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Beyond homophily: Syndication networks in venture capital investments

超越同質化：創投中的聯合網絡

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Abstract: Drawing on social embeddedness theory, the existing literature contends that interorganizational networks arise from familiarity, but relatively few studies have studied similarity. In this study, we address the issue of homophily as a mechanism for network formation and its limits. We explore the circumstances that motivate an organization to form a network comprising dissimilar partners. We tested our argument using data on syndication networks for 5,350 portfolio companies in the U.S. venture capital industry from 1980 to 2003. The results provide some evidence that spatial uncertainties and behavioral uncertainties are critical to the formation of a hybrid syndication network involving both CVC and IVC firms. Spatial uncertainties arise when VC investments involve substantial information asymmetries between VC firms and the companies invested in, particularly when there is geographic and industry space. Behavioral uncertainties result from the issue of incomplete information between lead VC firms and their partners, making it difficult to form expectations about another's intentions and behaviors. The negative relationship between the likelihood of hybrid network formation and the presence of geographic space is moderated by the presence of industry space between lead IVC firms and target companies. Past experience with hybrid networks and a large number of

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participants will facilitate the formation of a hybrid network by reducing partners' behavioral uncertainties.

Keywords: Homophily, syndication network, network formation.

摘要：現有文獻借鏡社會鑲嵌理論，認為組織之間網絡源自於熟悉度，但對於相似性的研究相對較少。本研究提出同質性作為網絡形成的機制及其局限性的問題。我們探討了促使組織形成包含異質夥伴之網絡的情境。本研究使用 **1980** 年至 **2003** 年美國創投產業 **5,350** 家投資組合公司的聯合投資網路資料檢驗了我們的論點。研究結果顯示空間不確定性和行為不確定性對於涉及 **CVC** 和 **IVC** 的混合聯合投資網路的形成至關重要。當創業投資涉及創投公司和被投資公司之間的大量資訊不對稱時，特別是當存在地理和行業空間時，就會出現空間不確定性。行為不確定性是由於領導創投公司與其合作夥伴之間的資訊不完整問題造成的，這使得人們很難對他人的意圖和行為形成預期。混合網絡形成的可能性與地理空間的存在之間的負向關係，透過領導投資的 **IVC** 公司和目標公司之間的行業空間的存在來調節。過去的混合網路經驗和大量參與者將透過減少夥伴的行為不確定性來促進混合網路的形成。

關鍵詞：同質性、聯合網絡、網絡形成

1. Introduction

The number of studies on network formation in management and sociology has been increasing drastically. Various theories of network formation ultimately boil down to two main theoretical arguments: familiarity and similarity. Inspired by Granovetter's social embeddedness theory, the familiarity argument proposes that network formation is subject to the influences of prior relations among actors on their subsequent economic behavior. It focuses on three mechanisms underlying network formation: repetitivity (when a past partner renews a

relationship) (Gulati, 1995; Podolny, 1994), transitivity (when a triad connects two actors) (Baker, 1990; Uzzi, 1996), and reciprocity (when a recipient of a sent tie returns an offer for interaction) (Dyer and Chu, 2003; Powell, 1990). In contrast, the similarity argument is based on homophily, or the notion that similarity breeds connection (Homans, 1950; Lazarsfeld and Merton, 1954). Homophily is the strongest single factor to predict various types of interpersonal relationships, ranging from marriage and friendship to work advice (McPherson *et al.,* 2001).

At the organizational level of business practices, firms tend to form alliances with familiar partners because trust generated through repetitivity, transitivity, and reciprocity between exchange partners is able to lower transaction costs (Dyer, 1997), increase flexibility to respond to market uncertainty (Beckman *et al.*, 2004; Iurkov and Benito, 2020; Uzzi, 1997), encourage knowledge sharing (Dyer and Chu, 2003), and allow role specialization and non-redundancy (McEvily *et al.*, 2003). Regarding the similarity argument, Rosenkopf and Padula (2008) studied inter-organizational ties among U.S. cellular communication firms and found that homophily, based on similarity in prominence between firms, predicts shortcut formation (where shortcuts refer to ties that span locally embedded clusters which were not connected) but not alliance formation within clusters. Schoenherr and Wagner (2016) studied new product development and showed that the higher the level of homophily within a project, the higher the supplier involvement (Ertug *et al.* 2022). Nevertheless, if the formation of networks is solely driven by familiarity or similarity, the network will evolve toward dense, unconnected clusters with familiar or similar actors - an assertion that is obviously inconsistent with many real-world networks.

While there is an existing understanding of the factors that influence the formation of relationships between firms, Ahuja *et al*. (2012) highlight the need to further understand the origins and evolution of alternative types of network structures. This raises the research question: How and why do organizational (and interorganizational) networks evolve to take the forms that they do? Thus, to account for network change, the familiarity argument aims to identify several factors that motivate actors to form relationships with unfamiliar partners.

Beckman *et al*. (2004), for instance, distinguished firm-specific uncertainty from market uncertainty and argued that the former caused firms to form new relationships with unfamiliar partners while the latter drove firms to reinforce relationships with existing partners. Drawing on the behavioral theory of the firm, Baum *et al.* (2005) argued that an organization was willing to take risks to partner with strangers when its performance was below its aspiration level.

Despite the central role that homophily plays in the study of social networks at the individual level, there has been relatively little literature concerning the reasons why firms form relationships with dissimilar partners. The closest work is by Sorenson and Stuart (2008). They extended Feld's (1982) similarity argument at the interpersonal level to consider how attributes of the social context affect firms' propensity to form distant ties in the U.S. venture capital (VC) industry. Moreover, the self-production characteristic of homophily may strengthen social stratification and dampen innovations. It is therefore critical to study the conditions under which a firm is more likely to go beyond homophily and form an interorganizational network with dissimilar partners.

In this paper, we attempt to accomplish this task by developing arguments to account for the formation of hybrid networks at the interorganizational level. A hybrid network refers to a network consisting of two distinct and dissimilar actors' attributes. The core argument of our paper is that the choice between a hybrid network and a homogeneous network depends on the information, resources, and capabilities required to achieve common goals, as well as the challenges of cooperation and coordination arising from spatial uncertainty and behavioral uncertainty. We developed several hypotheses and empirically examined them using a dataset on syndication networks by 8,403 portfolio firms in the U.S. VC industry from 1980 to 2003. The syndication network in the industry provides an excellent context for testing our hypotheses. This is not only because syndication network data in the U.S. VC industry is well-documented and readily available, but also because the characteristics of the industry's syndication network can alleviate two empirical issues in studying hybrid networks. First, defining a hybrid network can be challenging and tricky in some cases. Given multi-dimensional

attributes, any network must exhibit homophily in some attributes but heterophily in others. Second, incorporating information about actors' multi-dimensional attributes to explain network patterns is extremely complicated (Contractor *et al.*, 2006). The VC industry consists of two distinct types of VC firms: independent VC (IVC) and corporate VC (CVC). The former focuses on financial returns, while the latter focuses on strategic goals. This significantly simplifies the empirical concerns. Our empirical results indicate that the negative relationship between the likelihood of hybrid network formation and the presence of geographic space is moderated by the presence of industry space between lead IVC firms and invested companies. If such industry space exists, the likelihood of hybrid network formation increases with the mitigation of the information asymmetry problem. Past experience with hybrid networks can help ameliorate coordination difficulties caused by incomplete information, and a large number of participants will facilitate the formation of a hybrid network by reducing partners' behavioral uncertainties.

This paper is organized as follows. In the next section, we conceptualize homophily as an organizing principle underlying interorganizational networks and develop arguments regarding the limits of homophily. We then build upon the argument to develop hypotheses specifying conditions under which a firm is more likely to form a hybrid network. The next step involves operationalizing measures and conducting statistical analysis for empirical testing. We then present our empirical results on the formation of hybrid networks. The discussion concludes with an analysis of the results and their implications.

2. Theory and hypotheses

2.1 Homophily vs. heterophily and Network Change

Homophily is one of the most prevalent principles underlying personal networking behavior that has been widely observed in various kinds of personal relationships. Most people are most likely to interact with others who are similar in race, gender, education, social status, beliefs, etc. (Homans, 1950; Lazarsfeld

and Merton, 1954). Due to geographic proximity, family ties, organizational foci, and isomorphic positions in social systems, interpersonal networks tend to be homogeneous with regard to many sociodemographic, behavioral, and intrapersonal characteristics (Feld, 1982; McPherson *et al.*, 2001). McPherson *et al*. (2001) extensively reviewed empirical evidence on interpersonal networks and concluded that the literature consistently demonstrates homophily in network systems and homogeneity in personal networks across various relationships and dimensions of similarity.

While homophily plays a central role in the social network literature, it is relatively underutilized in explaining the formation of interorganizational networks. By only interacting with others who are similar to us, we reinforce anything as a result of our position. Homophily and social networks thus breed each other: An actor is more likely to form a relationship with someone who is similar to them. Communications between homophilous actors become more effective (Alpert and Anderson, 1973; Rogers and Bhowmik, 1970), leading to greater consensus and similarity between them. It also leads to a higher rate of interaction and so on. The self-production characteristic of homophily tends to lead networks toward stable, dense, unconnected clusters, unless they are disrupted by exogenous environmental shocks. The study of forming relationships with dissimilar partners is critical to the theory of network change. Accordingly, an improved understanding of network change is important for two reasons. First, networks often play significant functional roles at many levels of analysis. Different network structures and positions may also imply differential advantages or constraints for the actors embedded in the network (Burt, 1992). Understanding how the network will evolve can help us predict and understand the changes in the distribution of benefits and constraints within the network (Ahuja *et al.*, 2012). Second, a comprehensive understanding of network outcomes requires an appreciation of the evolution of the underlying network structures (Ahuja *et al.*, 2012).

Indeed, homophily and heterophily seem to characterize many motives for interorganizational network formation. The market power argument, based on

either collusion or economies of scale, is highly relevant for the formation of homophilous networks. Meanwhile, the arguments of risk reduction and accessing complementary resources and capabilities are relevant for the formation of heterophilous networks. Moreover, one of the central debates in the social network literature concerned the differential utilities of social capital derived from homophily and heterophily. Homophilous social capital is conceived as a network with high density or closure, as such a network promotes trust and norms of cooperation (Coleman, 1988). As network density highly correlates with homophily in characteristics and resources among actors (Burt, 1987; Homans, 1950; Lazarsfeld and Merton, 1954), such a network is associated with collective solidarity. In contrast, heterophilous social capital arises from sparse networks that enable actors to access novel information and resources in a timely manner through bridges (Burt, 1992; Lin, 1999). The diversity of information and resources embedded in networks facilitates specific actions to achieve instrumental goals. However, a review of the literature suggests that these arguments were originally derived from interpersonal networks. It is far from clear how to apply the concept of homophily to the interorganizational network setting as well as how to specify conditions under which an organization is more likely to form inter-organizational relationships with dissimilar partners.

Interacting with similar organizations may lead to over-embeddedness, hindering the inflow of novel information. In this scenario, the lack of dissimilar or distant partners that are not embedded in a focal firm's network may reduce the exposure of firms to new innovative ideas (Uzzi, 1997). As such, each relationship in the network contributes little instrumental value and becomes redundant. See also Burt (1992), who advanced our understanding of the importance of establishing heterophilous networks with dissimilar, non-redundant partners.

2.2 Syndication networks in the U.S. VC industry

VC firms are known for providing financing and business expertise to high-potential growth companies, enabling them to capitalize on market opportunities in the U.S. Using funds primarily raised from institutional investors and wealthy

individuals, they identify and finance risky, early-stage companies. Their investments are typically focused on cutting-edge, innovative sectors of the economy, such as ICT, biotechnology, and healthcare in the U.S. It is well known that VCs play a prominent role in the financing of high-growth and high-tech entrepreneurial ventures (Braunerhjelm and Parker, 2010). The high variation in expected returns on investment makes the selection of investment opportunities a key function of the VC organization (Lockett and Wright, 1999). Such selection is challenging because the projects that are the targets of VC investment are characterized by significant informational asymmetries compared to publicly listed companies (Fama, 1991). VC firms have developed various strategies for dealing with risk, deal selection, and monitoring (see Wright and Robbie, 1998, for a review), one of which is the syndication of investments (Cheng and Tang, 2019). An equity syndicate involves multiple VC firms taking an equity stake in an investment and sharing a joint payoff (Wright and Lockett, 2003). The operation of the syndication involves a lead and non-lead funds that make a common decision under uncertainties (Lockett and Wright, 1999). VCs typically finance specific projects despite numerous uncertainties, as there is limited public information available. These uncertainties lead to information asymmetries and incomplete information problems. Entrepreneurs often have private information about their businesses and tend to overstate future profitability to secure the supply of financial capital from VCs.

The VC industry comprises two types of organizations: independent VC (IVC) firms and corporate VC (CVC) firms. The majority of firms in the VC industry are known as IVC firms. These firms are formed by individuals through limited partnerships, pooling and managing money from entities such as pension funds and wealthy individuals (Cheng and Tang, 2019). IVC firms have a significant performance-pay component. They receive "carried interest," which amounts to approximately 20% of the profit generated by the fund (Cheng and Tang, 2019; Dushnitsky and Shapira, 2010). CVC firms are the second-most prevalent group in the market for entrepreneurial financing. CVC, in this context, refers to equity or equity-linked investments in young, privately held companies, where the

investors act as a financial intermediary for a non-financial corporation (Keil *et al.*, 2010). During the 1990s, large corporations in a wide variety of industries set up corporate venturing units (Cheng and Tang, 2019). CVC firms do not offer the same high-powered incentives as IVC firms. The most common form of compensation for managers in CVC programs is a fixed salary (Cheng and Tang, 2019; McNally, 1997). To sum up, IVC firms prioritize financial returns, while CVC firms prioritize strategic goals. The IVC-CVC dichotomy clearly represents a distinguishing attribute of VC firms.

In this study, we focus on these two types of investors to present heterogeneous actor attributes. While IVCs are primarily concerned with the financial returns from their portfolio companies, CVCs focus on other benefits that may arise from the investment for their corporate parents, such as gaining exposure to pioneering technology and establishing early alliances in the product markets. IVC firms have two strategic choices when they would like to finance their invested portfolio companies: making sole investments or joining syndication networks. Once a lead IVC firm decides to select a syndication network, it basically has two options for forming one: an IVC network (syndication with other IVC firms) or a hybrid network (syndication with both CVC and IVC firms).

2.3 Hybrid networks in VC Syndication

In the context of VC syndication, we argue that the choice between a hybrid network and a homophilous network depends on the resources and capabilities necessary for achieving common goals as well as cooperation and coordination difficulties arising from various kinds of uncertainties. Specifically, we distinguish between cooperation and coordination difficulties arising from two kinds of uncertainties: spatial uncertainties and behavioral uncertainties, with each corresponding to a distinct informational problem (Camerer, 2003; Gulati *et al.*, 2005; Shen and Reuer, 2005). Issues related to network formation can be classified as information asymmetry and information incompleteness. Information asymmetry increases cooperation difficulty, and information incompleteness leads to coordination failure. The problem of information asymmetry arises when one

actor has private information about the quality of the target in interest that the other actor does not have. The possibility of adverse selection arises when the informed actor cannot credibly signal its value to the less-informed actor, resulting in price discounting and a lower average quality level in equilibrium (Akerlof, 1970). In contrast, the incomplete information problem arises when one actor's knowledge about the possible actions of other actors and the corresponding payoffs is incomplete (e.g., Harsanyi, 1967), resulting in coordination failure (Camerer, 2003). In other words, cooperation involves aligning interests, while coordination involves aligning actions.

Actors in a homogeneous network find it easier to cooperate and coordinate compared to those in a hybrid network. This is because interactions with similar actors require less effort, and a shared common code can facilitate communication among actors, helping them reach a consensus on their actions. However, the network's effectiveness is less obvious than the argument suggests. In a completely homophilous network, actors are likely to have similar information and knowledge. As a result, each relationship in the network adds little instrumental value to it and becomes redundant. On the other extreme, in a completely heterophilous network, actors do not share a common code and can hardly communicate effectively. Indeed, the existing empirical evidence seems to support the idea that a certain degree of heterophily is necessary to enhance network effectiveness and facilitate innovations. (Burt, 1992; Rogers, 2003). More effective change agents are those who are most like other average actors in all characteristics except for the specialized knowledge necessary for the task. For instance, the most effective change agents in Taiwan's agricultural modernization program were more technically competent than their farmer counterparts, but they were perceived as homophilous on most other characteristics as they operated farms and gained experiences (Lionberger and Chang, 1970, as cited in Rogers and Bhowmik, 1970).

In summary, the likelihood of forming a hybrid network increases in the presence of surrounding uncertainties when (1) the requirement of diverse resources and capabilities is high and (2) the value derived from cooperation and coordination outweighs the cost. We elaborate on the argument based on VC-VC

(the horizontal relationship between two VC firms) and VC-I (the vertical relationship between a VC firm and an invested company) and develop the hypotheses below.

2.4 Spatial uncertainties

Uncertainty is a central concept in organizational theory (March and Simon, 1958). At the organizational level, uncertainty is defined as the "difficulty firms have in predicting the future, which comes from incomplete knowledge" (Beckman *et al.*, 2004, p. 260). This characterizes situations where actors cannot anticipate or predict future states of the world (Pfeffer and Salancik, 1978). Under conditions of uncertainty, imperfect information prevents actors from knowing how to behave and what to expect from their environment (Hogg and Terry, 2000). VC firms have contributed to innovation in the US economy, particularly in fast-growing, high-technology sectors characterized by information asymmetries and uncertainties.

Spatial uncertainties exist when VC investments involve substantial information asymmetries between VC firms and invested companies (VC-I). Entrepreneurs in invested companies usually have superior information about the quality of the company and its innovation. Yet, without a mechanism to send credible signals to VC firms, entrepreneurs have incentives to misrepresent the true value of innovation. To deal with the information asymmetry problem, VC firms' major roles are pre-investment opportunity identification and post-investment monitoring (e.g., Braune *et al.* 2021; Gupta and Sapienza, 1992; Sorenson and Stuart, 2001).

These tasks become more challenging when performed at a distance due to increased spatial uncertainties. Firms within the same geographic area tend to face the same regulatory environment and share social networks characterized by high clusters and low social distances, a phenomenon known as a small-world network (Watts and Strogatz, 1998). As a result, VC investments tend to be highly localized in terms of physical space (Gupta and Sapienza, 1992; Norton and Tenenbaum, 1993). The greater the geographic space between a lead VC firm and

the invested companies, the greater the degree of information asymmetry that the VC firm confronts. To mitigate this uncertainty, organizations may seek to establish partnerships with other firms (Beckman *et al.*, 2004; Gulati, 1995; Pfeffer and Salancik, 1978). Although associating with an exchange partner might enable an organization to mitigate some effects of market uncertainty, selecting the appropriate network partner is a challenging and critical issue. (Collet and Philippe, 2014).

Spatial uncertainties arise not only from geographic space but also from industry space. VCs usually invest in numerous deals over time, leading to a wealth of knowledge regarding investment portfolios. However, when a VC firm invests in a company from a brand new industry, it not only has to face an unfamiliar regulatory environment but also has fewer sources of information. VCs may find their existing knowledge pool has limited value in terms of understanding and selecting targets, let alone monitoring and adding value to invested companies.

Nevertheless, while prior research has found that VC syndication networks effectively reduce spatial uncertainties arising from information asymmetry by facilitating the diffusion of information across spatial boundaries (Sorenson and Stuart, 2001), this line of work does not differentiate between actor attributes. Specifically, IVC and CVC possess distinctive resources and capabilities to address various sources of information asymmetry between VC firms and invested companies. An IVC firm is more likely to choose an IVC partner to facilitate physical interaction with entrepreneurs for identifying opportunities and monitoring activities. Under this scenario, a lead IVC firm tends to select IVC partners because an IVC/homophilous network requires less effort to interact, making it easier to communicate and achieve consensus based on a shared common code. To overcome information asymmetry arising from the existence of geographic space between a lead VC and the target company it evaluates, the benefits of homophily outweigh the propensity to form a hybrid network. Accordingly, we expect that the likelihood of forming an IVC-lead IVC/homophilous network will increase with the presence of geographic space. That is to say, the propensity to form a hybrid network will decrease with the

existence of geographic space. Thus, we hypothesize that

H1: The likelihood of hybrid network formation is negatively related to the presence of geographic space between lead IVC firms and invested companies.

Additionally, cooperating with IVC partners encourages further interaction between firms, as similarities and mutual attraction reinforce each other. However, having similar partners can lead to a higher degree of information redundancy, limiting the possibilities for learning and reducing uncertainties by forming homophilous networks. In our argument, the focal IVC firm has the motivation to reduce spatial uncertainties between itself and the invested companies. Therefore, the attractiveness of a dissimilar partner increases when the relationship provides non-redundant information, leading to better opportunities to reduce spatial uncertainties. CVC investments focus on strategic purposes such as gaining exposure to new markets and technologies, identifying acquisition targets, exploring market extension possibilities (Siegel *et al.*, 1988; Sykes, 1990), and serving as conduits for knowledge spillovers from innovative start-ups to corporate investors (Wadhwa and Kotha, 2005). As a result, they are more likely to possess technological competence in related or complementary industries with respect to their parent firms. Therefore, a CVC partner is most likely to complement a lead IVC's knowledge in the presence of information asymmetry arising from industry space and moderate the above-mentioned negative relationship between geographic space and the formation of hybrid networks. As such, the advantage of hybrid networks must be evaluated in relation to the specific task at hand and the uncertainties associated with it. Hybrid networks (involving both CVC and IVC firms) are more likely to prevail when accessing diverse resources and capabilities is critical to accomplishing tasks and when the environment presents significant information problems to the actors. The resulting hybrid network enables the lead IVC to access not only common codes from IVC partners but also deeper and complementary knowledge from CVC partners, mitigating the information asymmetry problem. Hybrid networks, in turn, improve the lead IVC's portfolio selection and increase the value-added to the invested company. Thus, we argue that

H2: The negative relationship between the likelihood of hybrid network formation and the presence of geographic space is moderated by the presence of industry space between lead IVC firms and target companies. If such industry space exists, the likelihood of hybrid network formation increases.

2.5 Behavioral uncertainties

Allying with partners who are dissimilar comes with consequences and associated costs. Hybrid networks are likely to involve costlier governance arrangements and higher contracting costs between lead and no-lead VC firms. The behavioral uncertainty in networks arises from incomplete information about the possible actions of other partner VC firms. While information asymmetry is a problem between VC firms and invested companies (VC-I), the issue of incomplete information exists between lead VC firms and their partners (VC-VC). Information incompleteness makes it difficult to form expectations about another's intentions and behaviors, leading to uncertainty about a partner's behavioral integrity (Williamson, 1985), skills, goals, reliability, and the pair's ability to work together (Camerer, 2003; Powell, 1990). The most straightforward approach to addressing uncertainties in network behavior is to enhance the quality of the information used in selecting partners. Because IVC firms might not be able to effectively evaluate potential partners prior to syndication, a key issue in the selection process is to minimize uncertainties regarding the potential partners' capabilities (Kogut, 1988) and trustworthiness (Gulati, 1995).

Homophily is a powerful tool to address partners' behavioral uncertainty. Similar firms tend to communicate easier, share cultural norms, and better predict the behavior of others (Camerer, 2003; Lazarsfeld and Merton, 1954). Nevertheless, homogenous networks may come with the price of a lack of novel information, complementary capabilities, and resource diversity, which in turn limits the instrumental value of homophily. A hybrid network has its highest value when novel information, complementary capabilities, and resource diversity are required to achieve its performance of a network. To the extent that such an issue can be addressed in a cost-effective manner, firms tend to favor a hybrid network

over a homogenous one.

Past networking experience is a reliable and trustworthy source of information. Frequent interactions and the potential risk of termination can encourage the sharing of information. These relationships also provide valuable opportunities for valuable experience to gain the resources and capabilities of the partners involved. Past hybrid network experience can reduce partners' behavioral uncertainties by improving mutual understanding and creating a shared code between IVC and CVC firms. Since network partners tend to pursue enduring relations with one another (Podolny and Page, 1998), networking experience also promotes behavioral integrity in the shadow of the future. It improves the effectiveness of communication within hybrid networks, minimizes the potential for coordination failure, and releases the lead IVC from shackles for similar others who can't provide missing resources. Thus, we expect that past hybrid network experience will facilitate the formation of hybrid networks by reducing partners' behavioral uncertainties.

H3: The likelihood of forming a hybrid network is positively related to IVC firms that have past experience with hybrid networks

In the context of hybrid networks, IVC firms prioritize financial returns, while CVC firms prioritize strategic goals. Facilitating coordination between IVC and CVC firms to collectively work together to reduce the problem of incomplete information may still be challenging. For example, when considering the outcome of a syndication network as a collective good, each firm may perceive little incentive to contribute to the common good and instead choose to free ride on the efforts of other partners' efforts (Olson, 1965). Although profit-sharing is based on shares, some contributions, such as information sharing, are unobservable.

We argue that behavioral uncertainties can be ameliorated by risk sharing among a large number of participants within hybrid networks. The lead VC firms are concerned about the resources and capabilities that their partners bring to the table. According to Sorenson and Stuart (2008), they suggest that individuals may perceive the risks of affiliating with strangers (i.e., dissimilar partners) as lower in a setting with a large number of participants. A larger number of participants often

reduces the risk associated with the actions of any given member. The contribution of each member in a multilateral exchange, and consequently, the influence of the actor, diminishes as the total number of participants increases. In other words, the negative consequences of social loafing for the outcome of a team-based initiative fall with the size of the team. The "social loafing" effect occurs when individual effort declines in a curvilinear fashion when people work as a group or believe they are working in a group (Ingham *et al.*, 1974). In this sense, even if some members of the group fail to meet their obligations, the remaining participants can distribute the unanticipated costs across a larger whole (Sorenson and Stuart, 2008) to mitigate behavioral uncertainties due to incomplete information between lead IVC firms and their partners.

H4: The likelihood of forming hybrid networks is positively related to the number of participants in syndication networks.

3. Methods

In our analysis, we investigate the determinants of strategic choice between homogenous networks and hybrid networks made by lead venture capitalists in the U.S. We presume that different factors affect their choices and separate our database into subsamples to explore our distinct hypotheses on lead IVC firms, as they are the majority in the VC industry. To examine the choices between an IVC network and a hybrid network for lead IVC firms, we employ logit regression in a panel format to analyze the influence of spatial uncertainties and behavioral uncertainties. We also included year dummies and industry dummies to control for ten common categories in the model. Additionally, we concluded, based on the Hausman test, that a fixed effects model would be more appropriate for our dataset than a random effects model.

3.1 Sample

The data for our analysis is sourced from Thomson Financial's VentureXpert database, provided by Venture Economics. This database has been compiling data on venture capital investments since 1977, with historical data dating back to the

early 1960s. This extensive data source has been widely used in previous VC research (e.g., Braune *et al.* 2021; Bygrave, 1988; Gompers, 1995; Sorenson and Stuart, 2001, 2008). Venture Economics has been collecting VC investment data since the 1970s by utilizing annual reports of VC funds, establishing personal contacts with funds' personnel, analyzing initial public offering (IPO) prospectuses, and tracking acquisitions announced in the media. The database contains information on over 210,000 private equity investments. A single financing round consists of several individual investments. It is widely recognized as a leading source of U.S. VC investment data. We focus exclusively on investments made by U.S.-based VC funds and exclude those made by angels and buyout funds. We distinguish between funds and firms. While VC funds have a limited life, the VC firms that manage the funds have no predetermined lifespan.

We constructed our sample by including target companies, VC funds, and rounds of totaling 105,685 observations for all IVC and CVC funds between 1980 and 2003. We have a total of 9826 portfolio companies are included in our database. We identify a lead VC firm as the largest cumulative investor in a specific portfolio or invested company. 91% portfolio companies can identify their lead VC firms, CVC firms lead 677 portfolio/invested companies out of 2,226 target companies-VC firms observations, while IVC firms lead 8,285 portfolio/invested companies out of 22,187 target companies-VC firms observations. After removing the observations with missing information, we finally have 567 CVC lead portfolio companies and 7,836 IVC lead portfolio companies. This dataset includes three types of investment: 2,735 sole investments, 4,160 IVC networks (all IVC syndication), and 1,390 hybrid networks (syndication with both CVC and IVC firms). Sole investment refers to the VC firm investing in a target company independently, without collaborating with other VC firms. A homogenous network, is formed when a lead IVC (or CVC) firm selects partners with similar attributes to form syndicated network with other IVC firms (or CVC firms). A hybrid network is formed when a expresses the lead IVC (or CVC) firm selects partners with diverse attributes to form a syndicated network involving both CVC firms and IVC firms. To test our hypotheses, we focused on

5,550 portfolio companies invested by lead IVC firms and examined the strategic choices between IVC networks and hybrid networks. After removing the observations with missing information, we finally have a sample of 5,350.

3.2 Measures

3.2.1 Dependent variables

3.2.1.1 Hybrid network

This dependent variable was coded as 1 if the lead IVC firm formed a hybrid network, and 0 represented an IVC network instead.

3.2.2 Independent variables

3.2.2.1 Geographic space

Drawing on Cumming and Li's (2013) research on cross-state differences in VC investments, this independent variable was constructed by examining the locations of lead VC firms and their target companies. We coded them as "1" if they were located in different states and "0" otherwise.

3.2.2.2 Industry space

We initially used this variable to reflect the focal VC firm's past investment experience in specific industries. A dummy variable was used to indicate whether the focal VC firm had invested in the industries with the same 2-digit VEIC code. We code it as "1" if there was an investment and "0" otherwise. Given that some studies have emphasized the concentration of VC investments in specific industries, we have incorporated industry investment experience into this study to address our research questions.

Second, we adopted the measurement from Sorenson and Stuart (2001) to define industry distance, reflecting the similarity between the industry profile of the venture capitalist's prior investments and the industry of the target firm. Ideally, this measure would consider actual differences in the production processes and

market dynamics of different industries to capture the transferability of knowledge across domains. However, the construction of any such measure would necessitate making numerous arbitrary assumptions. To avoid such assumptions, we choose 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.

$$\text{industry distance}_{ij} = \frac{\sum p_{nm}}{\sum p},$$

where *i* indexes VC firms, *m* denotes the industry of the startup *j*, and *p* represents an array of all prior investments in any industry. Industry distance ranges from "0," indicating that all of a venture capitalist's prior investments fall within the target's industry, to "1," indicating that the venture capitalist has no previous investments in the target's industry.

3.2.2.3 Hybrid network experience

We used a dummy variable to capture whether a lead VC firm had prior experience with previous hybrid networks before making this investment. We code it as “1” only when a lead VC firm has previously invited other VC firms with different attributes, and “0” otherwise. Only past “leading” (not “joining”) hybrid network experience is counted in this variable. We believe that only by acting as the lead, the VC firm has sufficient experience to reduce the higher coordination costs resulting from the attributes of different actors.

3.2.2.4 The number of participants in syndication networks

To measure the number of participants in syndication networks, we tallied the number of VC investors involved in the syndicate for each invested company.

3.2.3 Control variable

3.2.3.1 Fund size

We used the total amount of committed capital to all portfolio companies by

a focal VC fund as its fund size. Log transformation is used for regression analysis because the data is highly skewed and kurtotic.

3.2.3.2 Firm age

We calculated the number of years between the focal VC firm's initial investment and its most recent investment. This variable was measured at the firm level, not the fund level, since we assume that investment experience accumulates at firms. Most VC funds are structured as closed-end, often ten-year, limited partnerships.

3.2.3.3 Investment amounts

We calculated the total amount invested in a specific portfolio company for this variable. The log-transformed amount is used in regression analysis.

3.2.3.4 Industries categories

Referring to Sorenson and Stuart (2008), we categorized all industries of portfolio companies into ten groups to control industry effects. They include communications and media, computer hardware, semiconductors, biotechnology, health/medicine, consumer-related businesses, internet-specific businesses, computer software, energy or industrial businesses, and other businesses.

4. Results

Table 1 presents descriptive statistics and correlations for all the variables of interest in IVC lead investments. The fund size, firm age, and investment amount variables have been log-transformed for multinomial logit regression analysis due to their highly skewed and kurtotic distributions.

The hypotheses that examine the relationship between explanatory variables and the likelihood of hybrid network formation are best tested using a logit model that compares hybrid networks with IVC networks. We test our hypotheses on IVC lead syndication to examine the determinants of hybrid network formation. Table 2 illustrates the governance mode choices of lead IVC firms. Model 1 in

Table 1
Descriptive statistics and correlations for IVC lead investments

Variable	Obs	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10
Hybrid network	5,550	0.2505	0.4333	0	1	1									
geographic space	5,550	0.5676	0.4955	0	1	-0.024	1								
industry distance	5,350	0.7610	0.2190	0	1	-0.0099	0.018	1							
industry space: dummy variable	5,550	0.2852	0.4516	0	1	-0.0423	0.0413	0.28	1						
geographic space x industry space: dummy	5,550	0.1694	0.3751	0	1	-0.0164	0.3742	0.195	0.728	1					
hybrid network experience	5,550	0.6769	0.4677	0	1	0.1139	0.0085	0.11	-0.31	-0.22	1				
number of participants	5,550	5.1751	3.6926	2	35	0.3878	-0.046	-0.015	-0.07	-0.05	0.166	1			
fund size	5,550	12.8288	1.5101	5.9809	15.1404	0.0831	0.0509	0.151	-0.35	-0.23	0.569	0.185	1		
firm age	5,550	12.1795	10.5721	0	43.9398	0.0157	-0.004	0.156	-0.28	-0.2	0.349	0.047	0.503	1	
investment amounts	5,550	10.8359	1.6925	2.9957	16.0753	0.3889	-0.023	-0.064	-0.16	-0.1	0.273	0.717	0.309	0.1252	1

Table 2 presents the main effects of geographic space and industry space. Model 2 incorporates the interaction effect of geographic uncertainties and industry uncertainties. Model 3 and Model 4 include the main effects of behavioral uncertainties based on past “hybrid network experience” and the “number of participants.”

In Model 1, hypothesis 1 is not supported because we found a non-significant coefficient. There’s no relationship between geographic space and the likelihood of lead IVC firms forming hybrid networks. The positive coefficient of interaction in Model 2 represents that lead IVC firms would be more likely to choose hybrid networks rather than IVC networks when there is an interaction of both geographic space and industry space. Therefore, hypothesis 2 is supported. Hypothesis 3 is supported, as previous experience with hybrid networks will lead IVC firms to choose hybrid networks over IVC networks. That means that when lead IVC invite both CVC and IVC firms to participate in their previous syndicates as leaders, they gain a better understanding of how to collaborate with partners who have diverse

attributes. This experience encourages them to form a hybrid network if necessary for future investments, and they may also gain better knowledge on reducing coordination costs from past hybrid network experiences. Likewise, hypothesis 4 is supported in Model 4. The finding confirms that the more participants in a syndication, the more likely the formation of a hybrid network is. Behavioral uncertainties can be reduced through risk sharing among a large number of participants in hybrid networks.

In Table 2, based on the perspectives of lead IVC firms, it concluded that smaller fund sizes would enable lead IVC firms to form hybrid networks. Larger investments in target companies increase the likelihood of forming hybrid networks. The age of the IVC fund has no or negligible effect on the formation of hybrid networks.

In summary, although we obtained an unsupported result regarding spatial uncertainties hypothesis, the interaction effect in the presence of both geographic space and industry space shows a positive relationship with hybrid network formation for lead IVC firms. Behavioral uncertainties, which serve as proxies for past experience in hybrid networks, and the number of participants are positively related to the likelihood of hybrid network formation for IVC lead firms.

5. Discussion and conclusion

The extant literature on interorganizational networks has almost exclusively focused on reciprocity, transitivity, and repetitivity to explain network formation. Relatively few studies on homophily in interorganizational networks account for network formation and network change. In this study, we contribute to an enhanced understanding of homophily/heterophily as a mechanism for interorganizational network formation by empirically examining the factors that influence the formation of hybrid networks within the context of the U.S. VC industry. We have found some evidence that the decisions of lead IVC firms to choose between IVC networks and hybrid networks are influenced by two dimensions of spatial uncertainties (geographic space and industry space) and behavioral uncertainties (experience with hybrid networks and the number of

Table 2
Logit regression for IVC lead investments

	Model 1	Model 2	Model 3	Model 4
	Hybrid networks vs. IVC networks			
geographic space	-0.007	-0.084	-0.084	-0.069
	(-0.099)	(-1.051)	(-1.048)	(-0.851)
industry distance	0.195	0.202	0.162	0.095
	(0.990)	(1.025)	(0.811)	(0.474)
industry space: dummy variable	0.012	-0.198	-0.162	-0.158
	(0.118)	(-1.349)	(-1.101)	(-1.076)
geographic space x industry space: dummy		0.348**	0.355**	0.369**
		(2.019)	(2.061)	(2.137)
hybrid network experience			0.299***	0.309***
			(2.913)	(3.012)
number of participants				0.086***
				(5.900)
fund size	-0.068*	-0.068**	-0.110***	-0.103***
	(-1.955)	(-1.964)	(-2.861)	(-2.690)
firm age	-0.004	-0.004	-0.005	-0.004
	(-1.106)	(-1.112)	(-1.298)	(-1.008)
investment amounts	0.688***	0.687***	0.681***	0.504***
	(23.69)	(23.641)	(23.378)	(12.253)
_cons	-7.998***	-7.952***	-7.530***	-6.095***
	(-16.417)	(-16.319)	(-14.754)	(-10.911)
N	5350	5350	5350	5350
pseudo R-sq	0.166	0.167	0.168	0.175

t statistics in parentheses.
* significant at the .05 level; ** significant at the .01 level; *** significant at the .001 level.

participants). When lead IVC firms need to address information asymmetry resulting from spatial uncertainties between themselves and the target firms, they are more likely to select a local IVC partner that demands fewer cooperation efforts. Simultaneously, the involvement of CVC firms in related or complementary industries may better help lead IVC firms reduce information asymmetry at the industry dimension and increase the likelihood of forming hybrid

networks. Thus, the interaction effect of geographic space and industry space is significant when lead IVC firms form hybrid networks. Lead VC firms will only choose a hybrid network if they determine that the benefits outweigh the costs when they are involved in the cooperation and coordination efforts. Syndicated investments across different attributes actually increase coordination costs and behavioral uncertainties, requiring significant alignment of different goals and actions between IVC and CVC firms. Our empirical results show strong evidence that lead IVC firms are encouraged by past hybrid network experience to reduce coordination costs and to invite actors with heterogeneous attributes as their network partners. We speculate that previous experience with hybrid networks can help guide lead VC firms in mitigating incomplete information in their partner selection process and reducing behavioral uncertainties during the formation of hybrid networks. On the other hand, our empirical results also confirm that a large number of participants would have a positive effect on the formation of a hybrid network. Inspired by the concept of social loafers, the negative impact of uncertain behavior on the outcome of a team-based initiative falls with the size of the team. A larger syndicate size mitigates their concern about incomplete information stemming from CVC partners and eases their burden of cooperation efforts required to manage the hybrid network.

Our study contributes to the rationale of interorganizational network formation involving actors with heterogeneous attributes. It has significant theoretical implications and suggests areas for future research. In contrast to the embeddedness perspective, which focuses on network formation with familiar actors, we conceptualize homophily as a mechanism for interorganizational network formation. We develop arguments to fill the theoretical gap regarding why firms form relationships with dissimilar partners. From a network structural perspective, our results provide some evidence of the importance of incorporating information about actors' attributes into network formation, although this is limited to two broad categories. By distinguishing between similarity and familiarity in network formation, our research suggests a new perspective for disentangling the different mechanisms underlying network formation and

network change. For instance, previous studies tend to consider transitivity and homophily as two distinct network formation mechanisms, with the former linked to familiarity and the latter to similarity (e.g., Baker, 1990; Iurkov and Benito, 2020; Sorenson and Stuart, 2008; Uzzi, 1996). However, the two mechanisms are not mutually exclusive, as a common third party may facilitate a connection with either a familiar partner or a similar partner. A reassessment of the interdependence among various network formation mechanisms can help clarify their relationships.

At a more micro level, such an endeavor may lead to a re-evaluation of the social foundations that network scholars traditionally consider specific to the embeddedness theory. The embeddedness theory typically focuses on the effects of trust generated from social networks with familiar partners, whether it be personal trust or organizational trust, on subsequent economic behavior and outcomes (Granovetter, 1985). However, despite the well-grounded theory and rigorous empirical testing, many of the mechanisms identified by scholars studying embeddedness are not specific to social embeddedness but rather related to similarity. For instance, in their synthesis on the roles of trust in organizational embeddedness, McEvily *et al.* (2003) argue that trust transfer through a common third party – transitivity – is driven by "perceived similarity among members of the collectivity" (p. 95). Likewise, Williams' (2001) research on trust, which many scholars cited to support social embeddedness theory, is indeed built upon similarity rather than familiarity. The lack of separation between familiarity and similarity in network research may impede a comprehensive understanding of the boundaries of social embeddedness theory and social network theory in general. A careful distinction between unique and general mechanisms for familiarity and similarity, respectively, might offer a better micro-foundation for understanding network formation and network change.

Theoretical arguments and empirical evidence presented here supplement previous studies on network change based on familiarity (Baum *et al.*, 2005; Beckman *et al.*, 2004; Iurkov and Benito, 2020; Sorenson and Stuart, 2008). While some studies advocate that firms are likely to reinforce their existing relationships or form close relationships under increasing uncertainty (Baker, 1990; Gulati,

1995; Podolny, 1994; Uzzi, 1996), we stand up for the alternative view that increasing uncertainty leads to an expansion in the array of strategic options, and the network corollary is that firms may seek new ties and/or new partners (Koka *et al.*, 2006). Future research could explore how network change may vary in different directions based on various factors influencing partner selection. For example, Beckman *et al.* (2004) found that firm-specific uncertainty drives the selection of unfamiliar partners, while market uncertainty drives the selection of familiar partners. Their findings are highly relevant to ours regarding the impacts of spatial uncertainty and behavioral uncertainty on the formation of hybrid and homogeneous networks. Further exploration of the relationships between various kinds of uncertainties and different types of partner selection, or by extension, and network change based on similarity and familiarity, could be a promising direction for future research.

Future research may explore the role of homophily from an evolutionary perspective (Kossinets and Watts, 2009). While homophily is an important mechanism to explain the formation of ties, the choice may be heavily constrained by other aspects of an actor's structure. Coined in 1987 by McPherson and Smith-Lovin, the concept of homophily as a foundation of the formation of ties has been extended to include choice homophily and induced homophily, corresponding to individual preferences and structural opportunities for interactions. Disentangling the two types of homophily and studying their interactions would require longitudinal data to explore the evolving nature of networks. To the best of our knowledge, such a distinction has not been applied in the context of interorganizational relations. Research in this area of thinking could be a fruitful and promising field.

Like most empirical studies, our study had a few limitations that provide opportunities for future research. For example, despite the clear implications for network change, limited data availability has hindered our further exploration of the evolution of hybrid and homogeneous networks. Future research could collect longitudinal datasets to investigate the evolution of hybrid networks, the interplay of hybrid networks with other governance modes, and the networking behaviors

of actors with heterogeneous attributes.

Finally, the present analysis relies on a discrete choice model and the conventional reduced form set-up that it implies. Thus, the paper is ultimately silent on the actual performance of hybrid networks with respect to homogeneous networks. Future research could examine the performance implications of hybrid and homogeneous networks for both VC firms and invested companies when spatial uncertainty and behavioral uncertainty problems are present or absent. For example, to assess the roles played by prior hybrid network experiences and the two types of uncertainties discussed here, this research could explore whether the time-to-IPO of invested companies, IVC's financial returns, and CVC's strategic goals are superior when there is a better fit of prior networking experiences and uncertainties. Research along these lines could enhance our understanding of the differential utilities of different types of organizational network forms, as well as the diverse mechanisms that underlie underlying hybrid and homogeneous networks.

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