JOURNAL OF MANAGEMENT STUDIES

Journal of Management Studies 45:3 May 2008
doi: 10.1111/j.1467-6486.2007.00747.x

Internal Knowledge Development and External Knowledge Access in Venture Capital Investment Performance

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ABSTRACT We examine the performance effects of two knowledge-driven strategies – internal knowledge development and external knowledge access through inter-firm relationships – in the context of venture capital investing. Using longitudinal data on the investments, syndication, and performance of 200 US-based venture capital firms, we find that investing in industries in which a firm has more knowledge and investing with more or familiar external partners enhances investment performance. In addition, we reveal important interactions between the two strategies, such that access to external knowledge is particularly beneficial when the investment exposes gaps in the firm's own expertise. Thus, access to external knowledge is more effective when an incongruity exists between what the firm knows and what it intends to do. We discuss the study's implications for organizational knowledge and learning, strategic alliance, and venture capital literature.

INTRODUCTION

According to the knowledge-based view, a firm might be conceptualized as a repository of knowledge, whereby knowledge constitutes a key factor for firm success (Nelson and Winter, 1982; Spender, 1996). On the one hand, the internal accumulation of knowledge through organizational learning represents an important driver of value creation because it opens new productive opportunities for the firm and then enhances its ability to exploit these opportunities (Penrose, 1959; Spender and Grant, 1996). In this regard, organizational advantage may be explained largely by a firm's absorptive capacity, or its ability to access, understand, and exploit knowledge (Cohen and Levinthal, 1990). On the other hand, inter-firm partnerships also fulfil an important role by providing firms with access to external knowledge (Dyer and Singh, 1998; Heimeriks and Duysters, 2007; Lane and Lubatkin, 1998; Mowery et al., 1996). Therefore, from a knowledge perspective, strategic alliances may offer a performance advantage because they provide a firm with access

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to valuable knowledge through its interactions with external partners (Grant and Baden-Fuller, 2004).

We examine the individual and combined performance effects of two alternative knowledge-driven strategies: (1) developing knowledge internally through learning; and (2) accessing knowledge externally through inter-firm alliances. Internal knowledge development and external knowledge access represent two important, performance-enhancing facets of firms' knowledge development, but to the best of our knowledge, few studies have addressed the *joint* performance effect of these two knowledge strategies, which is somewhat surprising because they are not mutually exclusive (Grant and Baden-Fuller, 2004). In this regard, we investigate the extent to which the potential benefits of external knowledge access depend on the firm's internal knowledge, particularly when knowledge is inappropriate or lacking. Following Grant and Baden-Fuller (2004), we empirically address this question by assessing whether any *incongruity* between a firm's knowledge domain (i.e. internally developed knowledge) and product domain (i.e. tasks to which the knowledge will be applied) affects the role of external knowledge in enhancing firm performance.

To test these ideas, we chose the venture capital industry, a setting in which both knowledge strategies are common and instrumental for firm performance. Venture capital firms (VCFs) typically invest, manage, and return institutional investors' money by funding entrepreneurial companies (hereafter, portfolio companies), contributing to their development, and selling their stakes to public or corporate investors. More so than investors in well-established or publicly traded companies, VCFs actively manage the uncertainty associated with selecting and developing portfolio companies. Although market-wide variations or unexpected developments are difficult to foresee or manage, VCFs enjoy significant management discretion to reduce company-specific risk and enhance the company-specific returns in their portfolio (Dimov and Shepherd, 2005). Furthermore, prior research suggests that VCFs' effectiveness in managing their portfolio depends on their ability to learn from the successes and failures of their prior investments (Gupta and Sapienza, 1992) and the extent of their co-investments (syndication) with other VCFs (Brander et al., 2002; Wright and Lockett, 2003). Learning from prior investments exemplifies internal knowledge development, whereas participation in syndicate partnerships represents external knowledge access.

We contribute to the broad management literature by showing that internal knowledge development and access to external knowledge through partnerships not only represent two important sources for knowledge application but also enhance each other through their mutual interaction. More specifically, accessing external knowledge offers a more effective strategy when there is incongruity between what the firm knows and what it intends to do. We also contribute to the literature on venture capital (VC) finance by elaborating on the roles of portfolio development and syndication as two key strategies that influence VCFs' performance and by highlighting their complementary nature.

THEORY AND HYPOTHESES

The knowledge-based view posits that firm performance depends on the level of knowledge exploitation, that is, the degree to which the firm successfully converts knowledge

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into planned outcomes (Spender and Grant, 1996; Zahra and George, 2002). Furthermore, the knowledge that firms exploit may be accumulated internally through organizational learning (Spender and Grant, 1996) or provided by external partners through the inter-firm relationships in which it participates (Grant and Baden-Fuller, 2004). Accordingly, we distinguish and discuss two approaches to knowledge exploitation: developing knowledge internally through organizational learning and accessing knowledge externally through collaborations with external parties.

Internal Knowledge Development

Organizational knowledge comprises the set of everything known or understood by an organization and its members (Nonaka and Takeuchi, 1995) and accumulates through a process of learning, as a result of either direct experience or the experience of others, such that historical inferences develop into routines and beliefs that guide future behaviour (Huber, 1991; Levitt and March, 1988). Learning is an important source of competitive advantage; it increases not only a firm's average performance but also the reliability of that performance (Levinthal and March, 1993). When facing new opportunities, firms use their knowledge to understand and evaluate them, so absorptive capacity – the ability to recognize the value of new, external information, assimilate it, and apply it to commercial ends – provides a key learning capability grounded in the firm's prior knowledge (Cohen and Levinthal, 1990). Such capability is path dependent, in that it develops over time through the continuous interaction of a firm's prior knowledge and current activities (Van den Bosch et al., 1999).

Continuing action and experience in a particular domain creates *deeper* knowledge of that domain, which in turn enhances domain-specific learning (Cohen and Levinthal, 1990) and, consequently, the firm's domain capabilities as a source of competitive advantage (Grant, 1996b). We suggest that three mechanisms explain why deeper knowledge makes a firm a superior learner in a specific domain and thus increases its domain-specific performance. First, knowledge depth gives the firm a more comprehensive understanding of new information it receives (Cohen and Levinthal, 1990), which increases its ability to identify valuable knowledge (Katila and Ahuja, 2002). Second, it facilitates more abstract mapping of the firm's activity domain and promotes a higher-level articulation and codification of its knowledge base; these more abstract representations allow for a smoother assimilation of newly acquired information into the firm's existing knowledge base (Zollo and Winter, 2002). With this ability, the firm can apply its knowledge to a wider set of problems. Third, deeper knowledge enhances the ability to incorporate additional knowledge into the firm's operations (Van den Bosch et al., 1999) and thereby provides structural mechanisms that sustain knowledge exploitation over extended periods of time (Zahra and George, 2002).

In the context of VC financing, VCFs derive knowledge from prior investments and manifest their absorptive capacity in their evaluation, selection, and management of investment opportunities. Previous research has found that VCFs differ in the extent to which they focus their investments and, accordingly, develop deep knowledge of certain domains. For example, some VCFs diversify investments across a broad range of industry sectors to decrease their exposure to volatility in individual industries (Norton and

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Tenenbaum, 1993; Ruhnka and Young, 1991) and spread their financial risk. Others specialize in particular industries to reduce company-specific risk (e.g. Gupta and Sapienza, 1992; Norton and Tenenbaum, 1993) and information asymmetries (Amit et al., 1998); their extensive industry knowledge counteracts any increased exposure to industry-specific risk. Our study focuses on this latter approach, which highlights the importance of internal knowledge development for explaining VCF performance. We consider this knowledge-based perspective of VCFs' investment behaviour complementary, rather than contrary, to the perspective that focuses on financial risk management. Although spreading financial risk provides an important rationale for constructing an investment portfolio, we contend that knowledge considerations are particularly important for explaining investment outcomes. Arguably, whereas financial risk management helps reduce a portfolio's downside, knowledge management helps increase its upside potential (Dimov and Shepherd, 2005).

Furthermore, we focus on the extent of the VCF's *industry* expertise[1] as a reflection of its internally accumulated knowledge and to explain the outcomes of specific investments. A VCF should be more successful when it invests in industries of which it is more knowledgeable, such as those in which it has invested previously. In managing its current investments, the insights and lessons a VCF has derived from governing its prior investments in the same industry – such as those related to monitoring company behaviour and performance (Sapienza and Korsgaard, 1996), providing strategic advice and network contacts (Busenitz et al., 2004), and recruiting management (Hellmann and Puri, 2002) – increase its value contribution and enhance investment performance (De Clercq et al., 2006). More specifically, investing in familiar industries provides VCFs with a better understanding of the complexities of their current investments and therefore enables them to develop their portfolio companies better (Lockett and Wright, 1999; Wright and Robbie, 1998). Dealing with repeated decision situations leads to learning curve effects (Argote, 1996) as problem definitions, alternative responses, and outcomes become encoded into knowledge that facilitates similar future decisions. Such knowledge might pertain to identifying and dealing with key industry stakeholders (e.g. customers, suppliers, management recruiting firms) for the benefit of the portfolio companies (Gupta and Sapienza, 1992). A stronger understanding of particular industries also may involve *tacit* comprehension of the strategic and operational decisions in those industries (Nonaka and Takeuchi, 1995), which the VCF may convey to portfolio companies during interactions (De Clercq et al., 2006). This line of reasoning leads to the following hypothesis:

Hypothesis 1: The greater the VCF's knowledge of the industry of a particular investment, the better the investment's performance will be.

Access to External Knowledge

In addition to relying on internal knowledge development, firms look for knowledge beyond their boundaries and benefit from access to others' knowledge (Dyer and Singh, 1998; Grant and Baden-Fuller, 2004). A firm's interactions with external partners can facilitate inter-organizational learning, which improves firm performance (Lane and Lubatkin, 1998). However, consistent with Grant and Baden-Fuller (2004), we acknowl-

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edge that though some learning likely takes place in most inter-firm relationships, a focal firm's *mere* access to external knowledge, irrespective of whether it is willing or able to assimilate and absorb it into its own knowledge base, provides an equally important motivator of many collaborative agreements and is a performance determinant.

In view of these considerations, we build our arguments on the basis of the assumption that, to the extent that a focal firm establishes external partnerships, its selected partners bring necessary missing knowledge to the table (Grant and Baden-Fuller, 2004). In other words, we attribute the benefits of access to external knowledge to the provision of knowledge that the focal firm needs to complete a particular task. Ultimately and in line with prior research on strategic alliances and networks (Burt, 1992; Deeds and Hill, 1996; Wright and Lockett, 2003), we consider two specific dimensions of a firm's access to external knowledge as possible determinants of firm performance: the scope and embeddedness of external relationships. Accordingly, conditional on the utility of the partners' knowledge to the focal firm, the *number* of partners with which the focal firm collaborates and its *familiarity* with these partners influence its performance. In discussing these relationships, we consider both the advantages and possible downsides of cooperating with external partners.

Scope of external relationships. Collaboration with more external partners implies access to a broader scope of knowledge and thus enhances a firm's ability to exploit knowledge for commercial ends (Grant and Baden-Fuller, 2004). Similarly, network literature suggests that large networks improve performance because they provide information and capabilities that may not be available inside the firm (Burt, 1992). For example, in Saxenian's (1991) study of Silicon Valley, firms' extensive networks of collaborative relationships enhanced technological advances and new product development, and Liebeskind et al. (1996) found that new biotechnology firms with broader interpersonal networks enjoyed greater success because of their access to cutting-edge scientific knowledge. These arguments suggest a positive relationship between the number of external partners and focal firm performance.

In the specific context of VCF syndication, we suggest two knowledge considerations may explain why the number of collaboration partners relates positively to investment success.[2] First, the selection of potential investment opportunities will be more effective as syndication leads to a higher-quality deal flow (Sorenson and Stuart, 2001) and better selection decisions as different parties are involved in these decisions (Lerner, 1994). Second, syndication increases the value-added potential of the focal VCF because syndicate partners can bring additional operational and strategic knowledge to the table (Brander et al., 2002). Different syndicate members have unique skills relevant to a particular portfolio company (e.g. detecting new customers, filling top management team vacancies, enabling contacts with additional investors), so all else being equal, more syndicate partners means a richer variety of knowledge from which the focal VCF can draw.

However, despite the strong indications of a positive relationship between the number of syndicate partners and investment performance, we acknowledge that the benefits from cooperation with a broad set of partners may be more difficult to realize for very large syndicates. Collaboration among more syndicate partners may entail significant

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costs, such as free riding (Gifford, 1997; Wright and Lockett, 2003), a more complex sanctioning decision-making process, or renegotiated investment contracts (Steier and Greenwood, 1995; Wright and Lockett, 2003). More generally, alliance literature suggests that the costs of inter-firm collaboration increase substantially with more external partners (Artz and Brush, 2000; Meuleman, 2006; Parkhe, 1993) because of the need to monitor opportunistic behaviour and the lack of proper coordination when the rules used to govern the relationships become unclear (Gulati et al., 2005; Meuleman, 2006; Sang and Mullineaux, 2004; Williamson, 1991).

On the basis of these insights into the benefits and costs of inter-firm collaboration, we argue that in the context of VC syndication, the relationship between the number of partners and performance is positive but non-linear. On the one hand, the specific nature of the close-knit VC industry, in which individual investors maintain close relationships with each other across firms (Wright and Lockett, 2003), should mitigate the costs of syndication because investors are wary of not being invited to future syndicates. As Black and Gilson (1998) suggest, the relative density of the VC community increases the transparency of the market and the chances that investors that engage in opportunistic behaviour suffer reputation damage and get excluded from future syndicate partnerships. On the other hand, with each additional partner, the costs associated with managing the (larger) syndicate increase, which diminishes the potential knowledge contribution of each partner to the focal VCF. We thus propose the following hypothesis:

> *Hypothesis 2a*: The more partners with which a VCF syndicates in a particular investment, the better the investment's performance will be. However, the contribution of each additional partner decreases as the number of partners increases.

Embeddedness of external relationships. Alliance literature has strongly argued that the relational embeddedness of external partnerships should facilitate partnership effectiveness (Hagedoorn and Hesen, 2007; Nahapiet and Ghoshal, 1998). Embedded relationships involve close social connections, mutual trust, and reciprocity between partner firms (Cook and Emerson, 1978; Granovetter, 1985) and thereby increase the amount and quality of knowledge exchanged (De Clercq and Sapienza, 2006). For example, highly embedded relationships demand fewer monitoring mechanisms, and the subsequent freeing of resources increases the potential for more extensive communication (Rutherford et al., 2007; Zaheer et al., 1998). Furthermore, relational embeddedness facilitates confidential information exchanges, because perceived opportunism risks diminish (Yli-Renko et al., 2001). Thus, embedded relationships reduce the need to engage in time-consuming, costly monitoring activities or hide sensitive information.

An important element of relational embeddedness concerns the extent to which partners have collaborated previously (Uzzi, 1997). Familiarity with exchange partners can facilitate access to information about others' future behaviour and therefore help reduce the *ex ante* costs of locating and screening exchange partners (Granovetter, 1985; Robinson and Stuart, 2001). More specifically, prior interactions – if they have been positive – facilitate trust building, knowledge transfer, and joint problem solving (Uzzi, 1997) and help firms assess the reliability and specific capabilities of potential partners (Gulati, 1995), which reduces the uncertainty the focal firm faces. Furthermore, the

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ex post costs of collaborating with familiar partners are lower, because their behaviour is more predictable and trustworthy (Gulati, 1995), and partner familiarity can exert an indirect disciplining effect on partners' behaviour (Granovetter, 1985; Robinson and Stuart, 2001).

Although prior relationships increase the potential for knowledge exchange and the effectiveness of inter-firm collaboration, their knowledge contribution to a particular task is not automatic. If prior relationships were unsuccessful, collaborations will be beneficial only to the extent that the partners have learned from past failures (Argote, 1996; Shepherd, 2003). Moreover, collaboration with a limited number of familiar partners may hamper the firm's access to new opportunities and provide only redundant information (Burt, 1992). In this regard, each additional interaction, though it greases the pipes of inter-firm information exchange (Podolny, 2001), increases the odds that redundant information is exchanged. This suggests that a focal firm will benefit from current interactions with familiar partners only to the extent that they can provide knowledge that the focal firm has not already obtained.

We apply this logic to the VC context and expect a positive, non-linear relationship between the number of prior interactions with syndicate partners and investment performance. Venture capital firms often interact repeatedly over long periods of time and across investments in different portfolio companies (Wright and Lockett, 2003), in which they take alternating roles of lead and non-lead investors (Gorman and Sahlman, 1989). Syndication with familiar parties should promote the flow of knowledge and joint problem solving with regard to the investment at hand, because we assume the focal VCF learned from its prior relationships, whether they were successful or not (Argote, 1996; Uzzi, 1997). Accordingly, for a given investment, when the VCF and syndicate partners have engaged in more interactions, knowledge flow and decision-making efficiency within the syndicate improves (Wright and Lockett, 2003), so the investment performs better. Furthermore, the danger of redundant information in 'over-embedded' syndicate partnerships (Uzzi, 1997) implies a decreasing marginal effect of each additional prior interaction on performance.

Hypothesis 2b: The more prior interactions between the focal VCF and its syndicate partners in a particular investment, the better the investment's performance will be. However, the contribution of each additional interaction decreases as the number of prior interactions increases.

Joint Effect of Internal Knowledge Development and Access to External Knowledge

We have argued so far that both internal knowledge development and access to external knowledge enhance firm performance. In this section, we extend our argument by acknowledging that these two knowledge-driven strategies are not mutually exclusive (and thus likely to interact) and examining the nature of their interaction effect on firm performance. More specifically, we argue that the potential synergistic effect between internal knowledge development and access to external knowledge likely depends on whether the firm's internal knowledge is appropriate for the task at hand. As such, our

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study extends prior research that has considered the complementarity between the knowledge domains of a focal firm and its partners as a predictor of success (e.g. Dyer and Singh, 1998) but not clarified why the firm *needs* partners' knowledge. That is, prior research typically suggests that partners' ability to provide knowledge the firm lacks offers an important impetus for a firm to engage in inter-firm collaborations (Harrigan and Newman, 1990; Mowery et al., 1996).

Our study adds to this body of literature by focusing on the incongruity between a firm's current body of knowledge and the knowledge it requires to accomplish a particular task as an important driver of inter-firm relationship performance (Grant and Baden-Fuller, 2004). More specifically, we examine how the number and embeddedness of partnerships may help a focal firm overcome the challenge associated with this knowledge mismatch. Furthermore, we assume that when a focal firm rationally decides to collaborate and seeks complementary knowledge through that collaboration, the partner firms bring missing knowledge to the table.

The knowledge-based view posits that a firm has different types of knowledge, which it converts into products or services (Spender and Grant, 1996). The relationship between the range of knowledge a firm possesses (i.e. knowledge domain) and the domain to which this knowledge may be applied (i.e. product domain) determines the efficiency with which the firm uses its knowledge (Grant and Baden-Fuller, 2004). In particular, the closeness of the firms' knowledge and product domains influences this efficiency:

> Efficient utilization of knowledge is achieved where the knowledge domain of the firm matches exactly the knowledge requirements of the product domain of the firm with no overlap and, thus, no underutilization of knowledge. The problem is that different types of knowledge are applicable to different sets of products. This presents difficult choices for the firm over which types of knowledge to possess and which products to produce. (Grant and Baden-Fuller, 2004, p. 71)

In other words, firms confront the challenge of establishing a perfect fit between their knowledge and product domains. They can strive to expand either their product range to use their existing knowledge more fully or their knowledge base to bring about the desired product range. Because of growth limitations on existing products, firms often need to introduce new products, but to the extent that these new products require knowledge the firm does not possess, its knowledge and product domains mismatch. In turn, these mismatches determine the extent to which firms can benefit from inter-firm relationships (Grant and Baden-Fuller, 2004). That is, the potential value firms derive from strategic alliances depends on the *incongruity* in the firm's knowledge and product domains, which ensures it has more to gain from establishing a strategic alliance, because its existing knowledge base does not cover all aspects necessary to generate the desired product. Alternatively, when the two domains are congruent, potential external partners can offer little knowledge that the focal firm does not already possess.

In the VC context, knowledge and product domains apply to particular investments: The VCF's product domain refers to guiding a particular portfolio company from initial investment to successful exit, and its knowledge domain pertains to its understanding of the decisions and processes involved in these activities. Incongruity exists when the VCF

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possesses knowledge that differs from that needed to make a particular company successful. On the basis of Grant and Baden-Fuller's (2004) arguments, we posit that in such situations, the VCF benefits from collaborating with syndicate partners. Again, we acknowledge that this argument assumes syndicate partners provide the knowledge the focal VCF needs, which is valid in the context of a rational investor motivated to engage in a partnership by its need for external knowledge, with good a priori insight into the knowledge it needs, and that can apply external knowledge to its investments (Brander et al., 2002; De Clercq and Dimov, 2004).

For a particular investment, the VCF's knowledge of the industry determines whether the investment fits the firm's expertise; high industry knowledge implies congruity, whereas low industry knowledge implies incongruity. Limited industry knowledge will not be sufficient for the focal VCF to bring the portfolio company to a successful exit (De Clercq et al., 2006; Sahlman, 1990). In line with our previous arguments, we posit that the scope and embeddedness of external relationships help alleviate the incongruity between what the VCF knows and what it intends to do. Exposure to a wide range of external partners through larger syndicates increases the likelihood that the firm will benefit from accessing external knowledge. In other words, when the VCF does not have sufficient knowledge of a specific industry, it has more to gain from its syndicate partners. Similarly, accessing and converting partners' knowledge into successful performance outcomes should be easier and more likely when the focal VCF collaborates with familiar, trustworthy partners. In short, external partnerships, in terms of both scope and embeddedness, benefit the focal firm more when its knowledge is incongruous with the task at hand. Therefore, conditional on the usefulness of syndicate partners' knowledge to the focal VCF, we propose:

Hypothesis 3a: The positive relationship between the number of syndicate partners and investment performance is moderated by the focal VCF's industry knowledge, such that the relationship is stronger at lower levels of industry knowledge.

Hypothesis 3b: The positive relationship between the number of prior interactions and investment performance is moderated by the focal VCF's industry knowledge, such that the relationship is stronger at lower levels of industry knowledge.

METHODOLOGY

Data collection

We tested our hypotheses using data on VC investments undertaken during the period 1962–2002. Because we were interested in the evolution and outcomes of VCF investment strategies over time, we selected VCFs that had made a sufficient number of investments. Therefore, we used as a sampling frame all independent, US-based VCFs that had invested in at least 20 portfolio companies by the end of 2002 (547 VCFs in total) according to data from Thomson Financial's VentureXpert database. From this frame, due to data management considerations, we randomly selected 200 focal VCFs to test our hypotheses.

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For each of the selected VCFs, we collected data on their *initial* investments in each portfolio company. To manage their financial risk, VCFs normally stage investments in each company across different rounds; a new (follow-up) round of investment usually requires certain development milestones (Sahlman, 1990). Thus, after its initial investment in a portfolio company, a VCF may decide to invest further if the performance prospects of that company remain satisfactory. Focusing only on the initial investment decision enabled us to examine a relatively homogeneous set of decisions – adding a company to the VCF's portfolio – and exclude the qualitatively different decision to continue to invest. The selected VCFs made a total of 14,129 initial investments during the specified period. We used this set of initial investments to represent the chronological development of each firm's investment portfolio and to measure the continuous evolution of its industry knowledge.

However, a focal VCF's initial investment may not be the first time the portfolio company receives VC. When a company has received prior funding from other VCFs, the focal VCF essentially joins an existing syndicate (Gompers, 1995; Sahlman, 1990). To pre-empt the possibility that joining an existing syndicate confers a more secondary investment management role on the focal VCF, which would make the effects of its knowledge-driven strategies less direct, we narrowed our data to the set of *first-round* investments. Contractual mechanisms enable first-round investors to preserve their influence and discretion over the portfolio company's future development, such as pre-emptive rights, anti-dilution clauses, rights of first refusal, and super-majority rights (Sahlman, 1990). Of the total initial investments made by the selected VCFs, 8162 were first-round investments.

Dependent Variable

We inferred the *performance* of each investment from the status of each portfolio company at the time of data collection (i.e. end of 2002) according to four main possibilities: (1) it went public (i.e. underwent an initial public offering (IPO)); (2) it was acquired by another company; (3) it was still private; or (4) it failed (Cochrane, 2005). The first two outcomes are more likely to represent successful exits for VCFs, because they could sell their investment stakes to third parties, often at a hefty premium (Sahlman, 1990); the latter two imply that the VCFs received no return on their investments.[3] A proper estimation of investment performance must take into consideration all four possible outcomes (Cochrane, 2005), but because we had no data about the exact returns achieved in the IPO and acquisition exits, we represented performance as a rank order of possible investment outcomes. That is, we considered an IPO the best outcome, acquisition the second-best, remaining private the third-best, and failure the worst investment outcome. Such coding implied that an investment resulting in an IPO generally performed better than investments resulting in any of the other outcomes, without regard to how much better (Sahlman, 1990). An investment failed if its status was listed as 'defunct', was still private if its status was 'private', was acquired if its status was 'subsidiary', and had undergone an IPO if its status was listed as 'public'. To examine the robustness of our findings, we also used an alternative, binary specification of investment performance, in which we coded IPO and acquisition exits as successful and the remaining outcomes as unsuccessful.

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Independent Variables

We measured the focal VCF's *industry knowledge* with respect to each investment as the log[4] of the number of *initial* investments made in the investment's industry prior to the year of the investment, which we derived from the set of *all* initial investments made by the focal VCF (not just first-round investments). The measure thus reflected the VCF's total investment activity prior to the investment in question. To derive the counts, we used the nine main industry categories included in the VentureXpert database: (1) communications and media; (2) computer related; (3) semiconductors; (4) biotechnology; (5) medical/pharmaceutical; (6) energy related; (7) consumer related; (8) industrial products; and (9) other manufacturing and services. As the measure implied, the more investments a focal VCF made in one of these industries, the higher its knowledge of that industry was when it made a new investment. In addition, using the log of the number of previous investments acknowledged the diminishing learning effect from each additional investment (e.g. Argote, 1996).

For each investment, we used the reported number of participating investors to measure the VCF's *number of syndicate partners*. Because a time gap existed between a focal VCF's first-round investment and the portfolio company's ultimate performance outcome, this measure's validity for predicting performance depended on the sustained influence of the investor over the course of the company's development. Our choice of first-round investments therefore enhanced its validity.[5] To specify the diminishing marginal effect of each additional partner, and thus account for the increasing costs of more partners, we used the log of the number of partners, which represented a non-linear, positive relationship and reflected the logic of Hypothesis 2a. We also explored an alternative, quadratic model specification that allows the effect of the number of syndicate partners to become negative, but we found no support for such a relationship.

To measure the *number of prior interactions* with the syndicate partners for a particular investment, we counted the number of times the focal VCF had co-invested with each syndicate partner previously and summed these counts to derive a score for the entire syndicate. Consistent with the logic underlying Hypothesis 2b, we used the log to allow for a diminishing learning effect for each additional interaction (we found no support for an alternative, quadratic model specification). We used the sum rather than the average of the number of prior interactions across the different partners because in more than two-thirds of the cases (69 per cent), the focal VCF and partner had not interacted previously. Furthermore, because the database did not disclose the identity of some syndication partners, we could not count the number of prior interactions of the focal VCF with those partners. To the extent that we could determine the number of prior interactions with the disclosed partners, we gained at least a partial indication of the relational embeddedness of that syndicate. To ensure that such missing data did not threaten the validity of our measure, we verified that the measure was not inflated for the cases in which we could identify more syndicate partners. The correlations of the measure of the total number of prior interactions with the number and proportion of partners for which data were available were low (0.24 and 0.06, respectively), so the missing cases were relatively random. In addition, because the number of partners for

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which data were available was highly correlated (0.73) with the total number of partners in the syndicate, our inclusion of the number of syndicate partners in the analysis ruled out the possibility of bias.

In many cases (1433), we could not identify any of the syndication partners, so we faced the challenge of many investments for which we could not estimate the number of prior interactions. This limitation both reduced the number of usable observations and posed the risk of estimation bias if the missing observations were not random. Our examination of the missing cases revealed that they were unrelated to the characteristics of the focal VCF, but they tended to include investments that were more recent, had fewer syndicate partners, and involved later-stage companies that were more likely to be private. Whereas the systematic exclusion of cases of the dependent variable does not lead to bias in logistic regression estimation (Allison, 2001), we nevertheless conducted additional analyses to ensure that our subsequent estimation was not biased. In particular, we estimated two-stage selection models (Heckman, 1979); in the first stage, we estimated the probability of missing data, and in the second stage, we used the self-selection probability for each observation (inverse Mills ratio) as a control in the substantive estimation analysis. None of these coefficients correcting for systematic self-selection was significant, which ruled out the possibility of bias in our analyses due to missing observations.

Control Variables

We included an extensive set of control variables to account for alternative rationales for syndication and eliminate alternative explanations of investment performance. Therefore, we included several characteristics pertaining to the focal VCF, syndicate partners, portfolio company, and particular investment undertaken.

Focal VCF characteristics. We controlled for whether the focal VCF was the *lead investor* in a particular investment, which would involve greater commitment to monitoring and managing portfolio companies (Snellman and Piskorski, 2003; Wright and Lockett, 2003). We considered the focal VCF the lead investor if the amount it invested in the company (in all rounds) was higher than the average amount invested by all participating investors.[6] To rule out the possibilities that VCFs that were (1) more experienced, (2) previously more successful, (3) or located in the clusters of Silicon Valley or Route 128 would achieve more successful exits, we controlled for the VCF's *age*, *total number of investments to date* (logged), *total number of IPOs achieved prior to the given year* (logged), and *location in California or Massachusetts*. Finally, because VCFs face restrictions in the maximum amount they can invest in a portfolio company from a given fund (Gompers and Lerner, 1999), we controlled for the *size of the fund* (logged) from which the VCF made a particular investment. This variable also covered an important facet of financial risk sharing as a rationale for syndication; the smaller the investment fund, the more likely it is that an investment would be syndicated (Manigart et al., 2006).

Syndicate partner industry knowledge. Because Hypotheses 2 and 3 depend on the assumption that syndicate partners provide useful knowledge, we controlled for their industry knowl-

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edge with regard to each specific investment. We measured the industry knowledge of each partner in the same way we did for the focal VCF – the total number of (initial) investments previously made in the industry – and used the log of the sum of these numbers as an industry knowledge score for the entire syndicate. Again, we used the sum rather than the average because in almost half the cases (47 per cent), the partners had made few (five or fewer) investments in that industry.

Portfolio company characteristics. To account for the possibility that more developed portfolio companies were closer to reaching a (successful) exit from a VCF's portfolio or had more established management, we controlled for the *stage* and *age* (in years) of the portfolio company. We used five stage categories – (1) seed, (2) start-up, (3) other early stage, (4) expansion, and (5) later stage/acquisition – and assigned them values from 1 to 5 to reflect the companies' increasing degree of development (Podolny, 2001). Also, acknowledging that VC exit patterns vary across industries, with a particularly high exit prevalence in high-tech industries, we controlled for whether the portfolio company was based in an IT (categories 1, 2, and 3) or biotech/medical (categories 4 and 5) industry.

Investment-related characteristics. Because shared financial risk drives syndication relationships (Lockett and Wright, 1999), we controlled for the amount invested in a particular deal (logged). The greater the amount invested, the more financial risk was involved, and the higher the likelihood that more investors would participate in that round (De Clercq and Dimov, 2004). In addition, we used four variables to capture whether investment timing was conducive to a successful exit. First, to account for the shorter time available for a focal VCF to exit investments made immediately prior to our data collection, we included an indicator of whether the investments occurred after 1999. The proportions of IPOs and trade sales dropped sharply for the years after 1999. Second, we included the total number (logged) of IPOs achieved by VC-backed companies in a given year across the total population of investments in the VentureXpert database to account for the surges and declines of the IPO market, as well as the overall quality of the deal flow in that year. Third, because VCFs typically expect to exit within five years of their initial investment, we controlled for the total number (logged) of IPOs achieved by VC-backed companies in the five years following each investment. Fourth, the intensity of VC investments in a given industry over time may create knowledge externalities across VCFs and thus decrease the advantage incurred by knowledgeable VCFs (Almeida and Kogut, 1999), so we controlled for the (log of the) total number of investments (i.e. all VCFs included in the VentureXpert database) in a particular industry prior to the focal VCF's investment, scaled by the number of years since investing began in that industry.

Analysis

Because of the ordinal nature of the dependent variable, we used an ordered logit model to estimate the effects of the independent and control variables on investment performance. Performance thus reflected a linear function of the independent and control variables and a set of cut-off points that characterized the transition from one performance level to the next. Thus, the probability of observing an outcome j for an

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investment made by firm i corresponded to the probability that the estimated linear function plus the error term fell within the respective range marked by the estimated cut-off points. More technically,

$$\text{Prob}(\text{outcome}_i = j) = \text{Prob}(k_{j-1} < \mathbf{B}_i\mathbf{X}_i + u_i \leq k_j),$$

where $\mathbf{B}_i$ and $\mathbf{X}_i$ represent the vectors of estimated coefficients and predictor variables, u_i is the random error assumed to be logistically distributed, and k_j and k_{j-1} represent the cut-off points for outcome j and the preceding, inferior outcome $(j - 1)$. To account for repeated observations by a VCF, we clustered the data by VCF and ran the estimation with robust standard errors adjusted for within-cluster correlation (Rogers, 1993). Finally, in the analyses in which we used an alternative, binary measure of performance to check the sensitivity of our results to the ordinal operationalization of investment performance, we used a logit model to estimate the likelihood of a successful exit (IPO or acquisition).

RESULTS

We provide the descriptive statistics and correlation coefficients for the analysis variables in Table I. Missing values for the portfolio company's age and investment amount reduced the usable number of observations to 5001. Follow-up analyses involving two-stage selection models that corrected for the probability of missing values for these variables revealed no evidence of selection bias. In Table II, we indicate the results of the estimation of investment performance. Model 1 included only the control variables; Model 2 added the main effects of industry knowledge, number of syndication partners, and number of prior interactions; and Models 3 and 4 added the interaction terms between industry knowledge and number of syndication partners and prior interactions, respectively. Both the main and interaction effects provided incremental improvements to the model fit.

In Hypothesis 1, we predicted a positive effect of industry knowledge on investment performance. The coefficient for industry knowledge was positive and marginally significant in Model 2 ($\beta = 0.086$, two-tailed $p = 0.086$) and positive and significant in Models 3 ($\beta = 0.175$, two-tailed $p = 0.009$) and 4 ($\beta = 0.109$, two-tailed $p = 0.038$). The effect of industry knowledge was stronger in the interaction models, suggesting that the focal firm's industry knowledge mattered more when the firm lacked external knowledge access (i.e. interaction terms become 0). These findings provided support for Hypothesis 1. To illustrate the size of the effect of industry knowledge on the probability of successful exits, we applied the weakest coefficient (Model 2) to a hypothetical firm with no industry knowledge and no syndicate partners. One prior investment in the same industry increased the investment's probability of IPO exit from 12.5 to 13.2 per cent and of acquisition exit from 23.1 to 23.8 per cent; ten prior investments increased the IPO probability to 15 per cent and the acquisition probability to 25.5 per cent.

In Hypothesis 2a, we expected positive effects for the number of syndicate partners and number of prior relationships on investment performance. The effect of the number of syndicate partners was positive and marginally significant in Model 2 ($\beta = 0.117$,

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two-tailed p = 0.067), significant in Model 3 (β = 0.282, two-tailed p = 0.003), and insignificant in Model 4 (β = 0.102, two-tailed p = 0.122). The variation in the magnitude of the coefficient suggested that the number of syndicate partners mattered most when considered in relation to the focal VCF's knowledge and when the focal VCF lacked industry knowledge (i.e. interaction term in Model 3 is 0). In addition, when we took the familiarity of the partners into consideration in relation to the focal VCF's industry knowledge (Model 4), the mere number of investment partners mattered less. These findings not only supported Hypothesis 2a – the log-transformation of the number of syndicate partners implied a decreasing marginal effect – but also highlighted the contingent nature of the effect of the number of partners, as we discuss subsequently. With regard to effect size, the coefficient in Model 2 suggested that, for a hypothetical firm with no industry knowledge and no syndicate partners, working with one partner increased the current investment's probability of IPO exit from 11.4 to 12.3 per cent and probability of acquisition exit from 21.8 to 22.8 per cent. Working with five partners would further increase the IPO probability to 13.7 per cent and the acquisition probability to 24.3 per cent.

Hypothesis 2b predicted a positive effect for the number of prior interactions between the focal VCF and its syndicate partners on investment performance. The coefficient for the number of prior interactions was positive and significant in all three models (β = 0.194, 0.210, and 0.291, respectively, two-tailed p = 0.000). We observed the strongest effect in Model 4, so prior interactions appeared to matter most when the focal VCF had no industry knowledge. In addition, the log specification suggested that the marginal effect of each additional interaction was decreasing. Overall, these results provided support for Hypothesis 2b. In terms of effect size, the coefficient in Model 2 suggested that, for a hypothetical firm with no industry knowledge and one unfamiliar partner, one prior interaction with that partner would increase the current investment's probability of IPO exit from 12.3 to 13.8 per cent and probability of acquisition exit from 22.8 to 24.4 per cent. Five prior interactions increased the IPO probability to 16.5 per cent and the acquisition probability to 26.8 per cent.

We used Models 3 and 4 to assess the interaction effects predicted by Hypotheses 3a and 3b. In Model 3, the interaction between industry knowledge and the number of syndicate partners was negative and significant (β = –0.085, two-tailed p = 0.008). To clarify the nature of this interaction, we plotted the effect of the number of syndicate partners on the probability of IPO for the values of industry knowledge one standard deviation below and above the average (Cohen and Cohen, 1983), as in Figure 1. When industry knowledge was low, more syndicate partners significantly increased the IPO probability for the current investment, but when industry knowledge was high, investment partners had no discernible effect on this probability. These findings supported Hypothesis 3a; cooperation with syndicate partners was more valuable when the focal VCF invested in an unfamiliar industry. In addition and consistent with Hypothesis 1, when the VCF invested alone, the probability of an eventual IPO was much higher if that VCF had high industry knowledge (Figure 1).

In Model 4, the interaction between industry knowledge and the number of prior interactions was negative, as expected, but not significant (β = –0.036, two-tailed p = 0.218). Because more than half of the cases in the analysis (57 per cent) had no prior

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interactions, which meant we could not distinguish between non-syndicated investments and investments with unfamiliar partners, we re-ran the analysis for those cases in which the focal VCF had had at least one prior interaction. Investing with unfamiliar partners increases uncertainty for the focal VCF, so this additional analysis considered the possibility that the interaction effect between the VCF's knowledge and its prior syndication relationships with current partners would be more pronounced when at least one partner was familiar. The results of this analysis indicated a stronger negative interaction effect (Model 5, $\beta = -0.090$, two-tailed $p = 0.055$).

In Figure 2, we depict the interaction plot for the effect of the number of prior interactions on the probability of IPO for high and low industry knowledge, as well as the relationships estimated from the full data, represented by thinner lines. For the *full* data, the two lines run relatively parallel, reflecting the lack of an interaction effect, so the probability of IPO increased with both the VCF's industry knowledge and the number of prior interactions with investment partners. In the plots for the *reduced* data (i.e. subset of cases with at least one prior interaction), whereas the probability of IPO increased with the number of prior interactions, the increase was much more pronounced (steeper) when the focal VCF had low industry knowledge. Therefore, prior interactions with the syndicate partners were more valuable when the focal VCF invested in an unfamiliar industry. In addition, compared with the full data plots, when the focal VCF invested with relatively unfamiliar partners (i.e. one prior interaction), the gap between the effects of high and low industry knowledge on the probability of IPO grew much wider. Although these findings provided some support for Hypothesis 3b, they also highlighted the difficulties in accessing knowledge from unfamiliar partners (i.e. fewer prior interactions). In such cases, investment performance was best when the knowledge was sourced internally.

The results presented so far have been based on the assumption that the knowledge provided by syndicate partners was that needed by the focal VCF. While we controlled for the industry knowledge of syndicate partners in the preceding analyses, this assumption suggested that a focal VCF's access to its syndicate partners' industry knowledge would be most valuable when the focal VCF lacked such knowledge. Given the importance of this assumption for the logic underlying Hypotheses 2 and 3, we explored its validity in the context of our data. Furthermore, our findings for Hypothesis 3b (Figure 2) suggested that access to external knowledge is most challenging when the focal firm dealt with unfamiliar partners. To shed more light on these relationships and validate the assumption underlying our hypotheses, we conducted additional analyses of the interaction among the focal VCF's industry knowledge, syndicate partners' industry knowledge, and the relative familiarity of the focal VCF with these partners.

More specifically, we extended the main effects model in Table II (Model 2) to include the two-way interactions among the three variables (Table III, Model 1) and then added their three-way interaction (Table III, Model 2). The negative two-way interaction in Model 2 between the focal VCF's and partners' industry knowledge ($\beta = -0.040$, two-tailed $p = 0.032$) suggested that partner industry knowledge was more beneficial for the focal VCF when the latter lacked this knowledge. Furthermore, the three-way interaction in Model 2 was significant ($\beta = -0.065$, two-tailed $p = 0.000$), and its inclusion improved model fit (lower Akaike information criterion value than Model 1), so Model 2

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Table I. Descriptive statistics and correlations (N = 5001)

		Mean	*St. dev.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1	Investment performance[a]	0.41	0.49	1.00																			
2	Industry knowledge (of focal VCF) (logged)	2.25	1.28	−0.10	1.00																		
3	Number of syndicate partners (logged)	1.09	0.72	0.10	0.05	1.00																	
4	Number of prior interactions with same partners (logged)	0.68	0.93	0.12	0.29	0.46	1.00																
5	Industry knowledge of syndicate partners (logged)	2.26	1.75	0.04	0.28	0.72	0.56	1.00															
6	Lead investor	0.63	0.48	−0.06	0.08	−0.19	−0.06	−0.15	1.00														
7	VC firm age	12.51	9.17	−0.04	0.59	0.00	0.23	0.08	0.03	1.00													
8	Number of prior investments (logged)	3.75	1.18	−0.09	0.79	0.06	0.35	0.16	0.07	0.77	1.00												
9	Number of prior IPOs by VC firm (logged)	1.79	1.41	−0.03	0.72	0.03	0.33	0.14	0.06	0.81	0.90	1.00											
10	Location in California	0.35	0.48	0.05	0.20	0.08	0.18	0.15	0.00	0.08	0.17	0.20	1.00										
11	Location in Massachusetts	0.22	0.42	0.00	0.10	0.01	0.05	0.03	0.03	0.09	0.13	0.10	−0.40	1.00									
12	Fund size (logged)	11.26	1.29	−0.08	0.44	−0.04	0.16	0.12	0.13	0.39	0.48	0.48	0.14	0.11	1.00								
13	PFC stage	2.85	1.34	0.04	−0.12	−0.13	−0.14	−0.19	0.01	0.00	−0.06	−0.04	−0.20	0.02	−0.02	1.00							
14	PFC age	3.35	8.22	0.01	−0.05	−0.11	−0.09	−0.12	0.02	0.03	−0.01	−0.01	−0.09	0.00	0.02	0.30	1.00						
15	Industry: ICT	0.64	0.48	−0.03	0.36	0.10	0.11	0.30	0.01	0.03	0.12	0.10	0.19	0.05	0.13	−0.19	−0.13	1.00					
16	Industry: biotech/medical	0.15	0.36	0.07	−0.18	0.02	−0.01	−0.07	−0.04	−0.03	−0.05	−0.03	−0.04	−0.03	−0.10	−0.10	−0.04	−0.55	1.00				
17	Round amount (logged)	8.01	1.48	−0.07	0.23	0.41	0.17	0.41	−0.06	0.17	0.22	0.22	0.00	0.04	0.34	0.15	0.05	0.10	−0.10	1.00			
18	Indicator for 1999, 2000, 2001	0.16	0.37	−0.30	0.22	0.05	−0.04	0.12	0.03	0.10	0.19	0.14	0.02	0.04	0.17	−0.10	−0.03	0.17	−0.06	0.33	1.00		
19	Total number of IPOs in current year (logged)	5.10	0.84	−0.19	0.30	0.03	0.02	0.17	−0.01	0.18	0.27	0.22	0.03	−0.06	0.22	−0.09	−0.02	0.15	−0.02	0.35	0.24	1.00	
20	Total number of IPOs over the next 5 years (logged)	6.57	0.56	0.12	0.08	−0.03	0.06	0.04	−0.05	0.11	0.10	0.13	0.05	−0.11	0.01	0.00	0.00	−0.03	0.06	0.01	−0.53	0.40	1.00
21	Total investments in industry (scaled, logged)	4.75	1.00	−0.25	0.55	0.00	0.02	0.29	0.00	0.19	0.32	0.27	0.07	−0.03	0.23	−0.13	−0.05	0.49	−0.24	0.34	0.40	0.64	0.24

Notes: All correlations with an absolute value greater than 0.03 are significant at $p < 0.05$. Variables 1, 6, 10, 11, 15, 16, and 18 are binary, and their correlations should be interpreted with care.

[a] The investment performance variable is binary, as used in the logit estimations (Table II, Models 6, 7; Table III, Model 3). The investment performance variable used in the ordered logit models is an ordinal variable and therefore not included in the correlation table. This ordinal variable is based on the following coding (labels and frequencies provided in parentheses): −1 (failure; 4.5%), 0 (still private, 61.5%), 1 (acquisitions, 20.0%), and 2 (IPO, 14.0%).

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Table II. Ordered logit and logit estimation of investment performance

	Four categories of performance (ordered logit models)															*IPOs and acquisitions (logit models)*					
	Model 1			*Model 2*			*Model 3*			*Model 4 (full data)*			*Model 5 (reduced data)*			*Model 6*			*Model 7*		
H1: Industry knowledge (of focal VCF)				0.086	(0.05)	+	0.175	(0.07)	**	0.109	(0.05)	*	0.243	(0.11)	*	0.208	(0.08)	*	0.152	(0.06)	*
H2a: Number of syndicate partners				0.117	(0.06)	+	0.282	(0.09)	**	0.102	(0.07)		0.191	(0.11)	+	0.264	(0.11)	*	0.114	(0.08)	
H2b: Number of prior interactions				0.194	(0.04)	***	0.210	(0.04)	***	0.291	(0.08)	***	0.430	(0.14)	**	0.217	(0.05)	***	0.280	(0.10)	**
H3a: Ind. knowledge × number of partners							−0.085	(0.03)	**							−0.073	(0.04)	+			
H3b: Ind. knowledge × prior interactions										−0.036	(0.03)		−0.090	(0.05)	+				−0.029	(0.03)	
Lead investor	−0.183	(0.06)	***	−0.180	(0.06)	**	−0.172	(0.06)	**	−0.177	(0.06)	**	−0.071	(0.07)		−0.152	(0.06)	*	−0.156	(0.06)	*
VC firm age	−0.005	(0.01)		−0.002	(0.01)		−0.002	(0.01)		−0.002	(0.01)		−0.009	(0.01)		−0.004	(0.01)		−0.004	(0.01)	
Number of prior investments	−0.235	(0.07)	***	−0.350	(0.07)	***	−0.362	(0.07)	***	−0.371	(0.07)	***	−0.519	(0.15)	***	−0.443	(0.09)	***	−0.449	(0.09)	***
Number of prior IPOs by VC firm	0.275	(0.07)	***	0.254	(0.06)	***	0.260	(0.06)	***	0.267	(0.06)	***	0.383	(0.09)	***	0.292	(0.07)	***	0.297	(0.07)	***
Location in California	0.179	(0.09)	*	0.160	(0.09)	+	0.153	(0.08)	+	0.160	(0.09)	+	0.307	(0.11)	**	0.108	(0.10)		0.114	(0.10)	
Location in Massachusetts	0.135	(0.07)	+	0.136	(0.07)	+	0.137	(0.07)	+	0.137	(0.07)	+	0.272	(0.11)	*	0.113	(0.09)		0.112	(0.09)	
Fund size (logged)	−0.055	(0.02)	*	−0.047	(0.02)	*	−0.044	(0.02)	+	−0.047	(0.02)	*	−0.008	(0.04)		−0.034	(0.03)		−0.036	(0.03)	
Industry knowledge of syndicate partners	0.05	(0.02)	**	−0.048	(0.03)	+	−0.043	(0.03)	+	−0.042	(0.03)		−0.050	(0.05)		0.005	(0.03)		0.006	(0.03)	
PFC stage	0.056	(0.02)	*	0.063	(0.02)	**	0.068	(0.02)	**	0.064	(0.02)	**	0.036	(0.03)		0.052	(0.03)	+	0.049	(0.03)	+
PFC age	0.008	(0.00)	+	0.008	(0.00)	+	0.008	(0.00)	+	0.008	(0.00)	+	0.023	(0.01)	*	0.006	(0.00)		0.006	(0.00)	
Industry: ICT	0.564	(0.09)	***	0.541	(0.10)	***	0.537	(0.09)	***	0.541	(0.09)	***	0.406	(0.17)	*	0.699	(0.10)	***	0.702	(0.10)	***
Industry: biotech/medical	0.569	(0.11)	***	0.575	(0.11)	***	0.574	(0.11)	***	0.573	(0.12)	***	0.530	(0.17)	**	0.566	(0.13)	***	0.564	(0.13)	***
Round amount (logged)	0.100	(0.03)	***	0.094	(0.03)	**	0.092	(0.03)	**	0.094	(0.03)	**	0.089	(0.04)	*	0.072	(0.03)	*	0.073	(0.03)	*
Indicator for 1999, 2000, 2001	−0.667	(0.14)	***	−0.597	(0.14)	***	−0.599	(0.14)	***	−0.604	(0.14)	***	−0.456	(0.18)	*	−1.497	(0.18)	***	−1.504	(0.18)	***
Total number of IPOs in current year	−0.239	(0.05)	***	−0.234	(0.05)	***	−0.238	(0.05)	***	−0.235	(0.05)	***	−0.233	(0.07)	***	−0.175	(0.06)	**	−0.172	(0.06)	**
Total number of IPOs over the next 5 years	0.544	(0.10)	***	0.566	(0.10)	***	0.550	(0.10)	***	0.561	(0.10)	***	0.793	(0.15)	***	0.530	(0.10)	***	0.542	(0.10)	***
Total number of investments in industry	−0.445	(0.04)	***	−0.421	(0.05)	***	−0.414	(0.05)	***	−0.418	(0.05)	***	−0.460	(0.07)	***	−0.585	(0.07)	***	−0.590	(0.07)	***
Constant (logit models)																−0.48	(0.56)		−0.40	(0.55)	
Threshold for 'still private' outcome	−2.62	(0.56)		−2.49	(0.54)		−2.40	(0.56)		−2.51	(0.54)		−0.48	(1.04)							
Threshold for acquisition outcome	0.98	(0.54)		1.13	(0.53)		1.21	(0.54)		1.10	(0.52)		2.81	(1.04)							
Threshold for IPO outcome	2.33	(0.54)		2.48	(0.53)		2.57	(0.54)		2.46	(0.53)		4.26	(1.04)							
Log likelihood	−5,318.9			−5,303.3			−5,299.8			−5,302.3			−2,404.7			−2,930.3			−2,931.8		
Chi-square	956.7	***		1,017.1	***		1,012.0	***		1,076.1			904.2			505.3	***		522.4	***	
AIC	10,677.8			10,652.6			10,647.7			10,652.7			4,857.5			5,904.6			5,907.5		
N	5,001			5,001			5,001			5,001			2,170			5,001			5,001		

Notes: Coefficient standard errors shown in parentheses.
*** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.10 (two-tailed).

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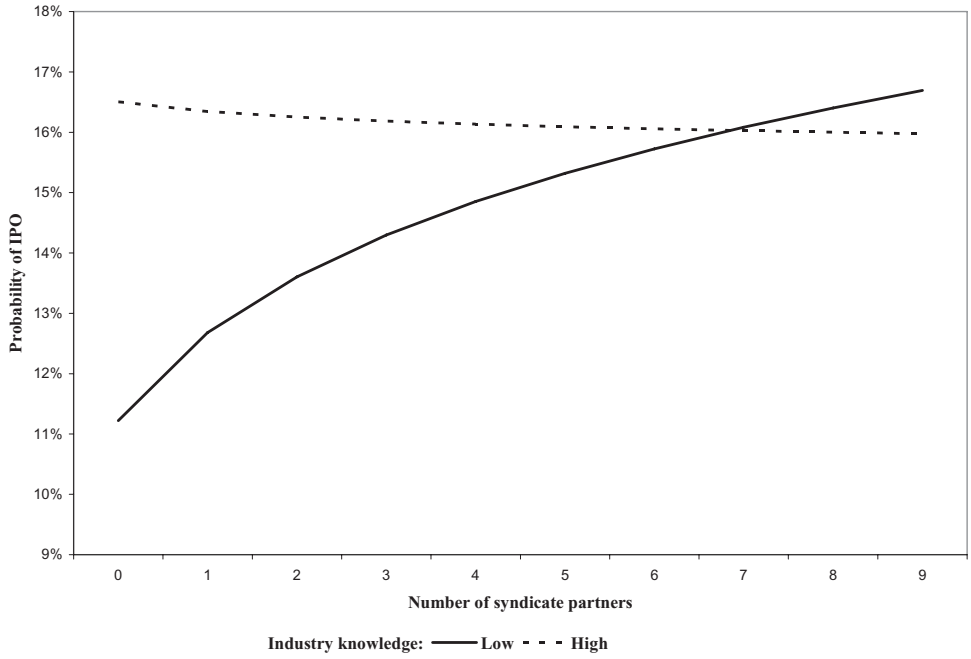

Figure 1. Interaction effect of focal VCF industry knowledge and number of syndicate partners on the probability of IPO

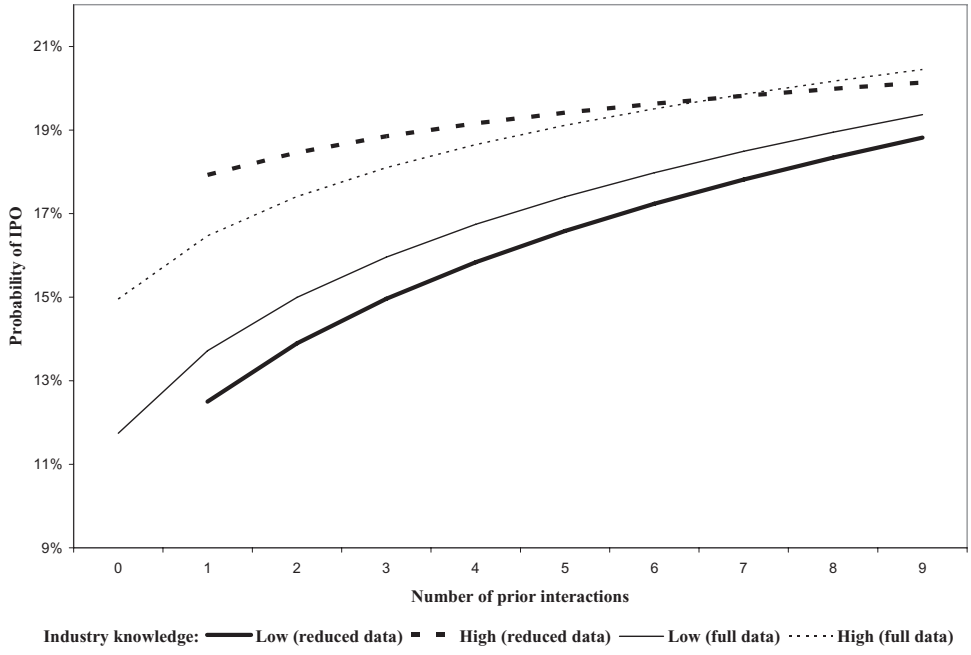

Figure 2. Interaction effect of focal VCF industry knowledge and number of prior interactions on the probability of IPO

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represented the most appropriate specification. To illustrate the nature of the three-way interaction, we plotted the effect of syndicate partners' industry knowledge on the probability of IPO for the cases in which the focal VCF had no industry knowledge, and we distinguished between cases in which the partners were unfamiliar versus well-known to the focal VCF. As we show in Figure 3, when the syndicate partners' industry knowledge increased, the probability of IPO increased substantially when the partners were familiar but remained flat when the partners were unfamiliar. Therefore, when syndicate partners had industry knowledge that the focal VCF lacked, investment performance increased, and the familiarity of these partners was instrumental for the focal VCF's effective access to such missing knowledge. Overall, the relationships illustrated in Figure 3 supported the validity of the assumption underlying Hypotheses 2 and 3 and provided additional insight into the *combined* interplay among the focal VCF's and syndicate partners' knowledge and their familiarity with each other as a result of prior interactions.

Finally, when we measured investment performance as a binary outcome, in which IPOs and acquisitions represented successful outcomes, the logit results (Table II, Models 6 and 7, replicating Models 3 and 4; Table III, Model 3, replicating Model 2) indicated that the coefficients in the logit models were fully consistent in sign and magnitude with those reported in the corresponding ordered logit models. These subsequent findings attested to the robustness of our initial findings.

DISCUSSION

Drawing from the knowledge-based view and strategic alliance literature, we examined the performance effects of the depth of the firm's knowledge on the one hand and the scope and embeddedness of its external relationships on the other. These constructs represent two distinct knowledge-driven strategies: developing knowledge internally and accessing knowledge externally through inter-firm alliances. In addition, and perhaps the most important contribution of this article, we argued that the benefits of accessing external knowledge depend on the appropriateness of the firm's internal knowledge to its tasks. Evidence from the context of venture capital investment performance reinforced some aspects of our conceptual framework and led to a more nuanced understanding of others. In the subsequent sections, we provide more detailed accounts of our findings and their theoretical and practical implications.

Internal Knowledge Development

Our findings regarding the effect of internal knowledge development on investment performance warrant special attention. Although the main effect of knowledge depth was positive, it was marginally significant (Table II, Model 2) and weaker than when considered in conjunction with the number and familiarity of external partners (Table II, Models 3 and 4). *Prima facie*, this result seems counterintuitive because it provides a relatively weak attestation for the expectations we derived from organizational knowledge and learning literature. Although it seems intuitive that more experience in a particular industry increases investment performance, our results suggest that the effect

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Table III. Estimation of the effect of focal VCF industry knowledge, partners' industry knowledge, and prior interactions on investment performance

	Four categories of performance (ordered logit models)						*IPOs and acquisitions (logit model)*		
	Model 1			*Model 2*			*Model 3*		
Industry knowledge (of focal VCF)	0.170	(0.06)	**	0.128	(0.06)	*	0.160	(0.08)	*
Number of prior interactions with same partners	0.246	(0.12)	*	−0.333	(0.22)		−0.234	(0.22)	
Industry knowledge of syndicate partners	0.059	(0.05)		0.012	(0.05)		0.045	(0.06)	
Industry knowledge of focal VCF × prior interactions	0.015	(0.04)		0.247	(0.09)	**	0.219	(0.08)	**
Industry knowledge of focal VCF × industry knowledge of syndicate partners	−0.040	(0.02)	*	−0.022	(0.02)		−0.016	(0.02)	
Prior interactions × industry knowledge of syndicate partners	−0.018	(0.03)		0.155	(0.06)	**	0.125	(0.06)	*
Ind. knowledge of focal VCF × ind. knowledge of synd. partners × prior interactions				−0.065	(0.02)	***	−0.056	(0.02)	**
Number of syndicate partners	0.082	(0.07)		0.090	(0.07)		0.104	(0.08)	
Lead investor	−0.173	(0.06)	**	−0.176	(0.06)	**	−0.158	(0.06)	**
VC firm age	−0.002	(0.01)		−0.002	(0.01)		−0.004	(0.01)	
Number of prior investments	−0.370	(0.07)	***	−0.368	(0.07)	***	−0.443	(0.09)	***
Number of prior IPOs by VC firm	0.266	(0.06)	***	0.266	(0.06)	***	0.292	(0.07)	***
Location in California	0.158	(0.08)	+	0.164	(0.09)	+	0.120	(0.10)	
Location in Massachusetts	0.133	(0.07)	+	0.126	(0.07)	+	0.103	(0.09)	
Fund size (logged)	−0.045	(0.02)	+	−0.045	(0.02)	+	−0.035	(0.03)	
PFC stage	0.066	(0.02)	**	0.065	(0.02)	**	0.050	(0.03)	+
PFC age	0.008	(0.00)	+	0.009	(0.00)	+	0.007	(0.00)	
Industry: ICT	0.525	(0.09)	***	0.518	(0.09)	***	0.679	(0.10)	***
Industry: biotech/medical	0.566	(0.11)	***	0.570	(0.11)	***	0.558	(0.13)	***
Round amount (logged)	0.093	(0.03)	**	0.095	(0.03)	***	0.074	(0.03)	*
Indicator for 1999, 2000, 2001	−0.617	(0.14)	***	−0.623	(0.13)	***	−1.525	(0.18)	***
Total number of IPOs in current year	−0.235	(0.05)	***	−0.238	(0.05)	***	−0.176	(0.06)	**
Total number of IPOs over the next 5 years	0.532	(0.10)	***	0.533	(0.10)	***	0.517	(0.10)	***
Total number of investments in industry (scaled, logged)	−0.414	(0.05)	***	−0.410	(0.05)	***	−0.575	(0.06)	***
Constant (logit model)							−0.324	(0.54)	
Threshold for 'still private' outcome	−2.56	(0.54)		−2.62	(0.53)				
Threshold for acquisition outcome	1.06	(0.52)		1.01	(0.51)				
Threshold for IPO outcome	2.42	(0.53)		2.37	(0.52)				
Log likelihood	−5,298.7			−5,293.0			−2,926.6		
Chi-square	1,101.9	***		1,102.2	***		568.9	***	
AIC	10,649.5			10,640.0			5,903.1		
N	5,001			5,001			5,001		

Notes: Coefficient standard errors shown in parentheses.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$ (two-tailed).

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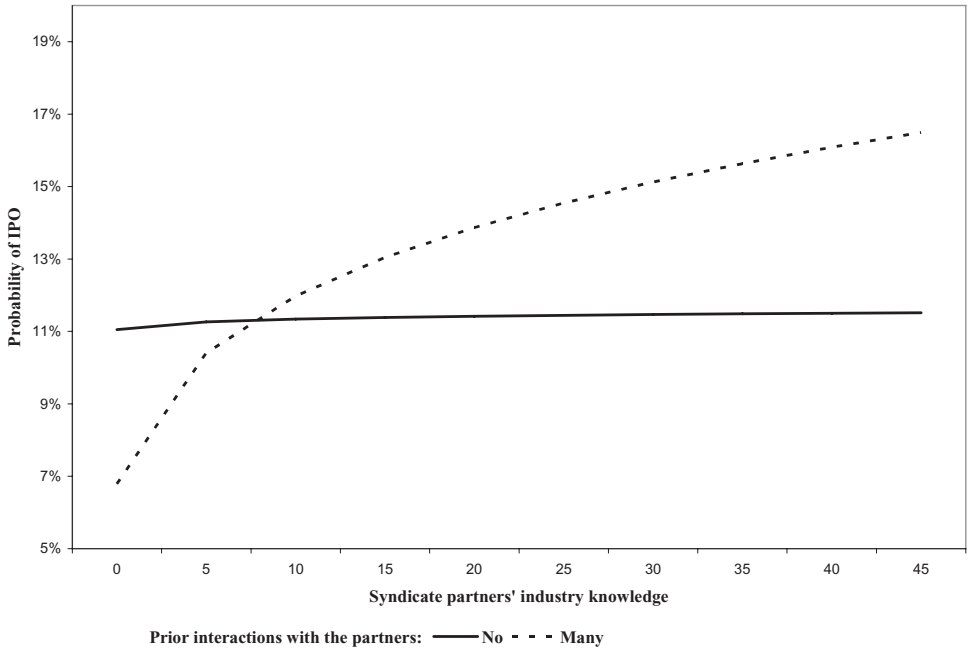

Figure 3. Interaction effect of syndicate partners' industry knowledge and prior interactions on the probability of IPO when the focal VC firm has no industry knowledge

of internal knowledge is suppressed but becomes more pronounced when we take into consideration the effects of external relationships. As Figures 1 and 2 show, the focal VCF's internal knowledge matters substantially when there are no syndicate partners involved or the partners are unfamiliar, but its importance declines as the firm sources the needed knowledge from external partners.

We believe these results from a VC setting are largely applicable to the broader context of inter-firm relationships. Overall, the results imply that internal knowledge depth represents an important but insufficient condition for better performance. Although it may be somewhat precarious to speculate about particular cases, the benefits from developing knowledge internally probably are not automatic when it is too time consuming or expensive for a firm to acquire knowledge on its own (Grant and Baden-Fuller, 2004). Similarly, for the context of joint ventures, it has been argued that firms are more inclined to cooperate and benefit from that cooperation when their shared objectives involve creating new products that each party would find difficult or time consuming to create individually (Harrigan, 1985).

In general, our findings add an important nuance to our original theoretical idea: experience and learning might improve focal firm performance, but interactions among competing organizations can create a context in which such internal performance improvements do not translate into competitive advantage. As the interactions between internal and external knowledge demonstrate (Figures 1 and 2), firms lacking in knowledge for a particular task can leverage a powerful pool of external knowledge through relationships with other firms. Firms with low knowledge could endanger their

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performance if they do not seek external relationships. In addition, to the extent that they work with fewer partners, choosing familiar partners might prompt the desired performance benefits. Experienced firms face no such constraints, and their performance remains stable even with no, little, or ad hoc external partnering. These conclusions may be particularly appropriate, and therefore useful, for the context of new ventures, which typically lack resources to develop in-depth knowledge in a particular domain (Stinchcombe, 1965; Zimmerman and Zeitz, 2002) and therefore have much to gain from collaborating with knowledgeable and trustworthy external parties (Stuart et al., 1999).

Access to External Knowledge

Consistent with our expectations, we found that access to external knowledge, in terms of the number of a firm's exchange partners, enhances performance. More partners increase the scope of knowledge the firm can access and offer more solutions to specific problems. In the context of our study, investments that involved more syndication partners were more likely to succeed, perhaps because more investors likely selected better deals (Lerner, 1994) and helped bring these investments to successful ends (Brander et al., 2002). Our findings thus reinforce the knowledge-sharing rationale for investment syndication and, more generally, inter-firm collaboration. Furthermore, we argued that with more partners, exchange relationships may face misaligned goals (Nahapiet and Ghoshal, 1998) or less efficient decision making because of coordination issues (Gulati et al., 2005). Our operationalization of the number of exchange partners incorporated this diminishing marginal effect of the number of syndicate partners on investment performance, and we thus found support for the notion that the increased costs of managing larger partnerships can make it more difficult to realize their knowledge benefits.

With regard to firms' relational embeddedness, we found that collaboration with familiar partners enhances performance. Although prior research provides some caveats about the usefulness of embedded relationships – prior interactions could be unsuccessful or result in redundant information exchanges (e.g. Burt, 1992) – the strong positive association between the prior interactions and performance variables indicated that embedded relationships were fruitful for the focal firm, albeit to a diminishing degree. More specifically, such relationships enhance the amount and quality of knowledge transfer between partners (De Clercq and Sapienza, 2006; Robinson and Stuart, 2001; Uzzi, 1997) and help reduce the costs of locating and screening exchange partners (Granovetter, 1985), assessing their reliability and specific capabilities (Gulati, 1995), and monitoring their commitment and performance. In the VC context, trusted, familiar partners likely provide better quality deals and represent a well-defined domain of post-investment involvement and added value. Because VCFs often interact repeatedly and across investments in different portfolio companies, interactions improve the knowledge flow and efficiency of decision making within the syndicate (Wright and Lockett, 2003).

The most interesting part of our results relates to the interplay between the benefits of access to external knowledge and the appropriateness of the firm's internal knowledge.

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We empirically showed that when a firm lacked the knowledge necessary to perform successfully in a particular (product) domain, collaborating with external partners was most beneficial. Conversely, when the knowledge and task were congruent, the effect of external collaboration was minimal. These results lend empirical credence to the claim that incongruity between firms' knowledge and product domains influences the extent to which they benefit from strategic alliances (Grant and Baden-Fuller, 2004). What a firm knows and what it intends to do reflect two domains that continuously align and misalign as firms learn from their prior actions and pursue new goals. Because this incongruity varies both in degree and over time, accessing external knowledge through inter-firm alliances represents a strategic choice that intertwines with firms' current goals and assessments of their own internal knowledge.

Our study also sheds light on the mechanism through which external partnerships can compensate for firms' internal knowledge gaps. In particular, our supplementary results indicated that *embedded* relationships (evidenced by prior interactions) were particularly beneficial when a focal firm lacked appropriate knowledge and therefore needed to rely on more knowledgeable partners (Figure 3). This finding qualified the formation of external relationships and reinforced the importance of trustworthiness for the effective absorption of external knowledge (De Clercq and Sapienza, 2006; Dyer and Singh, 1998; Lane and Lubatkin, 1998).

Taken together, our findings with regard to the joint performance effects of internal knowledge development and external knowledge access reinforced the view of the firm as a knowledge integrator (Grant, 1996a). That is, for performance of a particular task, internal knowledge may confer a competitive advantage, but so may the firm's ability to gain and integrate knowledge from other firms.

Limitations, Future Research, and Practical Implications

Several limitations to our study suggest avenues for further research. The first limitation pertains to the generalizability of our findings to contexts other than VC. Specifically, the dimension of internal knowledge we used may not apply readily to other, single-industry contexts. In addition, VC syndicates may be a special case of strategic alliances or equity joint ventures, and may possess specific characteristics, such as a temporary nature (Wright and Lockett, 2003), that distinguish them from 'classic' alliance settings. Our data also lacked sufficient detail to examine the specific nature and outcomes of prior interactions between partners. Additional research should distinguish between cases in which a focal firm's prior experience with a particular partner is positive versus is negative. Further studies also could examine the direction of knowledge flows among syndicate partners and compare lead and non-lead investors in terms of knowledge benefits received. Another research option involves the influence of alternative sources of external knowledge, such as consultants, VC forums, research universities, and existing portfolio company CEOs. Finally, we considered the focal firm a black box and therefore overlooked any potential links among the capabilities of its management team, its knowledge-management strategies, and alliance outcomes. The combination of the specific expertise of the focal firm's individual managers and

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that of individual managers outside the firm therefore represents a potentially important factor for consideration.

Our findings have important implications for practitioners. In the broader context of inter-firm relationships, firms should strike a balance between the knowledge they possess internally and the knowledge potential alliance partners offer. Firms must be aware that the degree to which they can benefit from collaborations depends on internal factors, such as the extent of mismatch between their current knowledge and the knowledge domains necessary to create desired products. They can manage this mismatch effectively by accessing knowledge from specific external relationships and thus avoiding the costs of internally developing knowledge for all product domains (Grant and Baden-Fuller, 2004). However, relying too heavily on others' knowledge may stifle internal knowledge creation and hinder exploration of knowledge domains that, though not currently essential, could become so in the future (Gupta et al., 2006; Levinthal and March, 1993).

In the context of VC investing, our results suggest that VCFs can benefit by devoting sufficient attention to internal learning processes and understanding the knowledge contributions of potential syndicate partners. Investments in less familiar industry sectors can succeed if undertaken in collaboration with familiar partners. On the receiving end of investments, entrepreneurs may extract higher benefits from VC investors by conducting elaborate due diligence of the specific strategic and operational competences that investors offer, particularly in terms of the VCFs' prior investment record with various industries and syndication partners.

ACKNOWLEDGMENTS

The authors acknowledge insightful comments from Michael Lubatkin, Harry Sapienza, Mike Wright, and three anonymous reviewers.

NOTES

[1] Prior literature has suggested other dimensions, such as geographic location or development stage, along which VCFs may exhibit portfolio specialization (Gupta and Sapienza, 1992; Norton and Tenenbaum, 1993). However, the rationale for geographic location specialization relies on convenience and a motive to monitor portfolio companies closely rather than the accumulation of specific knowledge. Compared with industry knowledge, stage knowledge is harder to assess and measure; even if a VCF focuses on particular stages, it gets exposed (and thus learns from) all subsequent development stages as the companies in its portfolio mature and prepare for exit.

[2] These knowledge benefits may be particularly strong for VCFs that take on the role of lead investor in the syndicate, because lead investors tend to be more active (Wright and Lockett, 2003). We thank an anonymous reviewer for this useful insight.

[3] We acknowledge, however, the uncertainty inherent in assessing VCF performance as, for instance, not all trade sales are successful (e.g. in the case of fire sales), or an investment that has not been exited is not necessarily unsuccessful.

[4] We used the specification $\ln(1 + n)$, where n is the number of prior investments.

[5] Nevertheless, our measure downplays the cases in which the focal VCF (or other members of the syndicate) invites other VCFs to join subsequent investment rounds. To the extent that no qualitative difference marks the syndication behaviour of VCFs across portfolio companies and across time as the companies progress towards exit, this downward bias represents a random component of unexplained variance in our estimations.

[6] We also assessed the focal VCF's role as lead investor using two alternative specifications: whether it had provided at least 30 or 50 per cent of the total amount invested in the portfolio company. All specifications yielded similar results; neither the pattern nor the significance of the results changed.

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