investors in the target. The following equation defines mean affiliation for VC firm i in investment target j :

$$\text{mean affiliation}_{ij} = \frac{\sum_k \sum_p x_{ik} x_{kj} x_{ip} x_{kp}}{\sum_k x_{ik}}$$

where k indexes all venture capital firms other than i , p indexes all previous investment rounds in all target companies, and x takes the value of 1 when an investing relation exists and 0 when it does not. The resulting quantity captures the average strength of relations between the focal venture capitalist and the other members of the investment syndicate for a particular target.¹⁵

The second variable, affiliate distance, captures the possibility that venture capitalists might feel that their trusted colleagues can successfully monitor and evaluate investments only when the affiliates lie close to the target. We create two variables to capture the distance between the target firm and the closest trusted affiliate in the investment syndicate. First, we create a variable that records the geographic distance of the closest syndicate partner to the target *with whom the reference VC firm has previously co-invested*. Using the inverse of this distance measure allows us to assign a 0 to investment options in which the VC does not have a prior

¹⁵ Without inverting the affiliate distance measure, nonexistent affiliates (i.e., when there is no k in the syndicate for target j with whom VC firm i has a previous relationship) should lie infinitely distant from the target. Practically, this would require us to assign some arbitrary large number to these cases. Thus, we invert the measure to eliminate the possibility that an arbitrary assumption in the coding of these cases would generate the effects.

affiliate invested in the target.¹⁶ For firm i 's consideration of target j , this measure can be defined as follows:

$$\text{affiliate distance}_i = \frac{1}{\min(d_{ij})}$$

where d is the distance metric between venture capitalist k and the target j when $x_{ij} = 1$ and $\sum_j x_{ij} x_{jk} x_{ip} x_{kp} = 0$, where x again denotes the existence of a relationship between two actors. Second, we generate a parallel measure to capture the industry distance of the closest prior affiliate in the syndicate. This measure has a natural upper bound of 1, so we do not need to invert it. For firm i 's consideration of target j , this measure can be defined as follows:

$$\text{affiliate distance}_i = \min(d_{ij})$$

where d is the distance metric between venture capitalist k and the target j when $x_{ij} = 1$ and $\sum_j x_{ij} x_{jk} x_{ip} x_{kp} = 0$, where x again denotes the existence of a relationship between two actors.

The third variable, centrality, captures the reach of a focal venture capitalist's information network. We compute the centrality of each VC in the syndication network as a measure of the information-gathering capability of the focal VC. Because ties to actors who occupy central positions themselves increase the reach of a VC's network more than ties to peripheral players do, we compute Bonacich's (1987) two-parameter centrality measure:

$$c_i(\alpha, \beta) = \sum_{k=1}^n (\alpha + \beta c_k) r_{ik}$$

where c is the centrality score, r indicates a relationship (co-investment) between i and k , α scales the measure, and β weights alters' centralities. When the parameter β takes a positive value (as in the present case), each VC's centrality increases as a function of the centralities of the VC firms with which it shares co-investment ties (when β equals 0, Bonacich's centrality measure correlates perfectly with the variable we label "general experience"). We assume that information travels between VC firms and, therefore, the amount of information available to the reference firm increases as a function of the centralities of those with whom it shares relations. In other words, ties to central firms increase the radius of the reference firm's information network. Practically, one solves for centrality scores by taking the eigenvector associated with the largest eigenvalue of the relationship matrix. Since the designation of β is arbitrary, we follow the example of earlier researchers and set it equal to $\frac{3}{4}$ of the reciprocal of the largest eigenvalue (e.g., Podolny 1993). To allow

¹⁷ The parameter α is set so that the mean centrality score across all VCs is one, but the mean value of the centrality measure in the analyzed data set exceeds one because the highly central venture capitalists do more deals on average than do the less central players. Also, we use all co-investment relations in the preceding five years to form the relationship matrix used to compute Bonacich centrality. By using only five years of co-investment data, we allow for the fact that relationships erode over time. If two firms have not co-invested within a five-year

period, it seems unlikely that their members remain close confidants.
¹⁸ The social psychological reasons for continuing investment seem to imply that the likelihood of future investment should increase with the number of prior investment rounds. To test this possibility, we also tried including a second term for the number of prior investments beyond the first. This count did not significantly affect the likelihood of investment in any of the models.

¹⁹ We defined the following financing types as early stage investments: "early stage," "first stage," "other early," "R&D early stage," "seed," and "start-up." We also generated a second dummy variable that indicated whether the investment was the first round of funding for a particular company recorded by SDC. The results behave similarly, so we report the models using only the early-stage dummy variable.

Figure 2

Geographic distribution of venture capital investments. Larger circles (proportionate to the square root of the number of target companies in a zip code) indicate the presence of more targets.

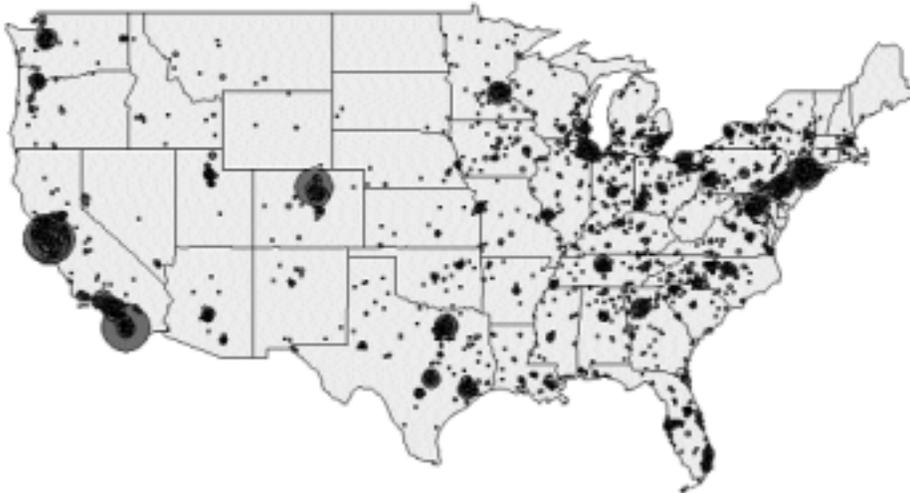


Figure 3

Geographic distribution of venture capital firms. Bigger diamonds (proportionate to the square root of the number of VCs in a zip code) indicate the presence of more venture capitalists.



comparison across networks of different size, we set α such that the mean centrality score in each period equals 1 (Bonacich 1987).¹⁷

Because we wish to document the factors that alter the spatial range of investments, we interact the measures of VC age, experience, and network position with the industry and geographic distance between VC firm and target in the models of the probability of an investment. Although our primary interest lies in the direction of the effects on the interaction terms, we must include the main effects of all the variables to adjust for the impact those factors might have on the intercept (Greene 1993).

3.3 Control Variables

Prior investment

For a variety of reasons, venture capitalists tend to continue to invest in companies in which they already own equity. Bergemann and Hege (1998) argue that maintaining a constant proportion of equity provides an optimal solution to the agency problems in the VC-target relationship. Thus, one might expect rational firms to participate in all subsequent financing rounds to preserve their investment level. Psychological forces also could compel VCs to invest repeatedly. Prior investments represent a commitment to the target company, and as Staw (1976) shows in a similar context, an unwillingness to act upon negative information can result in an escalation of the VC firm's commitment to the target. To control for these factors, we include a dummy variable that indicates whether the venture capitalist has previously invested in the target.¹⁸

Investment stage

The forces that drive VCs to make local investments may operate most strongly in early investment rounds. The earlier the developmental stage of the company, the shorter the track record of the new venture and the less information available to potential investors to assess the start-up's quality. Thus, monitoring and network-based evaluation strategies might be more important early in the target's life. We create a dummy variable that indicates whether Venture Economics classified the investment as an early stage.¹⁹

Supply of active VCs

Figures 2 and 3 display the location of all active VC firms and active targets in the U.S. in 1998. Since neither venture capital firms nor targets distribute evenly across regions or industries in the United States, the local supply of potential

Table 2: Rare event logit models of geographic scope determinants[†]

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Intercept | -47.79** (17.32) | -64.90** (17.32) | -72.45** (14.99) | -37.54** (15.29) | -30.49** (15.63) | -2.303** (.2034) |
| VC density | .0963 (.1928) | .0296 (.1740) | -.2045 (.1563) | -.3119 (.1611) | -.3349* (.1588) | -.3955* (.1605) |
| Target density | -.5858** (.1529) | -.5109** (.1378) | -.3682** (.1245) | -.3972** (.1216) | -.4202** (.1224) | -.4690** (.1286) |
| Early stage | .4391** (.0594) | .4317** (.0600) | .3808** (.0620) | .3661** (.0593) | .4065** (.0570) | .4217** (.0573) |
| Prior | 4.017** (.0936) | 4.057** (.0865) | 4.299** (.0866) | 4.512** (.0685) | 4.370** (.0662) | 4.247** (.0660) |
| VC age | | -.0475** (.0151) | .0143 (.0086) | .0002 (.0095) | -.0007 (.0093) | -.0009 (.0089) |
| General exp. | | | -.0031** (.0007) | .0013 (.0007) | .0013 (.0008) | .0014 (.0008) |
| Industry exp. | | | -.0058** (.0020) | -.0041* (.0020) | -.0039* (.0019) | -.0038* (.0018) |
| Mean affiliation | | | | -.1245** (.0203) | -.1244** (.0201) | -.1162** (.0192) |
| Bonacich power | | | | -.2974** (.0586) | -.2997** (.0559) | -.3088** (.0545) |
| Ln (distance) | -.1563** (.0179) | -.2313** (.0297) | -.2375** (.0230) | -.2927** (.0247) | -.2756** (.0244) | -.2685** (.0257) |
| Industry distance | -1.076** (.1089) | -1.018** (.1136) | -1.157** (.0802) | -1.084** (.0835) | -.9830** (.0827) | -1.083** (.0879) |
| VC age 3 ln (distance) | | .0057** (.0019) | -.0011 (.0012) | .0006 (.0015) | .0008 (.0014) | .0007 (.0014) |
| General exp. 3 ln (distance) | | | .0003** (.0001) | -.0002 (.0002) | -.0002 (.0002) | -.0002 (.0001) |
| Industry exp. 3 ln (distance) | | | .0005 (.0003) | .0003 (.0003) | .0003 (.0003) | .0003 (.0002) |
| Mean affiliation 3 ln(distance) | | | | .0120** (.0033) | .0123** (.0035) | .0111** (.0032) |
| Bonacich power 3 ln(distance) | | | | .0307** (.0077) | .0282** (.0075) | .0270** (.0074) |
| Min (affiliate distance) | | | | | -.1361** (.0138) | -.1413** (.0143) |
| Same state | | | | | | -.1040 (.0957) |
| Prior state exp. | | | | | | .5022** (.0470) |
| Log-likelihood | -35881.01 | -35863.83 | -35590.63 | -35231.96 | -35214.84 | -35086.46 |
| χ^2 (d.f.) | | 34.36 (2) | 546.4 (4) | 717.3 (4) | 34.2 (1) | 256.8 (2) |

[†]Matched sample analysis of 40,203 realized ties. * indicates $p < .05$ ** indicates $p < .01$

investors and investment opportunities varies tremendously both by region and market. We construct two control variables to control for this heterogeneity. The first variable measures the richness of the local supply of venture capital with respect to a focal target firm. We create a localized venture capital density, $vc dens_t$, for target j at time t , which we calculate using the following equation:

$$vc dens_t = \sum_i \frac{vc_i}{1 + (d_{ij})},$$

where i indexes all venture capital organizations, vc is the number of investments that firm i made in period t , and d_{ij} is the distance between target j and venture capitalist i . This variable sums the inverse distances between target j and all active VC firms (see Sorenson and Audia 2000 for a more lengthy discussion of geographically weighted density variables). The analogous variable for the industry-specific supply of venture capital simply sums the proportion of VC investments in the target's industry prior to the current period:

$$vc ind dens_t = \sum_i (1 - industry distance_i),$$

where i indexes all venture capital organizations.

Supply of active targets

We construct parallel measures to capture heterogeneity in the demand for venture capital across regions and industries. We calculate a localized target density, $tdens_t$, around any VC firm i at time t using the following equation:

$$tdens_{it} = \sum_j \frac{f_j}{(1 + d_{ij})},$$

where j indexes all targets, f takes a value of 1 if firm j received financing in period t or a 0 otherwise, and d_{ij} denotes the distance between the venture capitalist i and the target j . This variable sums the inverse distances between VC firm i and all active targets. The complementary measure for variation in industry-specific demand for venture capital weights, from the standpoint of a focal VC firm i , the number of active targets in each industry according to i 's past industry investment profile:

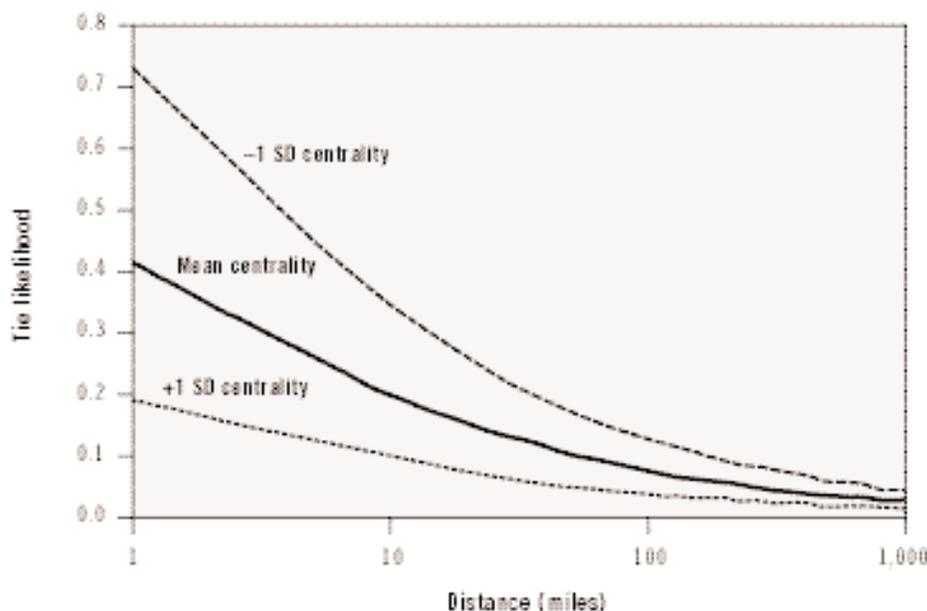
$$t ind dens_{it} = \sum_m p_m N_m,$$

where p denotes the proportion of VC i 's prior investments in industry m and N represents a count of targets in the current quarter in industry m .

²⁰ Because of the matched sample methodology, caution should be exercised when interpreting the main effects of VC attributes (as opposed to dyadic properties) on the probability of a tie. For example, it appears in Model 3 that the probability that a VC will make an investment in a target declines with experience. Since the probability of an investment remains relatively constant in each year of the data, variables such as age and experience that increase over time will appear to have negative effects on the probability of a tie. These terms should be understood primarily as intercepts for the interaction effects. In fact, in unreported models in which we include dummy variables for every calendar quarter, the reported results remain unchanged and most of the main effects fall to zero.

Figure 4

Investment likelihood by centrality and distance. The solid line indicates the impact of distance on the probability of investment for a VC of average centrality, whereas the dotted lines depict the importance of distance for VCs one standard deviation above and below the mean centrality level.



Prior state experience

Venture capitalists may develop new relationships in a geographic region when they invest in companies in it. If this occurs, then an initial investment in a locale should increase the likelihood of subsequent investment. We operationalize this idea by including a variable that indicates whether the VC has previously invested in the state where the target is located. To avoid simply picking up proximity to the venture capitalist's office, we also include a dummy variable that marks whether the target lies in the same state as the venture capitalist. The parallel term for industry distance would essentially dichotomize the industry experience variable, so we do not need to include an additional measure in the industry distance models to capture this effect.

4. Results

Table 2 reports the results of the rare events logit models for geographic distance. Model 1 provides baseline estimates of the probability of a tie using the local den-

²¹ The strong general experience interaction might stem from its relationship to the size of the VC firm (past deal count, which is the measure of general experience, also happens to provide the best measure of VC size available to us). As we noted above, in some instances—when the VC firm has a second office that is nearer to the target than its head office is—our measure of geographic distance underestimates the actual distance between the VC firm and target since we do not know the location(s) of satellite offices. Assuming that larger firms more likely have satellite offices, this might explain the greater tendency of more-experienced firms to invest in distant targets.

sity of VC firms around a target (VC density), the local density of active targets around a VC (target density), dummy variables indicating whether the target represents an early-stage investment and whether the VC has made a prior investment in the target, the measures of the geographic and industry distance separating the VC from the target, and an interaction between the early-stage dummy and the distance of the VC from the target. Consistent with the baseline expectation, the coefficients on the two distance variables indicate sharply lower investment probabilities as the distance between the VC firm and target increases; the likelihood that a VC invests in a target drops sharply as the target recedes from the VC in either geographic or industrial space. Thus, the main effect of distance operates as expected. The coefficient on the investment stage-by-distance interaction term suggests that, as we anticipated, geographic distance reduces the likelihood of investment even more precipitously if the focal target is at the seed or start-up stage. Not surprisingly, the baseline also shows that the probability of an investment increases substantially if a VC has invested in the target in a previous round.

Model 2 adds the age of the venture capitalist and an interaction term between VC age and the geographic distance between VC and target.²⁰ The positive and significant coefficient on the age-by-distance interaction term suggests that older venture capital firms more frequently make investments in geographically distant targets; the magnitude of the negative effect of distance on the probability of investment declines with the age of the VC. Thus, the geographic scope of investment activities increases with tenure in the industry. In Model 3, we begin to disentangle the concurrent processes that lie behind the age-distance interaction by adding the experience variables. The interactions between the two VC firm experience variables and the geographic distance between the target and VC both increase tie likelihood, demonstrating that the negative effect of distance on the probability of an investment attenuates with experience. Model 3 shows that general investing experience captures a larger share of the influence of the maturation process on the spatial reach of investments than does industry-specific experience. Contrary to our expectation, general investment experience extends the geographic scope of investment more substantially than does past investment experience in the target's industry.²¹

Model 4 incorporates the network-based measures derived from the quarterly co-investment matrices. After the regressions account for interactions between distance and (1) the strength of the relationship between a reference VC firm and the other members of the investment syndicate in a target, and (2) the centrality of the VC firm in the co-investment network, the interactions between distance and the age and experience variables no longer significantly affect the likelihood of investment. Thus, experience primarily influences the geographic scope of investing through the development of one's network through syndication; general

Table 3: Rare event logit models of geographic scope determinants[†]

| Variable | Model 7 | Model 8 | Model 9 | Model 10 | Model 11 |
|----------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Intercept | -21.69 (16.93) | -36.19** (17.50) | -54.68** (15.54) | -26.70 (16.09) | -7.735 (15.62) |
| VC industry density | .0080** (.0024) | .0069** (.0024) | -.0030 (.0023) | -.0003 (.0022) | -.0012 (.0021) |
| Target industry density | -.0060** (.0012) | -.0052** (.0012) | -.0031** (.0011) | -.0018 (.0011) | -.0031 (.0011) |
| Early stage | .4228** (.0604) | .4195** (.0604) | .3954** (.0627) | .3846** (.0592) | .3951** (.0544) |
| Prior | 4.019** (.0943) | 4.059** (.0879) | 4.300** (.0883) | 4.554** (.0697) | 4.222** (.0673) |
| VC age | | -.0266** (.0141) | .0071 (.0056) | .0032 (.0057) | .0070 (.0051) |
| General exp. | | | -.5207** (.1869) | -.9122** (.1955) | -.9917** (.1843) |
| Industry exp. | | | .5098** (.1863) | .9050** (.1962) | .9875** (.1851) |
| Mean affiliation | | | | -.0818* (.0341) | -.0854 (.0294) |
| Bonacich power | | | | -.3401** (.0696) | -.3288** (.0600) |
| Ln (distance) | -.1375** (.0174) | -.1400** (.0167) | -.1579** (.0163) | -.1625** (.0168) | -.1677** (.0167) |
| Industry distance | -1.473** (.0892) | -1.493** (.1064) | -1.363** (.0870) | -1.422** (.0895) | -.9934** (.0885) |
| VC age 3 industry dist | | .0177** (.0015) | .0024 (.0070) | .0018 (.0071) | .0000 (.0065) |
| General exp. 3 industry dist | | | .5183** (.1869) | .9112** (.1955) | .9906** (.1843) |
| Industry exp. 3 industry dist | | | .0138 (.0071) | .0150 (.0070) | .0010 (.0060) |
| Mean affiliation 3 industry dist | | | | .214** (.0435) | .0450 (.0371) |
| Bonacich power 3 industry dist | | | | .2889** (.0899) | .2773** (.0823) |
| Min (affiliate distance) | | | | | -1.973** (.0888) |
| Log-likelihood | -35756.77 | -35753.38 | -35473.05 | -35252.50 | -34701.17 |
| χ^2 (d.f.) | 6.78 (2) | 560.7 (4) | 441.1 (2) | 110.3 (1) | |

[†]Matched sample analysis of 40,203 realized ties. * indicates $p < .05$ ** indicates $p < .01$

experience proxies well for the development of a VC's network, but it has no net effect when we directly include the network-based variables in the models. The interactions in Model 4 indicate that a VC more likely invests in a far-off target when it has previously co-invested with other members of the syndicate financing that target. At a minimum, having other trusted partners in a syndicate augments a VC's confidence in the quality of a deal.

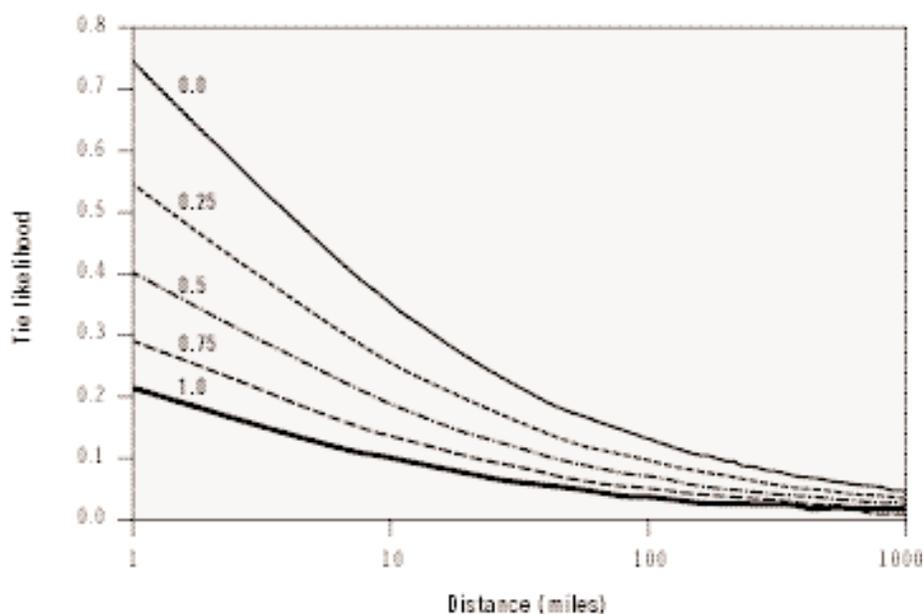
The coefficient on the Bonacich centrality-by-distance interaction in Model 4 demonstrates a substantial increase in the geographic range of investments among central VC firms. Thus, Model 4 reveals that increasing geographic distance has less of a negative effect on the probability of a tie for highly central venture capital firms. Figure 4 graphically depicts the relationship between centrality, geographic distance, and the likelihood that a VC invests in a target. The figure clearly illustrates that the decline in the probability of an investment as geographic distance increases is sharpest among peripheral (i.e., noncentral) firms. As we discuss in more detail below, this finding may stem either from central VC firms' ability to learn about distant targets from their relatively dispersed network, or from the higher status and visibility of central VC firms, leading other venture capitalists and entrepreneurs with attractive business plans to seek them out for investments.

The fifth model further demonstrates the importance of the composition of the syndicate for explaining spatial investment patterns. This model includes a separate term that represents the inverse of the geographic distance between a "trusted" member of a syndicate and the target, where a previous co-investment relation between the VC in a dyad and another member of the syndicate indicates trust. Thus, this variable measures the distance between the target and the closest member of the syndicate with whom the reference VC has an established relationship. The results demonstrate that the probability of an investment decreases sharply when the closest member of the syndicate with whom the VC has prior experience recedes from the target (recall that this variable codes the inverse distance, so an increase in the variable implies a decline in the distance between the trusted syndicate member and the target). Thus, the likelihood of a reference VC entering a deal increases considerably when it has a trusted colleague both in the syndicate and geographically near the target. We believe that venture capitalists' willingness to rely on the monitoring and advisory capabilities of other VC firms when they know them explains this result. Hence, VC firms appear to utilize trusted colleagues to identify, screen, and monitor potential investments in distant locations.

The final model in Table 2 introduces three variables, a prior state experience dummy (an indicator of whether VC firm i has previously invested in the same state as target j), a count of the number of past investments of the VC firm in the target's state, and a dummy indicating whether the VC firm and target are located in the same state. We include these measures to capture unobserved heterogeneity in VC

Figure 5

Investment likelihood by geographic and industry distance. The lines show the importance of geographic distance from the target in tie likelihood at different levels of industry distance, from an industry specialist (thin solid line) to an industry novice (thick solid line).



firms' geographic investment patterns. Not surprisingly, the results show that the likelihood of a VC funding a company in a state increases when the VC has previously funded a firm in the state. As the inclusion of the same state variable shows, location in the same state as the VC does not improve the likelihood of investment beyond the effects of geographic distance, thereby increasing our confidence in the specification of distance. Moreover, the inclusion of these control variables does not affect any of the coefficients of substantive interest.

Table 3 reports the estimates for the models using "industry distance" as the measure of distance between the VC firm and target in each dyad. Here, we report the same series of distance-by-age, experience, and network position interactions, but we define distance in terms of the dissimilarity of the VC's industry investment profile from the industry of the target. Model 7 forms the baseline and differs from Model 1 only in that it controls for heterogeneity in the supply of venture capital and of targets by industry, rather than by geography. Model 8 enters the VC age variable and an interaction between age and industry distance. Once again, the positive coefficient on the age-by-distance interaction in the regressions shows that the negative effect of industry distance on the probability of an investment attenuates for older VC firms. In Model 9, we include the terms for investing expe-

²² Given the strength of this effect, we also estimated the models only using the first financing round of each target in the data. Qualitatively, the results of models limited to the initial formation of a tie match the final models presented here identically.

rience. Paralleling the findings in the geography models, the previous investment experience variables appear to explain much of the variation in the maturation process with respect to the moderation of distance on the probability of an investment: the effect of the age-by-industry distance variable dissipates when we include the investment experience-by-industry distance interactions.

Model 10 includes the VC network variables and their interactions with industry distance, which again behave as anticipated. First, highly central VC firms and those that have previous investment experience with other members of a syndicate invest in targets at a greater industry distance. These results again coincide with the claim that venture capitalists exploit their contact network to gain access to deals in new areas. Past syndicate partners provide information about new deals and also augment a focal VC's confidence in the quality of investment candidates. However, unlike in the geography models, the experience terms remain significant predictors of the industry distance of investments. In Model 11, the addition of a term for the industry distance between the target company and the nearest affiliated syndicate partner allows us to investigate the importance of syndication in more detail. Paralleling the findings of the geography analysis, the likelihood of investment increases when a syndicate partner with whom the reference VC has prior experience lies near to the target in industry space (i.e., specializes in the target's industry). Thus, the findings on how industrial distance influences the probability that a VC invests in a target almost perfectly parallel the effects in the models that explore the influence of geographic distance.

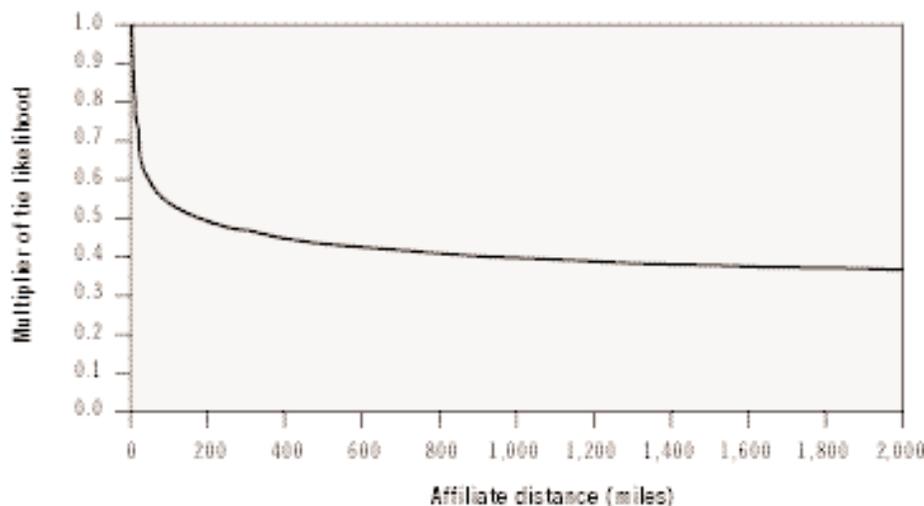
The control variables generally behave as expected. Prior investment in a target has a very large effect on the likelihood of subsequent investment. In the industry distance models, a prior investment increases the likelihood of future investment in a target by a factor of 50, while in the geographic distance models a prior investment increases the probability by a factor of 75.²³ The supply and demand variables have inconsistent and generally weak effects, but this should not surprise us because the matched sampling design itself substantially controls for these factors. The fact that ties appear more likely in early-stage investments merely reflects a somewhat lower draw of early-stage investments in the matched sample.

All models show that venture capital firms invest locally both in geographic and industrial space. Figure 5 depicts the likelihood of a venture capitalist investing in a target company as a function of both distance measures (using coefficients from Model 6). One can readily observe that the likelihood of an investment decreases rapidly. For example, venture capitalists invest in companies 10 miles from their offices at twice the rate of their investments in targets situated 100 miles away. Similarly, the probability of a financing relationship declines quickly with industry distance. A venture capitalist that specializes exclusively in the same industry in which the target company operates (i.e., it has no prior investments

²³ As one example, prominent VC firms typically have ongoing relations with prestigious investment banks. As several studies in finance document, "underpricing" in initial public offerings—the amount by which the closing price of a newly issued stock on the first day of public trading exceeds the price at which institutional investors buy the stock—typically declines when prestigious investment banks underwrite the IPO. Since underpricing lowers the amount of money raised in the IPO, the new venture typically benefits when prestigious investment banks underwrite its IPO. In addition, Stuart, Hoang, and Hybels (1999) show that start-ups with ties to high-status firms experience higher rates of IPO. Likewise, Podolny and Castellucci (1999) show that high-status VC firms can negotiate privileged access to investing in the later rounds of the best deals because of the many benefits they bring to the syndicate.

Figure 6

Investment likelihood by affiliate location. The line depicts the multiplier of tie likelihood given the affiliate's geographic distance (in miles) from the prospective target.



outside the target's industry) is nearly six times more likely to invest in that target than is a venture capital firm that has never before invested in the target's industry.

Because a variety of factors can explain the locality of investment, these results come as no surprise (other than perhaps the substantial magnitudes of the effects). Yet, the results also show that certain positional characteristics clearly affect venture capitalists' likelihood of investing outside of their local industrial and geographic neighborhoods. The Bonacich centrality measure has the strongest effect in the models. Given the inherent covariation between network centrality and actor prestige in communications networks, two subtly different processes probably combine to produce the overall result. On the one hand, central VC firms can deploy the extensive reach of their networks to identify and evaluate distant investment opportunities. Thus, highly central VCs have the capacity to activate the search and screening process over large distances. On the other hand, other VC firms and entrepreneurs, who hope to build relations with prestigious venture capitalists, solicit the participation of high-status VC firms in investment syndicates. Podolny (1993), Stuart (1998), and others discuss at length the value implicit in connections to highly central actors which, in this context, include enhanced legitimacy, quality certification, and access to the extensive social capital of central players.²³

Venture capitalists also look farther afield geographically and in industry space when they have prior experience investing with the other members of the syndicate. Two related factors—trust and reciprocity—account for this effect. First,

²⁴ This factor probably explains the bicoastal effect we observed in Figure 1 (a spike in the probability of investment in the 2,200- to 2,400-mile range). In the U.S., the heaviest concentrations of VC firms lie in the coastal regions (in particular, Silicon Valley, San Francisco, New York, and Boston). The linkages among these firms created by co-investment facilitate joint investments by East and West Coast venture capital firms. Our findings suggest that syndicates of East and West Coast firms occur most often when one of the members lies in close proximity to the target and has had previous dealings with VC counterparts on the opposite coast.

conditional on a willingness to invest together in the future, prior co-investing experience indicates perceptions of both trust and high competence between two venture capital organizations. Trust plays an important role in loosening localization constraints because it allows a VC firm to rely on the evaluations of another investor closer to the target in industrial or physical space. Second, the frequent appearance of repeated investments among the same sets of VC firms probably reflects an active norm of reciprocity in the VC community. VC firms build relationships with one another and then routinely “invite” trusted colleagues into new deals. Before the investing firm establishes itself in the venture capital community at large, however, it will probably not receive invitations from distant venture capitalists unaware of its existence or unsure about its competence. Only when a newly-established VC identifies promising deals in its local community can it begin to establish a position in the industry network by inviting co-investors into the deal, assuming that it can convince potential investors of the investment’s attractiveness.

The results also establish that VCs care not only whether their co-investors include trusted associates, but also that a trusted associate lies in close geographic proximity to the target company. Figure 6 shows the relationship between the probability of an investment and the distance of a target from the venture capitalist and the nearest syndicate partner with whom the venture capitalist has experience. From the figure, one can clearly observe the preference of venture capitalists to enter deals when a trusted party can conveniently monitor the target. From a policy perspective, this finding suggests that regions that lack a venture capital community might have difficulty accessing venture capital. Although venture capitalists expand the radii of their active investment spaces over time, this expansion appears to occur primarily through joining syndicates with lead venture capitalists in distant communities. This links the venture capital communities within the United States and possibly diversifies the risk specific to regional economic cycles.²⁴ Nevertheless, it does not open access to venture funding to communities and potential entrepreneurs that lie distant from venture capitalists’ offices.

5. Conclusion

Observers of economic geography often note that advances in communications media and methods of transportation paradoxically have done little to efface the spatial concentration of many industries; from film production and textiles to semiconductor chips and biotechnology, production concentrates in particular regions. Despite these communication advances, we believe that inherent boundaries around the flow of timely, reliable, and high-quality information produce localized patterns of exchange. These boundaries exist because interpersonal social relations concentrate within industries and regions more often than they bridge

industrial and regional boundaries. This observation reflects the simple fact that people converge in space and time more frequently when they live near one another and have occasion to meet in the course of work and play. Although the mass media and weak interpersonal ties routinely carry information across regional and community boundaries, we believe that the venture capital relation and other forms of exchange critical to the entrepreneurial process depend upon strong and embedded relations among the relevant actors. Because high uncertainty and significant information imbalances between market participants characterize this domain of activity, close and dense relationships among the relevant parties provide a critical catalyst to the process of mobilizing resources to build organizations.

Whenever personal and professional networks play a central role in economic activity, we will likely observe spatial patterns in the unfolding of that activity. We have demonstrated the existence of these spatial patterns in the investments venture capitalists make. We also have shown that the evolution of interfirm relationships in the venture capital community appears to provide the mechanism for the erosion of geographic and industrial boundaries in the dispensation of a venture capitalist's funds. VC firms with a history of provincial investment patterns and those without central positions in the industry's co-investment network tend to invest locally; those who have established many and dispersed relationships with other VC firms invest across geographic and industrial spaces more frequently. More generally, we believe that institutions supported by broad participation among market incumbents must precede the expansion of the spatial range of exchange in markets that rely on private information or require a high degree of trust for transactions to occur. In venture capital, the industrywide co-investment network provides this institutional infrastructure.

We believe that the exploration of when and how the local character of relationships intervenes in the functioning of markets offers an important avenue for further research. For example, anecdotal evidence suggests that the founders of early-stage companies employ network-based recruiting strategies to staff their fledgling enterprises. Indeed, one need look no further than the semiconductor industry in Silicon Valley, in which dozens of firms including Intel can trace their origins to the departure of key technologists from an established company (Fairchild Semiconductor) and whose founders then recruited friends and former colleagues to staff their new ventures. If founders' networks concentrate in space, then the reliance on network-based recruiting strategies may partially account for the geographic clustering of high-technology industries.

Before concluding, we wish to highlight again that the positional characteristics have virtually identical effects in moderating the influence of the two measures of distance—geographic and industrial—on the probability of an investment in a VC firm-target dyad. The similarity of the findings stems from the underlying

correspondence of the two measures of distance; both affect the likelihood that the two parties are embedded in a network of secondary relationships. Although a variety of factors can explain homophilous patterns of interaction, we believe that our findings provide substantial support for an opportunity-based theory of market exchange. Accounts that would attribute localized interaction patterns to preferences would suggest that the spatial range of investments should not expand over time unless firm preferences evolve. A change in the cost of investing at a distance as an investor gains experience seems to offer the most likely cause of such a preference shift. Although we do in fact show that the spatial reach of venture capital firms expands as they mature, we also decompose this effect by demonstrating that the development of a set of trusted colleagues throughout the investment community drives this expansion. Though we suspect that rational preferences for localized investing continue to operate, deviations in the salience of geographic and industrial proximity appear to stem from the underlying social structure of the investing community, rather than from shifts in the preference distribution for propinquity and homophily in exchange.

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