The Specialization Choices and Performance of Venture Capital Funds

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Abstract

It is often asserted that venture capital (VC) funds specialize by industry, stage, and geography. Little research in finance, however, has empirically examined how specialized VC funds really are, and how they make their specialization choices. Using a principal-agent model, I analyze why VC funds display various degrees of specialization from a theoretical perspective. In addition, I test the predictions of my model using a sample of 1586 funds with 64168 venture investments. My study shows that there exists great heterogeneity in fund specialization. Fund size, proxies for VCs' risk aversion, and proxies for the risk associated with the excess return of the fund all have negative effects on specialization. I construct two measures distinguishing VCs' specialized talent from their general talent. I find that it is VCs' specialized talent that really matters in determining specialization. There is also evidence indicating a positive relationship between specialization and fund performance. Furthermore, specialized talent and general talent are both positively related to performance.

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1. Introduction

It is often asserted that venture capital (VC) funds specialize, investing in a particular industry, at a specific stage of company development, or within a particular geographic region. Sahlman (1990) declares that "some will invest only in early-stage deals, whereas others concentrate on later-stage financings."[2] Barry (1994) states that "venture capitalists (VCs) typically specialize by emphasizing a particular industry, such as biotechnology, or by emphasizing a particular stage of company development, such as startup companies or companies in the expansion stage."[3] These assertions are based mainly on anecdotal evidence. The authors do not further examine how specialized VC funds are. Indeed, little research in finance has tried to measure the specialization patterns of VC funds using real investment data or to develop a formal model explaining the specialization choice of venture capitalists. In this study, I show that a large number of US venture funds are not specialized. There exists great heterogeneity in fund specialization. Some are narrowly focused, some are more inclusive, and others are well diversified over different industries, stages, or geographic regions.

The wide variation in specialization patterns raises the question of how venture capitalists choose a particular degree of fund specialization while selecting firms to finance. It also poses the question of how the choice of specialization affects fund performance. These questions are important in understanding the venture investment process and also the role of venture capitalists. Venture capital has been a leading source of financing for innovative young entrepreneurial firms. Although young firms account for a relatively small portion of the whole economy, they are the

[2] Sahlman, William A., 1990, The structure and governance of venture-capital organizations, *Journal of Financial Economics* 27, page 489.

[3] Barry, Christopher B., 1994, New directions in research on venture capital finance, *Financial Management* 23(3), page 5.

driving force of the technology revolution and economic growth. Over the past several decades, venture capital has backed many famous companies, including Apple Computer, Intel, Microsoft, and Google. Those companies have grown very fast and have been the job-creating engine of the society. As Gompers and Lerner (1999b) point out, exploring the incentives and factors of fund specialization can help us understand the dynamics of the VC industry and "make better recommendations about promoting new entrepreneurial firms".[4] In my study, I explore the motivation and the goal of venture capitalists when they select various firms to finance, and relate fundamental characteristics of a fund to its specialization choice. By examining how VCs' talent affects fund specialization, I further assess whether VCs' human capital plays an important role in selecting the right companies and assisting young firms to grow.

In addition, fund specialization is important because how VCs construct their portfolio will have a first-order effect on future performance of the funds. Previous research on VC investment has focused on how VCs supervise entrepreneurial firms after they have made the selection. Little attention is given to how VCs set up their portfolios in the very first place. My study fills this gap by exploring why funds display various specialization patterns and how the degree of specialization affects their performance. Furthermore, knowing the specialization preferences of venture capitalists can help entrepreneurs target the right fund while seeking VC financing.

From a venture capitalist's perspective, there are costs and benefits to fund specialization. The idea of gain from specialization was pioneered by the Scottish philosopher Adam Smith. In his seminal book, The Wealth of Nations (1776), Smith argues that workers should concentrate on what they do best. As workers specialize, they become skilled and proficient at their tasks, hence increasing productivity and output. When a venture capitalist displays talents well suited to a particular industry, stage, or geographic region, he will most likely do a good job managing VC

[4] Gompers, Paul A., and Josh Lerner, 1999b, What drives venture capital fundraising? Working paper, page 31.

funds by focusing on that specific area. Sahlman (1990) observes that specialization can reduce marginal operating costs when VCs learn things and develop skills over time. By specializing, the VCs can accumulate area-specific experience in a fast and efficient fashion. They can establish long-term relationships with suppliers, customers, lawyers, and investment bankers. This network of contacts cultivates a flow of profitable deals for VC firms. The ultimate effect is that the marginal cost of selecting and supervising a portfolio company declines over time, and the VC firm becomes more productive. Gompers and Lerner (2004) also indicate that VCs have highly specialized skills. These skills are very difficult to develop. It would be costly and time-consuming for VCs to switch to new product or business areas.

Fund specialization, however, entails costs as well as benefits. People have long been aware of the importance of diversification. Markowitz (1952, 1958) was the first to demonstrate rigorously how diversification can reduce portfolio risk without affecting expected returns. This result is the foundation of modern portfolio theory (MPT). On the basis of MPT, William Sharpe (1961, 1964) and John Lintner (1965) developed the Capital Asset Pricing Model (CAPM). They classify risk into two types, systematic risk and idiosyncratic risk. Diversification reduces idiosyncratic risk. By spreading investments over different industries, stages, or geographic regions, VCs can reduce idiosyncratic risk and improve the Sharpe ratio (the ratio of excess return to risk) of their funds.

Furthermore, venture capital is a very risky business. Gompers and Lerner (2004) characterize VC investments by four critical factors: uncertainty, information asymmetry, asset intangibility, and unpredictable market conditions. Cochrane (2003) states that venture capital is very illiquid and hence involves more risk than traditional assets. Barry (1994) notes that more than one-third of VC portfolio investments result in losses, and "a sizable fraction results in loss of the entire original investment."[5]

[5] Barry, Christopher B., 1994, New directions in research on venture capital finance, *Financial Management*, 23(3), page 3.

In sum, there is a tradeoff between generating return and controlling risk when venture capitalists make portfolio selections. By specializing, VCs can fully utilize their expertise and generate superior expected return. By diversifying, VCs can reduce return variance and better control portfolio risk. Exploring how VCs balance the costs and benefits by choosing a particular degree of specialization helps us better understand the VC fund construction and investment process.

Based on the intuition discussed above, I develop an economic model of fund specialization choice within the basic principal-agent framework. Venture investors are the principals. They seek to maximize the risk-adjusted expected return from venture funds. VCs are risk-averse agents and differ in specialized skills. They have the potential to generate superior expected return by actively managing the venture portfolio. However, VCs care about not only the expected return from the fund, but also the risk incurred. The choice of fund specialization is modeled through the tradeoff between generating superior expected return and controlling risk for venture capitalists. As the principal, venture investors design the compensation scheme to align their interests with VCs and affect the degree of specialization. In the model, fund specialization and VCs' compensation are simultaneously determined by fundamental characteristics of the fund. These characteristics include fund size, GPs' talent, GPs' degree of risk aversion, and the risk associated with the excess return of the fund. More specifically, the model implies a positive relationship between fund specialization and the amount of VCs' specialized talent. In addition, the degree of specialization is negatively related to fund size, VCs' risk aversion, and the riskiness of the area where VCs have specialized talent.

Using a sample from the Securities Data Company (SDC) VentureXpert database, I examine the specialization patterns of U.S. VC funds and test the empirical predictions of my model. The final sample has 1586 funds (64168 financing rounds) with detailed fund investment information

about their portfolio companies. The empirical results strongly support my model's predictions. In particular, I construct two measures distinguishing VCs' specialized talent from general talent. I find that it is VCs' specialized talent, not general talent, that helps explain fund specialization. This implies that VCs' human capital plays an important role in determining portfolio construction. If VCs have no specialized talent, they will choose a diversified portfolio. If VCs have talent, they will emphasize firms in their specialty area. That is to say, VCs select portfolio companies that match with their talent and experience. By choosing the right companies to finance, VCs may give valuable advice to entrepreneurs on product development and business strategy, and help young firms to grow. There is also strong evidence that specialization is negatively related to fund size, to proxies for VCs' degree of risk aversion, and to proxies for VCs' expertise-area risk.

The evidence, moreover, shows that specialization affects fund performance. I use two proxies to measure fund performance. One is the fraction of firms that went public or were in registration for an offering in a venture portfolio, and the other is the fraction of firms that were acquired, merged, went public, or were in registration for an offering in a VC fund. I find that the degree of specialization is positively related to fund performance. This reinforces the argument that by utilizing their talent and expertise for a particular area, VCs can add value to portfolio firms. However, industry and stage specialization appear to improve performance more than geographic specialization. The result also shows that both specialized talent and general talent are positively related to fund performance.

Finally, I examine the behavior of Small Business Investment Companies (SBICs). SBICS are a part of the VC industry and have played an important role in financing small firms. However, because SBICs are backed and regulated by the Federal Government, their specialization choices may differ from those of regular VC funds. I find that SBICs display a lower degree of industry and

stage specialization, but a higher degree of geographic specialization than other VC funds. In terms of fund performance, the SBICs tend to under-perform regular VC funds.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 sets up the model and derives testable hypotheses. In section 4, I discuss the empirical methods and report the results. Section 5 concludes.

2. Related Literature

2.1. The history and nature of venture capital

According to Gompers and Lerner (2004), the first modern venture capital firm, American Research and Development (ARD), was initiated in 1946 by MIT President Karl Compton and Harvard Business School Professor Georges F. Doriot. It was structured as a publicly traded closed-end fund and the investors were mostly wealthy individuals. Lacking participation of institutional investors, the venture capital industry raised little money in the 1960s and 1970s, and received little attention. Gompers and Lerner (2004) report that annual VC fundraising was only about several hundred million dollars or less during these years.

In 1979 the clarification of the prudent man rule played a critical role in encouraging VC investment. The prudent man rule is based on the common law of trusts, stemming from the 1830 Massachusetts court case of Harvard College v. Amory.[6] The rule required trustees to invest very carefully, like a prudent man. Most pension fund managers were concerned that VC investments may be deemed imprudent due to the high risk involved. Hence, they seldom participated in venture investments. In 1979 the Department of Labor published an amendment to the prudent man rule. The amendment specified that a fiduciary should give "appropriate consideration" to "the composition of the portfolio with regard to diversification", and that "the relative riskiness of a

[6] The court stated that "a fiduciary shall exercise the judgment and care, under the circumstances then prevailing, which men of prudence, discretion, and intelligence exercise in the management of their own affairs".

specific investment does not render such investment either per se prudent or per se imprudent." The Department further expressed the opinion that "although securities issued by a small or new company may be a riskier investment than securities issued by a blue chip company, the investment in the former company may be entirely proper under the Act's prudence rule." Under this amendment VC investment may be viewed as a prudent way to diversify. It explicitly allowed pension funds to allocate a portion of their total managed wealth to venture investment. Since then, pension funds and other institutional investors have become a significant source of VC capital and the VC industry has experienced dramatic growth. According to Thomson Venture Economics and the National Venture Capital Association (NVCA), new venture funds in 2005 attracted 25.2 billion dollars in fundraising, the highest yearly total since 2001 when new funds raised 38 billion dollars.

Sahlman (1990) gives a detailed description of how venture capitalists operate. He defines venture capital as a "professionally managed pool of capital that is invested in equity-linked securities of private ventures at various stages in their development."[7] Gompers and Lerner (1999a) put together their recent studies into a complete volume, examining the whole cycle of VC fundraising, investing and exiting process. They define venture capital as "independently managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high-growth companies."[8]

There are various forms of VC organizations, including publicly traded closed-end funds, independent VC corporations, industrial corporate venture programs, affiliations or subsidiaries of financial firms, small-business investment companies, and private limited partnerships. The predominant form in the U.S. is the private limited partnership, with venture capitalists serving as

[7] Sahlman, William A., 1990, The structure and governance of venture-capital organizations, *Journal of Financial Economics* 27, page 473.
[8] Gompers, Paul and Josh Lerner, 1999, The venture capital cycle, 1st edition, MIT Press, page 349.

general partners (GPs) and venture investors as limited partners (LPs). Venture capitalists raise money from the limited partners, which include wealthy individuals, university endowments, pension funds, banks and insurance companies. They usually invest in young and risky firms, with the potential for high future returns. Venture capitalists, on behalf of LPs, actively manage their investment in entrepreneurial firms. VCs may sit on boards of directors to closely monitor company progress. They may also advise and assist entrepreneurs in recruiting employees, designing products, and planning business strategies. They sometimes assume managerial roles in firms, as well.

The limited partnership typically has a pre-determined, finite life of 10 years. Upon the approval of limited partners, the life can be extended, usually up to 3 years. The partnership is designed to be self-liquidating. At the end of the fund's life, all of its assets must be distributed to the partners. Venture capitalists usually raise a new fund well before an old fund is completely dissolved, so that they can have continual investment activities. Most limited partnerships also require annual distributions from realized fund profits. General partners can decide whether they want to make distributions in the form of cash or securities, or both. If a venture-backed firm becomes successful and has an initial public offering, the general partners usually allocate the registered shares to limited partners in proportion to their amount of fund investment.

The compensation of general partners consists primarily of two parts: management fee and carried interest. General partners are entitled an annual fixed management fee, expressed as a fraction of the fund's committed capital or net asset value. They also receive a specified fraction of the fund's realized profits, often around 20%. This is referred to as carried interest. In addition, limited partnerships often require GPs to invest their own money, usually 1% of the fund capital. Hence, GPs will share some proportionate fund return.

2.2. Related work on VC fund specialization

The topic of VC fund specialization was first considered by Norton and Tenenbaum (1993). They ask the simple question of whether the VC firms tend to be diversified or specialized in their portfolio construction. They collect survey data from 98 venture capitalists. Their specialization measures denote the number of industries or the number of companies in a venture portfolio. They first look at the correlation coefficients between the specialization measures and the percentage of funds invested in early stages. But the results are mixed. They further propose that if VCs specialize by stage, the percentage of financing in a given stage may be positively related to those of nearby stages as a result of follow-on investments. By examining the correlation coefficients between the percentages of funds in each financing stage, they claim that VC firms appear to specialize by stage.

Gupta and Sapienza (1992) try to identify some factors affecting VCs' preferences regarding industry and geographic scope of their investments. They argue that VC funds investing only in early-stage firms would prefer more industry and geographic diversity because of the high risk involved in early-stage financing. They also suggest that larger VC funds tend to be more diversified because larger funds need more projects to invest in and their managers may possess superior capabilities relevant to a wider set of investment opportunities. Using a sample of 169 venture capital funds, they find some support for their hypotheses. However, the data for this study was obtained through questionnaire surveys completed by sampled venture firms. Those firms were asked about their willingness to invest in multiple industries and geographic areas. So the proxy for fund specialization used by Gupta and Sapienza is a measure of VCs' personal preferences rather than the actual investment patterns. Furthermore, Gupta and Sapienza do not consider another important aspect of VC investment, specialization choices regarding stage of development.[9]

[9] Gupta and Sapienza examine whether VC funds with early-stage focus prefer more industry diversity and geographic scope, but they don't study how funds choose different stage focus.

In sum, both of the above papers use questionnaires and small samples of VC funds. Their specialization measures reflect the subjective intentions of VCs, but not the true investment patterns of the funds.

Two recent papers (Schertler (2004), Mayer, Schoors and Yafeh (2005)) examine the specialization patterns of VC investments in foreign countries. Both papers focus on how sources of funds affect fund specialization. Schertler (2004) argues that in a financial market with frictions and rigidities, there exist asymmetric information and transaction costs between suppliers of funds and the enterprises demanding capital. Because suppliers of funds differ in their risk preferences and capability to deal with information and transaction problems, they would choose different risk prospects of fund specialization. In particular, Schertler suggests that banks may favor a low-risk profile, while Government, corporations, pension funds, insurance companies, and academic institutions may prefer a high-risk profile for VC funds.

Schertler examines her hypotheses using a panel dataset of 224 observations, across 16 Europeans countries from 1988 to 2002.[10] She studies the focus of country-level aggregate VC investment on two risky industries, the information industry and the life science industry, and on two stages of company development, the early stage and the expansion stage. Schertler finds some evidence indicating the link between sources of funds and stage specialization, but her empirical results with respect to industry specialization are very weak. Schertler utilizes a macro-level database and examines the total VC investment for a whole country. Therefore, her work does not address the question of how individual VC funds make portfolio selections.

Mayer, Schoors and Yafeh (2005) compare VC fund investment focus and sources of finance across Germany, Israel, Japan, and the United Kingdom. Using a dataset of 508 venture funds, they empirically explore whether the sources of funds are related to the stage, industry, and geographic

[10] The 16 Europeans countries are Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

focus of those funds. Their empirical results show some relationship between fund specialization and VC financing. However, much of the within and cross-country variation is not mainly due to sources of funds. Mayer, Schoors and Yafeh finally conclude that the pronounced differences of VC investment focus in these four countries are not primarily related to either financial systems or sources of funds.

A very recent paper by Gompers, Kovner, Lerner and Scharfstein (2006) examines how organizational structure of VC firms, particularly the degree of specialization, affects the performance of venture capital firms. They measure specialization at the VC firm level and also at the individual venture capitalist level. Using a dataset containing 2690 venture capitalists from 768 VC firms, Gompers, Kovner, Lerner and Scharfstein find a strong positive relationship between the degree of specialization by individual VCs at a firm and its success. The effect of firm-level specialization on fund performance is much weaker when the individual VCs are highly specialized. However, Gompers, Kovner, Lerner and Scharfstein only study the effect of industry specialization on VC firm success. How specialization by stage and geography affects fund performance is still unclear. Furthermore, they take the specialization choices of VC firms as given. How VCs choose different degree of specialization in the first place is not addressed.

The existing literature indicates that the degree of specialization is an interesting aspect of the venture investment process and that it may affect fund performance. Therefore, it is important to examine what drives the specialization choices of VC funds. Mayer, Schoors and Yafeh (2005) suggest that there are important factors other than the sources of funds affecting VC investment focus, but what those factors are remains unknown. Little previous research has focused on analyzing the specialization choices of VCs from a theoretical perspective, or examining the specialization patterns of a large sample of US venture funds. My study adds to the literature by developing an economic model and proposing fundamental factors underlying fund specialization.

In addition, I draw a complete picture of VC specialization patterns in the U.S. by empirically analyzing the three dimensions of fund focus: by industry, by stage and by geography.

The next section sets forth an economic model that provides a theoretical framework for analyzing the specialization choices of VC funds.

3. Model and Hypothesis

Since the end of the 1970s, the independent limited partnership, unaffiliated with any bank or other corporate entity, has become popular and now is the dominant form of VC organization. Gompers and Lerner (2004) have shown that during the 1990s and early 2000s, limited partnerships accounted for about 80% of total venture capital fundraising. Therefore, I only consider private limited partnerships in my analysis.

Following Holmström (1979), Ramakrishnan and Thakor (1982), Ramakrishnan and Thakor (1984), Starks (1987), and Golec (1992), I use the basic principal-agent framework to model the decision-making process of GPs and LPs. The GPs actively manage the VC funds on behalf of LPs. GPs select an optimal degree of fund specialization by weighing the cost of and benefits of having a specialized portfolio. As the principal, LPs monitor the funds' progress and use GPs' compensation scheme to align their interests and affect the degree of specialization.

The following section sets up the model. Section 3.2 derives some testable hypotheses.

3.1 Modeling Specialization Choices

3.1.1 Return-generating process

Investors are assumed to care about the aggregate return on a venture portfolio instead of returns on individual portfolio companies. Let $\tilde{R}_p$ denote the total random return of a particular

venture fund. Similar to Ramakrishnan and Thakor (1984) and Golec (1992), I assume the following return-generating process:

$$\tilde{R}_p = \tilde{R}_n + \alpha(\eta, s) + \left[V(s)\right]^{1/2} \cdot \tilde{\varepsilon} \tag{3.1}$$

where $\tilde{R}_n \sim N\left(\overline{R}_n, \sigma_n^2\right)$, $\tilde{\varepsilon} \sim N\left(0, \sigma_\varepsilon^2\right)$, and $\operatorname{cov}\left(\tilde{R}_n, \tilde{\varepsilon}\right) = 0$.

$\tilde{R}_n$ denotes the benchmark return for this VC fund. It is assumed to be normally distributed with mean $\overline{R}_n$ and variance σ_n^2. $\tilde{\varepsilon}$ is the random portfolio-specific return. It is also assumed to be normally distributed with mean zero and variance σ_ε^2. Due to its unsystematic nature, I assume $\tilde{\varepsilon}$ is independent of the benchmark return $\tilde{R}_n$. It follows immediately that $\tilde{R}_p$ is also normally distributed.

Venture capitalists are assumed to have different amounts of specialized talent and can generate superior returns by actively managing the portfolio companies. Starks (1987) assumes that mutual fund managers can invest resources to generate superior returns. Similarly, I assume that venture capitalists can generate superior returns by focusing in areas where they have specialized talent. $\alpha(\eta, s)$ denotes the units of nonrandom superior return generated by the venture capitalist. It is a function of η and s. η is the amount of specialized talent a venture capitalist possesses, and $\eta \geq 0$. s is the degree of specialization for this venture fund, and $0 \leq s \leq 1$. When $s = 0$, $\alpha = 0$.

I assume that $\frac{\partial \alpha(\eta, s)}{\partial s} > 0$ for $\eta > 0$, and $\frac{\partial \alpha(\eta, s)}{\partial \eta} > 0$ for $s > 0$. The first term means that a venture capitalist can generate more superior return if his portfolio is more concentrated in his specialty area. The second term implies that a venture capitalist can generate more superior return

if he has more specialized skill. I also assume $\frac{\partial^2 \alpha(\eta, s)}{\partial \eta \partial s} > 0$. When a venture capitalist has more specialized talent, the marginal increase in superior return will be bigger with increased specialization.

Concentrating on a specialty area, however, increases the idiosyncratic risk of the venture portfolio. The term $[V(s)]^{1/2} \cdot \tilde{\varepsilon}$ captures this effect. I assume $V(s) \geq 0$ for $0 \leq s \leq 1$, and $V'(s) > 0$. When $s = 0$, the venture fund is perfectly diversified, implying $V(s) = 0$. When s increases and the portfolio becomes more focused, $V(s)$ also increases.

I further assume that $V''(s) > 0$ and $V'''(s) > 0$. When the venture portfolio becomes more specialized, the marginal increase of idiosyncratic risk speeds up and the acceleration in marginal changes also increases. This assumption is consistent with the generally accepted proposition that the portfolio variance decreases at a reducing rate when the portfolio gets more diversified.

In addition, I assume that $\frac{\partial^2 \alpha(\eta, s)}{\partial s^2} > 0$ and $\frac{\partial^3 \alpha(\eta, s)}{\partial s^3} < 0$. The first condition says that when the venture portfolio becomes more focused, the marginal change in superior returns also increases. By focusing more on their specialized areas, the venture capitalists can make better use of their area expertise and social network. They may even be able to develop more area-related skills. Therefore, the marginal changes of superior returns increase with specialization. However, the ability to generate superior return in one particular area may be limited. Hence I assume that the acceleration of such marginal changes slows down with specialization.

3.1.2. Compensation of general partners

The compensation of general partners consists of two parts, management fees and carried interest.[11] Management fees are paid as a fixed fraction of the fund's committed capital. Carried interest is a fraction of the fund's realized profits. Like Gompers and Lerner (1999c), I assume that venture capitalists have the following compensation scheme:

$$\phi\left(\tilde{R}_p\right) = f \cdot A + c \cdot A \cdot \tilde{R}_p \tag{3.2}$$

where A denotes fund size in terms of managed capital, f denotes fixed management fee as a fraction of fund size, c is the carried-interest as a share of fund profits.

Since $\tilde{R}_p$ is normally distributed, it follows that $\phi\left(\tilde{R}_p\right)$ is also normally distributed, with the following mean and variance:

$$E\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \left[\overline{R}_n + \alpha(\eta, s)\right]$$

$$Var\left(\phi\left(\tilde{R}_p\right)\right) = c^2 \cdot A^2 \cdot \left[\sigma_n^2 + V(s) \cdot \sigma_\varepsilon^2\right]$$

3.1.3. Objective function of limited partners

Investors in venture funds are primarily large institutions, such as pension funds, insurance companies and university endowments. Gompers and Lerner (1999a) report that, on average, 72% of the total venture capital fund raising is from pension funds, endowments, insurance companies and banks, during the period from 1990 to 1997 in the United States. For these large institutional investors, the money they invest in venture funds is a relatively small portion of their total managed wealth. Even though the venture fund may possess a great amount of idiosyncratic risk, the entire wealth portfolios of these large institutions are well diversified. For this reason, these venture investors may not care about the idiosyncratic risk of a particular venture fund. Therefore, I assume that limited partners seek to maximize the expected payoff from venture investment after adjusting

[11] Limited partnerships often require GPs to invest their own money, usually 1% of the fund capital. Hence, GPs will share some proportionate fund return. Because 1% is a relatively small number, I ignore this part of GPs' compensation in my model setup. My analysis is also robust to the inclusion of GP profit sharing in the model.

for systematic risk and GPs' compensation. More specifically, let π denote their risk- and fee-adjusted payoff from the venture portfolio. It can be expressed as $\pi = A \cdot \tilde{R}_p - A \cdot \tilde{R}_n - \phi(\tilde{R}_p)$. It follows easily that π is normally distributed with the following mean:

$$E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \bar{R}_n \cdot c - f \cdot A$$

Therefore, limited partners have the following objective function:

$$\max_{\{c,\ f\}} \quad E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \bar{R}_n \cdot c - f \cdot A \tag{3.3}$$

3.1.4. Objective function of general partners

General partners are assumed to be risk averse. They spend most of their time managing VC funds on behalf of investors. The value of their human capital depends on the performance of their funds. Their main income comes from the same funds, too. Even though they may have relatively diversified personal portfolios, they are much less diversified than the portfolios managed by large institutional investors. Therefore, general partners may care about not only the return, but also the idiosyncratic risk involved in the venture portfolio. As in Ramakrishnan and Thakor (1984), and Golec (1992), we assume general partners have the following utility function:

$$U\left(\phi\left(\tilde{R}_p\right)\right) = E\left(\phi\left(\tilde{R}_p\right)\right) - \tau \cdot Var\left(\phi\left(\tilde{R}_p\right)\right)$$

where τ is a strictly positive risk aversion parameter.

Substituting for the mean and variance of $\phi\left(\tilde{R}_p\right)$, general partners thus have the following objective function:

$$\max_{\{s\}} \ U\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \bar{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 \tag{3.4}$$

3.1.5. Optimization problem from LPs' perspective

From LPs' perspective, the optimization problem is summarized in the following system of relationships:

$$\max_{\{c,\ f,\ s\}} \quad E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \bar{R}_n \cdot c - f \cdot A \tag{3.5}$$

s.t.

$$U\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \bar{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 \geq \underline{u} \tag{3.6}$$

$$s \in \arg\max U\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \bar{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 \tag{3.7}$$

where $\underline{u}$ is the reservation utility of general partners.

We assume that the degree of specialization is not contractable between LPs and GPs. Although we can observe whether or not a fund is focused in a particular area, it is hard to specify the exact degree of specialization in venture contracts. Gompers and Lerner (2004) note, "the partnership agreements rarely state the funds' objectives" regarding industry or stage focus.[12] Therefore, we assume s is not fully contractable or enforceable. As the principal, limited partners maximize their risk- and fee-adjusted expected return by choosing the optimal fee structure. In order for GPs to work for LPs as an agent, GPs must achieve at least their reservation expected utility $\underline{u}$. General partners consider the tradeoff between generating superior return and controlling the risk of the venture portfolio. They react to their compensation scheme by choosing a specialization level that maximizes their own expected utility.

3.2 Developing Hypotheses

Recall the previous optimization problem from LPs' perspective. The second constraint implies the following first-order condition:

[12] Gompers, Paul, and Josh Lerner, 2004, The venture capital cycle, 2nd edition, MIT Press, Page 523.

$$c \cdot A \cdot \frac{\partial \alpha(\eta, s)}{\partial s} = \tau \cdot c^2 \cdot A^2 \cdot \sigma_\varepsilon^2 \cdot V'(s) \tag{3.8}$$

This equation shows the tradeoff between generating superior return and incurring portfolio-specific risk when general partners focus on a specialized area. The left hand side of equation (3.8) is the marginal expected utility gain from higher superior return when a venture fund gets more specialized. The right hand side of equation (3.8) is the marginal expected utility loss from the additional idiosyncratic risk incurred. At the optimum, general partners choose the specialization level s such that the marginal expected utility gain will be equal to the marginal expected utility loss.

Assume s^* is the optimal degree of specialization. In Appendix A I show that s^* must satisfy the following equilibrium condition:

$$\begin{aligned} & A \cdot \tau \cdot \left(\sigma_\varepsilon^2\right)^2 \cdot \left(V'\left(s^*\right)\right)^3 - \sigma_\varepsilon^2 \cdot \left(V'\left(s^*\right)\right)^2 \cdot \left(\partial \alpha(\eta, s) / \partial s\right) + 2 \cdot \sigma_n^2 \cdot \left(\partial \alpha(\eta, s) / \partial s\right) \cdot V''\left(s^*\right) \\ & + 2 \cdot \sigma_\varepsilon^2 \cdot V\left(s^*\right) \cdot \left(\partial \alpha(\eta, s) / \partial s\right) \cdot V''\left(s^*\right) - 2 \cdot \sigma_n^2 \cdot \left(\partial^2 \alpha(\eta, s) / \partial s^2\right) \cdot V'\left(s^*\right) \\ & - 2 \cdot \sigma_\varepsilon^2 \cdot V\left(s^*\right) \cdot \left(\partial^2 \alpha(\eta, s) / \partial s^2\right) \cdot V'\left(s^*\right) \equiv 0 \end{aligned} \tag{3.9}$$

where $s^* = s^*\left(A, \tau, \eta, \bar{R}_n, \sigma_n^2, \sigma_\varepsilon^2\right)$.

From equation (3.9) I derive several propositions regarding the comparative statics of s^* with respect to the parameters A, τ, σ_ε^2, and η, respectively. Recall that A stands for fund size in terms of managed capital, σ_ε^2 captures the extra risk incurred from fund specialization, η is the amount of specialized talent venture capitalists possess, and τ denotes the degree of risk aversion for general partners. The derivations of the propositions are provided in Appendices B to E.

Proposition I (Fund Size): The optimal degree of fund specialization is negatively related to fund size, or $\frac{\partial s^*}{\partial A} < 0$.

Proposition II (VCs' Risk Aversion): The optimal degree of fund specialization is negatively related to the VCs' level of risk aversion, or $\frac{\partial s^*}{\partial \tau} < 0$.

Proposition III (VCs' Expertise-area Risk): The optimal degree of fund specialization is negatively related to the riskiness of the particular industry (geographic region, or stage of development) where the VCs have expertise, or $\frac{\partial s^*}{\partial \left(\sigma_\varepsilon^2\right)} < 0$.

Proposition IV (VCs' Specialized Talent): If $\frac{\left(\partial^3 \alpha(\eta,s) \big/ \partial s^2 \partial \eta\right)}{\left(\partial^2 \alpha(\eta,s) \big/ \partial s \partial \eta\right)} \geq \frac{V''\left(s^*\right)}{V'\left(s^*\right)}$, the optimal degree of fund specialization is positively related to the VCs' amount of specialized talent, or $\frac{\partial s^*}{\partial \eta} > 0$.

To understand Proposition IV, I rewrite the inequality condition as the following:

$$\frac{\frac{\partial^2 \left(\partial \alpha(\eta,s) \big/ \partial \eta\right)}{\partial s^2}}{\frac{\partial \left(\partial \alpha(\eta,s) \big/ \partial \eta\right)}{\partial s}} \geq \frac{V''\left(s^*\right)}{V'\left(s^*\right)}$$

This relationship says that with more specialized talent, the benefit of superior return acceleration will exceed the cost of extra risk acceleration as the degree of specialization increases. This condition implies that more specialized talent will make GPs better off when the fund becomes more focused.

The above hypotheses are intuitively reasonable and also empirically testable. With particular talents, GPs can generate superior returns by specializing and share in them through the carried-interest. They must bear, however, more idiosyncratic risk since the portfolio is not well diversified. For a larger fund with more committed capital, GPs can invest in a larger pool of portfolio companies to offset the higher risk from more specialization. If GPs become more risk averse, the

disutility from unsystematic risk will be bigger than before. So they will choose a relatively lower degree of specialization. If GPs' specialized areas become more risky, they will incur more unsystematic risk if maintaining the same specialization level as before. The marginal benefit of specialization will be smaller than the marginal cost. So they will choose a relatively lower degree of specialization. If GPs have more specialized talents, they can generate more superior returns at the same specialization level as before. The marginal utility gain from specialization will outweigh the marginal utility loss. So they will choose a relatively higher degree of specialization.

In the next section, I describe my sample of U.S. VC funds, explain my hypothesis tests, and present my empirical results.

4. Empirical Analysis

To test my model's predictions regarding VC fund specialization, I have collected a large sample of 1586 US venture capital funds from the SDC VentureXpert database. The cross-sectional and time-series patterns of fund specialization are first presented. Then I empirically examine whether fund size, VCs' risk aversion, expertise-area risk, and specialized talent are important factors affecting the specialization choices of VC funds. Finally, I explore the relationship between VC fund specialization and fund performance.

The following section describes the data. Section 4.2 explains the construction of key variables. Summary statistics are presented in section 4.3, and section 4.4 reports the main regression results.

4.1 Data

The SDC VentureXpert Portfolio Company Disbursement database reports detailed investment information for each financing round of VC funds. This includes the name of the portfolio company which receives venture financing, the state or state region where the company's

headquarter is located, its industry group, the stage of company development, the current public status (private or public), and the estimated amount of dollar investment in the company. I compile a sample with this detailed financing-round information from the SDC VentureXpert database. The U.S. venture capital funds with fund initial closing year between 1978 and 2000 are considered. I restrict my analysis to private partnerships since other organization forms of VC funds have quite different features. The VC management firms must be classified as "private equity firm investing own capital" to be included in the sample. Funds that were not closed or were withdrawn are excluded. Other data items reflecting fund characteristics are also collected from the VentureXpert database. These include fund committed capital, fund sequence number, the investment history of the VC management firm, and their total amount of capital under management. There exist some observations with contradictory fund characteristics. For example, some funds are classified as "venture capital funds", but half or more of their investment deals are not "standard US venture disbursement". Some funds are classified as “follow-on funds”, but have fund sequence number equal to one. I hence exclude those observations. In the original data, the basic unit of observation is the financing round of VC funds. The resulting sample has 64168 financing rounds for 1586 venture funds. The degree of specialization is measured at the fund-level using the number of financing rounds. In most cases, VentureXpert reports an “estimated amount of dollar investment” in portfolio companies for each financing round. This data item is estimated by VentureXpert based on information from fund managers and public sources. There are some cases, though, where this information is missing. To check the robustness of my results, I have also constructed a sample with non-missing dollar investment information so that I can measure specialization using the dollar amount of investment. This results in a relatively smaller sample of 60513 financing rounds for 1580 VC funds.[13]

[13] The empirical results using dollar amount of investment are similar and available upon request.

4.2 Variables

Venture capital firms may specialize by industry, development stage, or geographic region. Correspondingly, I consider the degree of specialization along these three dimensions.

VentureXpert uses its own industry classification system, the Venture Economics Industry Codes (VEIC). Since private firms differ from public firms, this classification is better suited to the VC industry than the standard SIC codes. There are several levels of industry classification. In my analysis, I use the industry classification of Minor Groups, where all companies are divided into 9 categories: communications, computer hardware, software and services, semiconductors and other electronics related, biotechnology, medical and health related, consumer related, industrial and energy, all other products.[14] There are also several levels of company stage classification in VentureXpert. The coarsest classification is early stage, expansion stage, and later stage. Early stage can be further classified into seed stage, startup stage and first stage. Expansion stage includes second stage and third stage. I use the VentureXpert classification of Stage Level Three, where companies are divided into the following groups: seed stage, startup stage, first stage, other early stage, second stage, third stage, other expansion stage, and other stages.[15] Please see Appendix F for detailed definitions of various stages. To measure geographic specialization, I use the state of company headquarters.[16]

Two alternative proxies are constructed to measure fund specialization. The first one is the Herfindahl-Hirschman Index (HHI), calculated as the sum of the squares of the fraction of portfolio companies in each area (industry, stage, or state). The second one is the focus area concentration

[14] I also tried the industry major group classification, where all companies are divided into 6 categories: communications, computer related, semiconductors and other electronics related, biotechnology, medical and health related, non-high technology. The empirical results are very similar and available upon request.

[15] I also tried the classification of Stage Level Two: seed stage, startup stage, other early stage, expansion stage, later stage, and others. The empirical results are very similar and available upon request.

[16] I also tried the classification of state regions, where the whole U.S. territory is divided into several state regions: Northern California, Southern California, New York Tri-State, New England, Mid-Atlantic, Rocky Mountains, Great Lakes, Great Plains, Northwest, Southeast, Southwest, South, etc. The empirical results are very similar and available upon request.

ratio (CRT), measured as the number of portfolio companies in the focus area divided by the total number of portfolio companies in a fund. The focus area refers to the particular industry, stage or state with the highest number of portfolio companies in a fund.[17] In my final sample with the specialization measures, each VC fund has one observation.

To test what fundamental factors affect the specialization choices of VCs, I gather additional fund-level data items from VentureXpert. These include fund committed capital, fund vintage year, fund sequence number, the investment history of the VC management firm, and their total amount of managed capital. I construct the following variables to measure fund characteristics.

Fund size is measured as the total amount of capital committed by limited partners and general partners for each VC fund. I refer to this variable as SIZE. The Fund Size Hypothesis predicts a negative relationship between the SIZE variable and the degree of fund specialization.

VentureXpert doesn't provide direct information on the age of VCs. However, it reports the dates when a VC fund makes its first and last investments. It also reports the dates when a VC management firm makes its first and last investment. I measure the age of a VC management firm at the time when a VC fund makes its last investment. For each fund, the age of its VC management firm is roughly measured as the difference between the date of the fund's last investment and the date of the VC management firm's first investment. Please note that the first investment of the VC management firm may often not be the first investment of this particular fund. I refer to this variable as AGE. I use AGE as a proxy for the risk aversion of VCs. Older VC firms care about their well-established reputations and may be more risk averse than younger firms. Therefore, I expect a negative relationship between AGE and fund specialization.

[17] VentureXpert has a data item called "management firm's industry preference". This item is self-reported by venture firms and may not reflect the actual investment patterns. Further, it only qualitatively captures the portfolio choice of specialization versus diversification, but doesn't reflect the degree of specialization. Finally, Gompers and Lerner (2004) point out that the industry and stage focus data are "imperfectly recorded by Venture Economics". Therefore, I construct my own measure of industry specialization by going through the detailed profiles of portfolio companies. I measure geographic and stage focus similarly.

In a similar fashion to Gompers, Kovner, Lerner and Scharfstein (2006), I construct two proxies to measure VCs' talent: Special Talent and General Talent.[18] Special Talent is measured as the number of company investments the VC management firm has made in the focus area (industry, stage, or state) before this fund. General Talent is measured as the total number of company investments the VC management firm has ever made before this fund. According to the Specialized Talent Hypothesis, VCs' Special Talent and the degree of fund specialization are positively related. However, General Talent should have no effect on fund specialization.

VentureXpert also reports information on the total amount of capital under management by a VC firm. I refer to this variable as CAPITAL. The CAPITAL variable may proxy for the experience of VCs, hence as a measure for the amount of expertise they have. Well-established VC firms with nice track records can raise more funds and tend to have more capital under management than young VC firms. So there may exist a positive relationship between VC firms' managed capital and their experience. In addition, CAPITAL may proxy for the risk aversion of VCs. The VC firms with more managed capital tend to be more experienced and prestigious than others. They would care about their hard-earned reputation and may be more risk averse. Therefore, the empirical relationship between CAPITAL and fund specialization depending on how much CAPITAL captures the experience effect relative to the risk aversion effect. If the experience effect dominates the risk aversion effect, I would expect a positive relationship between the CAPITAL variable and the degree of fund specialization. If the risk aversion effect dominates the experience effect, I would expect a negative relationship.

To examine how the degree of fund specialization affects their performance, I need a proxy to measure fund performance. The internal rate of return (IRR) information on individual funds is not

[18] Another proxy for VCs' talent could be fund sequence number (1, 2, 3, 4, etc), which indicates the position of each fund within a fund sequence family. As VCs raise more funds, they become more skilled and experienced over time. However, fund sequence number could not distinguish between special talent and general talent.

publicly accessible. Similar to Gompers and Lerner (1999c), I use two alternative proxies. One is the fraction of firms that went public or were in registration for an offering in a venture portfolio. I refer to this variable as IPORATE. The other is the fraction of firms that were acquired, merged, went public, or in registration for an offering in a VC fund. I refer to this variable as IPOARATE. It has been well acknowledged that IPO and acquisition are the two most important ways of exit for venture capitalists. The two performance proxies should be positively correlated with the IRR.

To account for the effect of different focus industries on fund specialization choices, I generate a set of focus industry dummies. There are nine dummy variables, taking the value of one for a particular focus industry, otherwise zero. A set of focus stage dummies and a set of focus geography dummies are also generated. I use eight dummies denoting whether the portfolio company is in seed stage, startup stage, first stage, early stage, second stage, third stage, expansion stage, or other later stage. Due to the large number of states, I do not use a dummy variable for each state. Instead, I use four dummies denoting whether the portfolio company is located in New York, Massachusetts, California or Texas.

To control for time effects on fund specialization choices, a set of year dummies is generated based on fund year. Fund year refers to the fund initial closing year. There is a dummy variable for each year from 1978 to 2000. The year dummy takes the value of one for a particular fund year, otherwise zero.

For reference, I summarize all of the variable definitions in Appendix G.

4.3 Summary Statistics

Venture capital funds display various degrees of specialization regarding industry, stage, and geographic focus. Figure 1 plots the frequency of VC funds for different levels of specialization, measured using Herfindahl-Hirschman Index, for VentureXpert classifications of 9 minor industry

groups, Stage Level Three, and 50 states, respectively. Fund specialization measured using the Focus Area Concentration Ratio has similar patterns, as shown in Figure 2. Some funds are narrowly focused, while others are more diversified.

Table 1 reports the summary statistics for my sample of 1586 VC funds. The average industry HHI is around 0.36, with a standard deviation of 0.23. The average stage HHI is a little bit lower (0.31), while the average geography HHI is much higher (0.47). The focus area concentration ratios display similar patterns. Those funds tend to have a higher degree of geographic specialization, compared to industry and stage specialization. My sample funds have an average size of 105 million dollars. The average VC management firm in the sample is 14 years old.

I also examine the time patterns of fund specialization over my sample period of 23 years. The results are summarized in Table 2. I report the median value of fund specialization along the three dimensions, industry, stage, and geography. Fund specialization also differs over time. From 1978 to 2000, the median Industry HHI varies from 0.18 to 0.46. The stage HHI shows relatively smaller variations over time, ranging from 0.16 to 0.33. The geographic HHI fluctuates widely between 0.23 and 0.56.

To sum up, regardless of the way it is measured, there exists considerable variation in VC fund specialization, both cross-sectionally and also over time. In the next section, I examine why funds display various degrees of specialization.

4.4 Factors Affecting Fund Specialization

In my model, four factors have direct effects on fund specialization: fund size, VCs' degree of risk aversion, VCs' specialized talent, and VCs' expertise-area risk. Given previously constructed variables from VentureXpert, I can estimate the relationships between specialization and fund size, VCs' risk aversion, and VCs' specialized talent. I consider the following functional form:

$$\begin{aligned} &HHI \text{ or } CTR \\ &= b_0 + b_1 \cdot SIZE + b_2 \cdot AGE + b_3 \cdot SPECIAL\ TALENT + b_4 \cdot CAPITAL \\ &+ b_6 \cdot FOCUS\ AREA\ DUMMIES + b_5 \cdot FUND\ YEAR\ DUMMIES + z \end{aligned} \tag{4.1}$$

where z is the error term. The dependent variable is the degree of fund specialization, measured using Herfindahl-Hirschman Index or Focus Area Concentration Ratio. The focus area dummies stand for either the focus industry dummies, focus stage dummies, or focus geography dummies. I use ordinary least squares to estimate the coefficients.[19] To distinguish the effect of VCs' specialized talent from their general experience, I also include the GENERAL TALENT variable. Therefore, I consider two additional specifications:

$$\begin{aligned} &HHI \text{ or } CTR \\ &= b_0 + b_1 \cdot SIZE + b_2 \cdot AGE + b_3 \cdot GENERAL\ TALENT + b_4 \cdot CAPITAL \\ &+ b_6 \cdot FOCUS\ AREA\ DUMMIES + b_5 \cdot FUND\ YEAR\ DUMMIES + u \end{aligned} \tag{4.2}$$

$$\begin{aligned} &HHI \text{ or } CTR \\ &= b_0 + b_1 \cdot SIZE + b_2 \cdot AGE + b_3 \cdot SPECIAL\ TALENT + b_4 \cdot GENERAL\ TALENT \\ &+ b_5 \cdot CAPITAL + b_6 \cdot FOCUS\ AREA\ DUMMIES + b_7 \cdot FUND\ YEAR\ DUMMIES + v \end{aligned} \tag{4.3}$$

where u and v are normally distributed error terms.

The regression results regarding the effect of size, age and talent are summarized in Table 3. In Panel A, fund specialization is measured using Herfindahl-Hirschman Index (HHI), and in Panel B, it is measured by focus area concentration ratio (CTR). In all cases, fund size has a negative and significant effect on the degree of specialization by industry, stage, and geography. VC firm age is also negatively related to fund specialization and the estimate is significant at the 1% level. The results with respect to VCs' talent are more interesting. When there is only one talent measure included in the regression, both SPECIAL TALENT and GENERAL TALENT are statistically significant and have positive sign. However, when the two talent measures are simultaneously

[19] Because the dependent variable always lies between 0 and 1, I also estimated two-way censored Tobit model regressions. The results are very similar and available upon request.

included in one regression, SPECIAL TALENT is still significant and positive, while GENERAL TALENT becomes insignificant and sometimes negative. The significance of GENERAL TALENT in the simple regression without the SPECIAL TALENT variable is caused by the correlation between SPECIAL TALENT and GENERAL TALENT. This implies that it is VCs' specialized talent that really matters in determining fund specialization. The VCs with more specialized talent prefer a higher degree of fund specialization. VCs with more general talent tend to have more diversified funds, especially by geographic area. The managed capital of VC firms is always negatively related to fund specialization, but the coefficients are mostly insignificant.

To test how VCs' expertise-area risk affects fund specialization I need to measure this risk. It is hard to associate different degrees of risk to various geographic areas. Therefore, I only test this particular hypothesis in terms of industry specialization and stage specialization.

VentureXpert assigns SIC codes to portfolio companies in a venture fund. I collect monthly returns of publicly traded stocks matched with the SIC codes of portfolio companies in my VC sample. Then I calculate the return standard deviation and idiosyncratic risk of each stock in my matched public stock sample from year 1950 to 2005. The idiosyncratic risk is calculated as the residual standard deviation from a regression of the monthly stock returns on the Fama-French three factors.[20] Then I calculate the average stock return standard deviation and average residual standard deviation for each of the 9 industry minor groups. I refer to these two averages as RETURN VOLATILITY and RESIDUAL VOLATILITY. In the following regression analysis, I use the return volatility and residual volatility of the focus industry as two alternative proxies for VCs' expertise-area risk:

[20] See Fama, Eugene F., and Kenneth R. French, 1993. Common risk factors in the returns on stocks and bonds, *Journal of Financial Economics*, 33, 3-56.

$$
\begin{aligned}
&INDUSTRY\ HHI\ or\ CTR \\
&= b_0 + b_1 \cdot RETURN\ VOLATILITY\ or\ RESIDUAL\ VOLATILITY \\
&+ b_2 \cdot SIZE + b_3 \cdot AGE + b_4 \cdot SPECIAL\ TALENT + b_5 \cdot GENERAL\ TALENT \\
&+ b_6 \cdot CAPITAL + b_7 \cdot FOCUS\ AREA\ DUMMIES + b_8 \cdot FUND\ YEAR\ DUMMIES + k
\end{aligned}
\tag{4.4}
$$

where k is a normally distributed error term.

Table 4 presents the regression results of focus industry risk on fund specialization. As proxies for VCs' expertise-area risk, both RETURN VOLATILITY and RESIDUAL VOLATILITY have negative effect on the degree of specialization. The coefficients are all significant at the 1% level. Still, fund size and firm age are negatively related to specialization. Again, VCs' SPECIAL TALENT has a significant and positive effect on fund specialization, even with the presence of GENERAL TALENT variable.

To measure the risk of focus stage, I construct a new variable called STAGE RISK RANK. It is a number, ranging from one to eight, denoting the increasing degree of risk from later stages to earlier stages. I assign the value of 8 to seed stage, 7 to startup stage, 6 to first stage, 5 to other early stage, 4 to second stage, 3 to third stage, 2 to expansion stage, and 1 to later stage. I then estimate the following regression specification:

$$
\begin{aligned}
&STAGE\ HHI\ or\ CTR \\
&= b_0 + b_1 \cdot STAGE\ RISK\ RANK \\
&+ b_2 \cdot SIZE + b_3 \cdot AGE + b_4 \cdot SPECIAL\ TALENT + b_5 \cdot GENERAL\ TALENT \\
&+ b_6 \cdot CAPITAL + b_7 \cdot FOCUS\ AREA\ DUMMIES + b_8 \cdot FUND\ YEAR\ DUMMIES + g
\end{aligned}
\tag{4.5}
$$

where g is a normally distributed error term.

The impact of focus stage risk on fund specialization is reported in Table 5. As expected, the regression coefficient for STAGE RISK RANK is always negative and significant, regardless of the way specialization is measured. Again, fund size and firm age have negative effects, and VCs' specialized talent has positive effects.

In sum, the empirical results strongly support the Fund Size Hypothesis, VCs' Risk Aversion Hypothesis, VCs' Specialized Talent Hypothesis, and VCs' Expertise-area Risk Hypothesis derived from the model.

4.5 The effect of specialization on fund performance

The performance of VC funds will be affected by many factors. Two proxies are used to measure fund performance. One proxy, IPORATE, is the fraction of firms that went public or were in registration for an offering in a venture portfolio. The other, IPOARATE, is the fraction of firms that were acquired, merged, went public, or in registration for an offering in a venture portfolio. The following functional form is considered in regressions:

$$\begin{aligned} &IPORATE \text{ or } IPOARATE \\ &= b_0 + b_1 \cdot INDUSTRY \text{ (}STAGE\text{, or } GEOGRAPHY\text{) } HHI \\ &+ b_2 \cdot SIZE + b_3 \cdot AGE + b_4 \cdot SPECIAL\ TALENT + b_5 \cdot GENERAL\ TALENT \\ &+ b_6 \cdot CAPITAL + b_7 \cdot FOCUS\ AREA\ DUMMIES + b_8 \cdot FUND\ YEAR\ DUMMIES + q \end{aligned} \tag{4.6}$$

where g is a normally distributed error term. The explanatory variables include the degree of fund specialization measured using Herfindahl-Hirschman Index, fund size, VC firm age, VCs' talent, total managed capital of the VC firm, focus area (industry, stage, or geography) dummies, and fund year dummies.[21]

Tables 6 through 8 report the ordinary least squares regression results regarding the effect of industry, stage, and geography specialization on fund performance, respectively.[22] In all cases, industry specialization and stage specialization are positively related to fund performance. The coefficients are mostly significant at the 1% level. The results imply that for venture capitalists with industry or stage expertise, a higher degree of specialization will lead to better fund

[21] To conserve space, I report here only results using the Herfindahl-Hirschman Index to measure specialization. Results using the focus industry concentration ratio are similar.

[22] The regression results using the two-way censored Tobit model are very similar and available upon request.

performance. The relationship between performance and geographic specialization is weak when the performance proxy of IPORATE is used. However, when IPOARATE is used, geographic specialization also has a positive and significant effect on fund performance. Another interesting observation is about VCs' talent. When I include either SPECIAL TALENT only or GENERAL TALENT only in the regression, both talent measures are statistically significant and have positive coefficients. However, when the two variables are simultaneously included in one regression, GENERAL TALENT remains positive and significant, while SPECIAL TALENT becomes mostly insignificant. The results suggest that VCs' talent plays an important role in affecting fund performance. However, after controlling for fund specialization, it is VCs' general experience that matters.

I also estimated regression models that include simultaneously all three specialization variables, industry HHI, stage HHI, and geographic HHI. The results are summarized in Table 9. A higher degree of industry specialization is always associated better expected fund performance, regardless of the way performance is measured. Stage specialization is also positively related to fund performance, and the effect is more significant when the performance is measured using IPOARATE. It is interesting that the estimated coefficients for geographic specialization are mostly negative, and significant, when IPORATE is used to measure performance. This suggests that industry specialization and stage specialization tend to improve fund performance more than geographic specialization.

In sum, there is evidence indicating that a higher degree of specialization leads to better fund performance. In addition, the experience and human capital of VCs have significant and positive effects on fund performance. After controlling for fund specialization, VCs' general talent plays an important role in improving fund performance. VCs' specialized talent, however, does not.

4.6 The Behavior of Small Business Investment Companies

In my sample, 75 funds are organized as Small Business Investment Companies. These funds are managed by 54 different VC management firms and made a total of 1311 venture investments. SBICs have played an important role in the VC industry. They are licensed and regulated by the U.S. Small Business Administration (SBA). In addition to their own capital, SBICs can borrow funds at favorable rates from the Federal Government, up to 300% of their private capital. SBICs invest only in qualifying small business concerns as defined by SBA regulations. Since SBICs are licensed, assisted and regulated by the SBA, their contracting and operating procedures may differ from regular venture funds. Hence, their investment behavior may be quite different. To investigate this possibility I empirically examine the specialization choices of SBICs and their associated performance. I use a dummy variable, SBIC DUMMY, denoting whether a fund is organized as a SBIC, and consider the following regressions:

$$\begin{aligned} &INDUSTRY\ (STAGE,\ or\ GEOGRAPHY)\ HHI \\ &= b_0 + b_1 \cdot SBIC\ DUMMY \\ &+ b_2 \cdot SIZE + b_3 \cdot AGE + b_4 \cdot SPECIAL\ TALENT + b_5 \cdot GENERAL\ TALENT \\ &+ b_6 \cdot CAPITAL + b_7 \cdot FOCUS\ AREA\ DUMMIES + b_8 \cdot FUND\ YEAR\ DUMMIES + t \end{aligned} \tag{4.7}$$

$$\begin{aligned} &IPORATE\ or\ IPOARATE \\ &= b_0 + b_1 \cdot SBIC\ DUMMY + b_2 \cdot INDUSTRY\ (STAGE,\ or\ GEOGRAPHY)\ HHI \\ &+ b_3 \cdot SIZE + b_4 \cdot AGE + b_5 \cdot SPECIAL\ TALENT + b_6 \cdot GENERAL\ TALENT \\ &+ b_7 \cdot CAPITAL + b_8 \cdot FOCUS\ AREA\ DUMMIES + b_9 \cdot FUND\ YEAR\ DUMMIES + d \end{aligned} \tag{4.8}$$

where t and d are normally distributed error terms.

The ordinary least squares results regarding the specialization choices of SBICs are presented in Table 10. In general, the SBICs prefer a lower degree industry specialization and stage specialization, but a higher degree of geographic specialization than regular VC funds. This observation is probably driven by the regulation nature of SBICs. Table 11 shows how SBICs differ from regular VC funds in terms of fund performance. In Panel A, the three types of fund

specialization (industry, stage, and geography) are considered separately, while in Panel B, they are considered simultaneously. In all cases, the regression coefficients for SBIC DUMMY are negative and statistically significant. The result is very robust across three types of fund specialization and regardless of the way performance is measured. This suggests that, as a government subsidized and regulated program, SBICs tend to under-perform other VC funds.

5. Conclusions

As a leading source of financing for young innovative firms, venture capital has spawned the growth of U.S. economy. One important aspect of VC funds is their specialization patterns by industry, stage, and geography. Whether a VC fund has an area focus will determine the type of entrepreneurial firms receiving financing. How a venture capitalist chooses a particular degree of specialization will directly affect portfolio construction and hence fund performance. In this paper I provide a theoretical rationale underlying the specialization choices of VC funds. I develop hypotheses relating specialization to fundamental characteristics of VC funds. These characteristics include fund size, VCs' degree of risk aversion, VCs' focus-area expertise, and the risk associated with the excess return of the fund.

I test the predictions of my model using a large sample of 1586 funds with 64168 venture investments. Contrary to the general wisdom that funds are mostly specialized, VC funds display wide variation in their degrees of specialization. Fund size, VCs' risk aversion, VCs' expertise area risk all have significantly negative impacts on fund specialization. I construct two measures distinguishing VCs' specialized talent from their general talent. I find that VCs' specialized talent significantly affects the degree of specialization, while VCs' general talent does not. This suggests that VCs tend to finance companies that match with their area expertise. In doing so, they can make good use of their focus-area talent and network to general superior returns. The evidence also

indicates that specialization and fund performance are significantly positively related. Furthermore, specialized talent and general talent are both significantly positively related to fund performance. These results together suggest that VCs tend to finance companies that match well with their areas of expertise and that this, in turn, tends to enhance fund returns. Hence, the VCs' human capital appears to play an important role in determining fund performance.

I also find the intriguing result that SBICs significantly under-perform other VC funds after controlling for specialization and other determinants of fund performance. This result is very robust across types of specialization (industry, stage, geographic) and performance measures. My current sample, however, has only a small number (75) of SBICs. For this reason more empirical work is needed to better assess the performance of SBICs and to investigate why their performance differs from that of other VC funds.

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Appendix A: Derivation of the Equilibrium Condition for s^*

Recall the previous optimization problem from LPs' perspective:

$$\max_{\{c,\ f,\ s\}} \quad E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \overline{R}_n \cdot c - f \cdot A \tag{A.1}$$

s.t.

$$U\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \overline{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 \geq \underline{u} \tag{A.2}$$

$$s \in \arg\max U\left(\phi\left(\tilde{R}_p\right)\right) = f \cdot A + c \cdot A \cdot \overline{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 \tag{A.3}$$

The first-order condition of constraint (A.3) is the following:

$$c \cdot A \cdot \frac{\partial \alpha(\eta, s)}{\partial s} = \tau \cdot c^2 \cdot A^2 \cdot \sigma_\varepsilon^2 \cdot V'(s) \tag{A.4}$$

To guarantee the existence of interior solutions, we assume the sufficient second-order condition of (A.3) also holds:

$$\frac{\partial^2 U(\phi)}{\partial s^2} = c \cdot A \cdot \frac{\partial^2 \alpha(\eta, s)}{\partial s^2} - \tau \cdot c^2 \cdot A^2 \cdot \sigma_\varepsilon^2 \cdot V''(s) < 0 \ . \tag{A.5}$$

Assuming constraint (A.2) is binding, I substitute (A.2) with its equality. Also replace (A.3) with its first-order condition. The LPs' optimization problem becomes:

$$\max_{\{c,\ f,\ s\}} \quad E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \overline{R}_n \cdot c - f \cdot A \tag{A.6}$$

s.t.

$$f \cdot A + c \cdot A \cdot \overline{R}_n + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 = \underline{u} \tag{A.7}$$

$$c \cdot A \cdot \frac{\partial \alpha(\eta, s)}{\partial s} - \tau \cdot c^2 \cdot A^2 \cdot \sigma_\varepsilon^2 \cdot V'(s) = 0 \tag{A.8}$$

From (A.6):

$$-f \cdot A - c \cdot A \cdot \overline{R}_n = c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 - \underline{u} \tag{A.9}$$

Substitute (A.8) back into (A.5):

$$E(\pi) = A \cdot \alpha(\eta, s) \cdot (1-c) - A \cdot \bar{R}_n \cdot c - f \cdot A$$
$$= A \cdot \alpha(\eta, s) \cdot (1-c) + c \cdot A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 - \underline{u}$$

$$\rightarrow \; E(\pi) = A \cdot \alpha(\eta, s) - \tau \cdot c^2 \cdot A^2 \cdot \sigma_n^2 - \tau \cdot c^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 - \underline{u} \tag{A.10}$$

From (A.7):

$$c = \frac{1}{\tau \cdot A \cdot \sigma_\varepsilon^2 \cdot V'(s)} \cdot \frac{\partial \alpha(\eta, s)}{\partial s} \tag{A.11}$$

Substitute (A.11) into (A.10):

$$E(\pi) = A \cdot \alpha(\eta, s) - \tau \cdot \left[\frac{1}{\tau \cdot A \cdot \sigma_\varepsilon^2 \cdot V'(s)} \cdot \frac{\partial \alpha(\eta, s)}{\partial s} \right]^2 \cdot A^2 \cdot \sigma_n^2$$
$$- \tau \cdot \left[\frac{1}{\tau \cdot A \cdot \sigma_\varepsilon^2 \cdot V'(s)} \cdot \frac{\partial \alpha(\eta, s)}{\partial s} \right]^2 \cdot A^2 \cdot V(s) \cdot \sigma_\varepsilon^2 - \underline{u}$$

After simplification:

$$E(\pi) = A \cdot \alpha(\eta, s) - \frac{\left({}^{\partial \alpha(\eta, s)}\!/_{\partial s} \right)^2}{\tau \cdot \sigma_\varepsilon^2 \cdot \left(V'(s) \right)^2} \cdot \left[\frac{\sigma_n^2}{\sigma_\varepsilon^2} + V(s) \right] - \underline{u}$$

The optimization problem then becomes:

$$\max_{\{s\}} \quad E(\pi) = A \cdot \alpha(\eta, s) - \frac{\left({}^{\partial \alpha(\eta, s)}\!/_{\partial s} \right)^2}{\tau \cdot \sigma_\varepsilon^2 \cdot \left(V'(s) \right)^2} \cdot \left[\frac{\sigma_n^2}{\sigma_\varepsilon^2} + V(s) \right] - \underline{u} \tag{A.12}$$

The first-order condition of (A.12) is:

$$\frac{\partial E(\pi)}{\partial s} = A \cdot \frac{\partial \alpha(\eta, s)}{\partial s} - \frac{\left({}^{\partial \alpha(\eta, s)}\!/_{\partial s} \right)^2}{\tau \cdot \sigma_\varepsilon^2 \cdot \left(V'(s) \right)^2} \cdot V'(s) - \frac{\left({}^{\partial \alpha(\eta, s)}\!/_{\partial s} \right)^2}{\tau \cdot \sigma_\varepsilon^2} \cdot \left[\frac{\sigma_n^2}{\sigma_\varepsilon^2} + V(s) \right] \left[- \frac{2}{\left(V'(s) \right)^3} \cdot V''(s) \right]$$
$$- \frac{2 \left({}^{\partial \alpha(\eta, s)}\!/_{\partial s} \right) \left({}^{\partial^2 \alpha(\eta, s)}\!/_{\partial s^2} \right)}{\tau \cdot \sigma_\varepsilon^2 \cdot \left(V'(s) \right)^2} \cdot \left[\frac{\sigma_n^2}{\sigma_\varepsilon^2} + V(s) \right] = 0$$

$$
\begin{aligned}
& A\cdot\tau\cdot\left(\sigma_{\varepsilon}^{2}\right)^{2}\cdot\left(V'(s)\right)^{3}-\sigma_{\varepsilon}^{2}\cdot\left(V'(s)\right)^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)+2\cdot\sigma_{n}^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''(s) \\
\rightarrow\ & +2\cdot\sigma_{\varepsilon}^{2}\cdot V(s)\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''(s)-2\cdot\sigma_{n}^{2}\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'(s) \\
& -2\cdot\sigma_{\varepsilon}^{2}\cdot V(s)\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'(s)=0
\end{aligned}
\tag{A.13}
$$

Assume the above equation has a solution as denoted by $s^{*}=s^{*}\left(A,\tau,\eta,\bar{R}_{n},\sigma_{n}^{2},\sigma_{\varepsilon}^{2}\right)$. Substitute s^{*} back into equations (A.13), and then I have the following equilibrium condition for s^{*}:

$$
\begin{aligned}
& A\cdot\tau\cdot\left(\sigma_{\varepsilon}^{2}\right)^{2}\cdot\left(V'\left(s^{*}\right)\right)^{3}-\sigma_{\varepsilon}^{2}\cdot\left(V'\left(s^{*}\right)\right)^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)+2\cdot\sigma_{n}^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^{*}\right) \\
& +2\cdot\sigma_{\varepsilon}^{2}\cdot V\left(s^{*}\right)\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^{*}\right)-2\cdot\sigma_{n}^{2}\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'\left(s^{*}\right) \\
& -2\cdot\sigma_{\varepsilon}^{2}\cdot V\left(s^{*}\right)\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'\left(s^{*}\right)\equiv 0
\end{aligned}
\tag{A.14}
$$

Appendix B: Derivation of the Comparative Statics $\frac{\partial s^{*}}{\partial A}$

Recall the equilibrium condition for s^{*}:

$$
\begin{aligned}
& A\cdot\tau\cdot\left(\sigma_{\varepsilon}^{2}\right)^{2}\cdot\left(V'\left(s^{*}\right)\right)^{3}-\sigma_{\varepsilon}^{2}\cdot\left(V'\left(s^{*}\right)\right)^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)+2\cdot\sigma_{n}^{2}\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^{*}\right) \\
& +2\cdot\sigma_{\varepsilon}^{2}\cdot V\left(s^{*}\right)\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^{*}\right)-2\cdot\sigma_{n}^{2}\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'\left(s^{*}\right) \\
& -2\cdot\sigma_{\varepsilon}^{2}\cdot V\left(s^{*}\right)\cdot\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\cdot V'\left(s^{*}\right)\equiv 0
\end{aligned}
\tag{B.1}
$$

Differentiate equation (B.1) with respect to A. After simplification, I get:

$$
\left\{\begin{array}{l}
3\cdot\sigma_{\varepsilon}^{2}\cdot\left[V'\left(s^{*}\right)\right]^{2}\cdot\left[A\cdot\tau\cdot\sigma_{\varepsilon}^{2}\cdot V''\left(s^{*}\right)-\left(\partial^{2}\alpha(\eta,s)/\partial s^{2}\right)\right] \\
+2\cdot\left[\sigma_{n}^{2}+\sigma_{\varepsilon}^{2}\cdot V\left(s^{*}\right)\right]\cdot\left[\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V'''\left(s^{*}\right)-V'\left(s^{*}\right)\cdot\left(\partial^{3}\alpha(\eta,s)/\partial s^{3}\right)\right]
\end{array}\right\}\cdot\frac{\partial s^{*}}{\partial A}\equiv-\tau\cdot\left(\sigma_{\varepsilon}^{2}\right)^{2}\cdot\left[V'\left(s^{*}\right)\right]^{3}
$$

Let the variable q denote the whole term before $\frac{\partial s^{*}}{\partial A}$, i.e.,

$$q = 3\cdot\sigma_\varepsilon^2\cdot\left[V'\left(s^*\right)\right]^2\cdot\left[A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''\left(s^*\right)-\left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\right]$$
$$+2\cdot\left[\sigma_n^2+\sigma_\varepsilon^2\cdot V\left(s^*\right)\right]\cdot\left[\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V'''\left(s^*\right)-V'\left(s^*\right)\cdot\left({}^{\partial^3\alpha(\eta,s)}\!/_{\partial s^3}\right)\right] \quad \text{(B.2)}$$

Then I have the following simple expression:

$$q\cdot\frac{\partial s^*}{\partial A}\equiv-\tau\cdot\left(\sigma_\varepsilon^2\right)^2\cdot\left[V'\left(s^*\right)\right]^3 \quad \text{(B.3)}$$

Since $V'(s)>0$, the right-hand side of equation (B.3) is negative. So the sign of $\frac{\partial s^*}{\partial A}$ will be the opposite of q.

Recall the sufficient second-order condition from Appendix A:

$$\frac{\partial^2 U(\phi)}{\partial s^2}=c\cdot A\cdot\frac{\partial^2\alpha(\eta,s)}{\partial s^2}-\tau\cdot c^2\cdot A^2\cdot\sigma_\varepsilon^2\cdot V''(s)<0\ . \quad \text{(A.5)}$$

$$\rightarrow\quad c\cdot A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''(s)>\frac{\partial^2\alpha(\eta,s)}{\partial s^2}$$

Variable c denotes the carried interest of GPs, and lies between [0,1]. So:

$$A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''(s)>c\cdot A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''(s)>\frac{\partial^2\alpha(\eta,s)}{\partial s^2}$$

$$\rightarrow\quad A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''\left(s^*\right)-\frac{\partial^2\alpha(\eta,s)}{\partial s^2}>0\ . \quad \text{(B.4)}$$

It implies the first addend of q, i.e., $\left\{3\cdot\sigma_\varepsilon^2\cdot\left[V'\left(s^*\right)\right]^2\cdot\left[A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''\left(s^*\right)-\left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\right]\right\}$ is positive.

Now consider the second addend of q: $\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V'''\left(s^*\right)-V'\left(s^*\right)\cdot\left({}^{\partial^3\alpha(\eta,s)}\!/_{\partial s^3}\right)$. It follows easily that this term is also positive.

Because q is positive, then $\frac{\partial s^*}{\partial A}$ should be negative.

Appendix C: Derivation of the Comparative Statics $\frac{\partial s^*}{\partial \tau}$

Recall the equilibrium condition for s^*:

$$\begin{aligned} & A\cdot\tau\cdot\left(\sigma_\varepsilon^2\right)^2\cdot\left(V'\left(s^*\right)\right)^3-\sigma_\varepsilon^2\cdot\left(V'\left(s^*\right)\right)^2\cdot\left(\partial\alpha(\eta,s)/\partial s\right)+2\cdot\sigma_n^2\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^*\right) \\ & +2\cdot\sigma_\varepsilon^2\cdot V\left(s^*\right)\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^*\right)-2\cdot\sigma_n^2\cdot\left(\partial^2\alpha(\eta,s)/\partial s^2\right)\cdot V'\left(s^*\right) \\ & -2\cdot\sigma_\varepsilon^2\cdot V\left(s^*\right)\cdot\left(\partial^2\alpha(\eta,s)/\partial s^2\right)\cdot V'\left(s^*\right)\equiv 0 \end{aligned} \tag{C.1}$$

Differentiate equation (C.1) with respect to τ. After simplification, I get:

$$\left\{\begin{aligned} & 3\cdot\sigma_\varepsilon^2\cdot\left[V'\left(s^*\right)\right]^2\cdot\left[A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''\left(s^*\right)-\left(\partial\alpha^2(\eta,s)/\partial s^2\right)\right] \\ & +2\cdot\left[\sigma_n^2+\sigma_\varepsilon^2\cdot V\left(s^*\right)\right]\cdot\left[\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V'''\left(s^*\right)-V'\left(s^*\right)\cdot\left(\partial\alpha^3(\eta,s)/\partial s^3\right)\right] \end{aligned}\right\}\cdot\frac{\partial s^*}{\partial\tau}\equiv -A\cdot\left(\sigma_\varepsilon^2\right)^2\cdot\left[V'\left(s^*\right)\right]^3$$

$\rightarrow$

$$q\cdot\frac{\partial s^*}{\partial\tau}\equiv -A\cdot\left(\sigma_\varepsilon^2\right)^2\cdot\left[V'\left(s^*\right)\right]^3 \tag{C.2}$$

Because $V'(s)>0$, the right-hand side of equation (C.2) is negative. So the sign of $\frac{\partial s^*}{\partial\tau}$ will be the opposite of q. I have shown in Appendix B that q is positive. Therefore, $\frac{\partial s^*}{\partial\tau}<0$.

Appendix D: Derivation of the Comparative Statics $\frac{\partial s^*}{\partial\left(\sigma_\varepsilon^2\right)}$

Recall the equilibrium condition for s^*:

$$\begin{aligned} & A\cdot\tau\cdot\left(\sigma_\varepsilon^2\right)^2\cdot\left(V'\left(s^*\right)\right)^3-\sigma_\varepsilon^2\cdot\left(V'\left(s^*\right)\right)^2\cdot\left(\partial\alpha(\eta,s)/\partial s\right)+2\cdot\sigma_n^2\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^*\right) \\ & +2\cdot\sigma_\varepsilon^2\cdot V\left(s^*\right)\cdot\left(\partial\alpha(\eta,s)/\partial s\right)\cdot V''\left(s^*\right)-2\cdot\sigma_n^2\cdot\left(\partial^2\alpha(\eta,s)/\partial s^2\right)\cdot V'\left(s^*\right) \\ & -2\cdot\sigma_\varepsilon^2\cdot V\left(s^*\right)\cdot\left(\partial^2\alpha(\eta,s)/\partial s^2\right)\cdot V'\left(s^*\right)\equiv 0 \end{aligned} \tag{D.1}$$

Differentiate equation (D.1) with respect to σ_ε^2. After simplification, I get:

$$\left\{\begin{array}{l} 3\cdot\sigma_\varepsilon^2\cdot\left[V'\left(s^*\right)\right]^2\cdot\left[A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V''\left(s^*\right)-\left({}^{\partial\alpha^2(\eta,s)}\!/_{\partial s^2}\right)\right] \\ +2\cdot\left[\sigma_n^2+\sigma_\varepsilon^2\cdot V\left(s^*\right)\right]\cdot\left[\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V'''\left(s^*\right)-V'\left(s^*\right)\cdot\left({}^{\partial\alpha^3(\eta,s)}\!/_{\partial s^3}\right)\right] \end{array}\right\}\cdot\frac{\partial s^*}{\partial\left(\sigma_\varepsilon^2\right)}$$

$$\equiv\left\{\begin{array}{l} 2\cdot V\left(s^*\right)\cdot\left[\left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\cdot V'\left(s^*\right)-\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V''\left(s^*\right)\right] \\ +\left(V'\left(s^*\right)\right)^2\cdot\left[\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)-2\cdot A\cdot\tau\cdot\left(\sigma_\varepsilon^2\right)\cdot V'\left(s^*\right)\right] \end{array}\right\}$$

Let variable g denote the right-hand side of the above equation:

$$g=\left\{\begin{array}{l} 2\cdot V\left(s^*\right)\cdot\left[\left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\cdot V'\left(s^*\right)-\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V''\left(s^*\right)\right] \\ +\left(V'\left(s^*\right)\right)^2\cdot\left[\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)-2\cdot A\cdot\tau\cdot\left(\sigma_\varepsilon^2\right)\cdot V'\left(s^*\right)\right] \end{array}\right\} \tag{D.2}$$

Then I have the following simple expression:

$$q\cdot\frac{\partial s^*}{\partial\left(\sigma_\varepsilon^2\right)}\equiv g \tag{D.3}$$

Recall the necessary first-order and the sufficient second-order conditions from Appendix A:

$$c\cdot A\cdot\frac{\partial\alpha(\eta,s)}{\partial s}=\tau\cdot c^2\cdot A^2\cdot\sigma_\varepsilon^2\cdot V'(s) \tag{A.4}$$

$$\frac{\partial^2U(\phi)}{\partial s^2}=c\cdot A\cdot\frac{\partial^2\alpha(\eta,s)}{\partial s^2}-\tau\cdot c^2\cdot A^2\cdot\sigma_\varepsilon^2\cdot V''(s)<0\ . \tag{A.5}$$

Divide the two sides of (A.5) by the two sides of (A.4), I get:

$$\left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\cdot V'\left(s^*\right)<\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V''\left(s^*\right)\ \rightarrow\ \left({}^{\partial^2\alpha(\eta,s)}\!/_{\partial s^2}\right)\cdot V'\left(s^*\right)-\left({}^{\partial\alpha(\eta,s)}\!/_{\partial s}\right)\cdot V''\left(s^*\right)<0\ .$$

Therefore, the first addend of g is negative.

Rewrite equation (A.4) as the following:

$$\frac{\partial\alpha(\eta,s)}{\partial s}=c\cdot A\cdot\tau\cdot\sigma_\varepsilon^2\cdot V'(s)$$

Because c is the share of carried-interest for general partners, it lies between 0 and 1. So I have:

$$\frac{\partial \alpha(\eta, s)}{\partial s} \leq A \cdot \tau \cdot \sigma_{\varepsilon}^2 \cdot V'(s) < 2 \cdot A \cdot \tau \cdot \sigma_{\varepsilon}^2 \cdot V'(s)$$

It follows that the second addend of g is also negative. Therefore, the whole term denoted by g is negative. The sign of $\frac{\partial s^*}{\partial(\sigma_{\varepsilon}^2)}$ is thus the opposite of q. I have shown in Appendix B that q is positive. Therefore, $\frac{\partial s^*}{\partial(\sigma_{\varepsilon}^2)}$ is negative.

Appendix E: Derivation of the Comparative Statics $\frac{\partial s^*}{\partial \eta}$

Recall the equilibrium condition for s^*:

$$\begin{aligned} & A \cdot \tau \cdot (\sigma_{\varepsilon}^2)^2 \cdot (V'(s^*))^3 - \sigma_{\varepsilon}^2 \cdot (V'(s^*))^2 \cdot \left(\partial \alpha(\eta, s) / \partial s\right) + 2 \cdot \sigma_n^2 \cdot \left(\partial \alpha(\eta, s) / \partial s\right) \cdot V''(s^*) \\ & + 2 \cdot \sigma_{\varepsilon}^2 \cdot V(s^*) \cdot \left(\partial \alpha(\eta, s) / \partial s\right) \cdot V''(s^*) - 2 \cdot \sigma_n^2 \cdot \left(\partial^2 \alpha(\eta, s) / \partial s^2\right) \cdot V'(s^*) \\ & - 2 \cdot \sigma_{\varepsilon}^2 \cdot V(s^*) \cdot \left(\partial^2 \alpha(\eta, s) / \partial s^2\right) \cdot V'(s^*) \equiv 0 \end{aligned} \tag{E.1}$$

Differentiate equation (E.1) with respect to η. After simplification, I get:

$$\left\{ \begin{aligned} & 3 \cdot \sigma_{\varepsilon}^2 \cdot \left[V'(s^*)\right]^2 \cdot \left[A \cdot \tau \cdot \sigma_{\varepsilon}^2 \cdot V''(s^*) - \left(\partial^2 \alpha(\eta, s) / \partial s^2\right) \right] \\ & + 2 \cdot \left[\sigma_n^2 + \sigma_{\varepsilon}^2 \cdot V(s^*) \right] \cdot \left[\left(\partial \alpha(\eta, s) / \partial s\right) \cdot V'''(s^*) - V'(s^*) \cdot \left(\partial^3 \alpha(\eta, s) / \partial s^3\right) \right] \end{aligned} \right\} \cdot \frac{\partial s^*}{\partial \eta}$$

$$\equiv \left\{ \begin{aligned} & \sigma_{\varepsilon}^2 \cdot \left[V'(s^*)\right]^2 \cdot \left(\partial^2 \alpha(\eta, s) / \partial s \partial \eta\right) \\ & + 2 \cdot \left[\sigma_n^2 + \sigma_{\varepsilon}^2 \cdot V(s^*) \right] \cdot \left[V'(s^*) \cdot \left(\partial^3 \alpha(\eta, s) / \partial s^2 \partial \eta\right) - V''(s^*) \cdot \left(\partial^2 \alpha(\eta, s) / \partial s \partial \eta\right) \right] \end{aligned} \right\}$$

Let variable k denote the right-hand side of above equation, i.e.,

$$k = \sigma_\varepsilon^2 \cdot \left[V'\left(s^*\right)\right]^2 \cdot \left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right) + 2 \cdot \left[\sigma_n^2 + \sigma_\varepsilon^2 \cdot V\left(s^*\right)\right] \cdot \left[V'\left(s^*\right) \cdot \left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right) - V''\left(s^*\right) \cdot \left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right)\right] \quad \text{(E.2)}$$

Then I have the following simple expression:

$$q \cdot \frac{\partial s^*}{\partial \eta} \equiv k \quad \text{(E.3)}$$

It follows easily that the first addend of k is positive.

Now consider the term $\left[V'\left(s^*\right) \cdot \left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right) - V''\left(s^*\right) \cdot \left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right)\right]$:

$$V'\left(s^*\right) \cdot \left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right) - V''\left(s^*\right) \cdot \left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right) > 0 \Leftrightarrow \frac{\left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right)}{\left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right)} > \frac{V''\left(s^*\right)}{V'\left(s^*\right)}$$

It implies that if $\frac{\left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right)}{\left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right)} \geq \frac{V''\left(s^*\right)}{V'\left(s^*\right)}$, then $k > 0$. If k is positive, the sign of $\frac{\partial s^*}{\partial \eta}$ will be the same of q. I have shown in Appendix B that q is positive. Therefore, if $\frac{\left(\partial^3\alpha(\eta,s)/\partial s^2\partial\eta\right)}{\left(\partial^2\alpha(\eta,s)/\partial s\partial\eta\right)} \geq \frac{V''\left(s^*\right)}{V'\left(s^*\right)}$, then $\frac{\partial s^*}{\partial \eta} > 0$.

Appendix F: VentureXpert Definitions of Company Stage Development

There are several levels of company stage classification in VentureXpert. The coarsest classification is early stage, expansion stage, and later stage.

Early stage involves investment in companies for product development and initial marketing, manufacturing and sales activities. Early stage can be further classified into seed stage, startup stage and first stage. Seed stage refers to the case where a relatively small amount of capital is provided to test a concept, maybe involving product development but not initial marketing. Startup stage is the financing for product development and initial marketing, without product sales. First stage is the financing for initial commercial manufacturing and sales.

Expansion stage involves investment in companies that are producing and shipping, have growing accounts receivable and inventories, or are breaking even or profitable. Expansion stage can be further classified into second stage and third stage. In second stage, working capital financing is provided, but the firm is likely to have no profits. Third stage is the financing for plant expansion, marketing and working capital, with expected profits.

The later stage involves financing for the further expansion of a company that is producing and increasing its sales volume.

Appendix G: Summary of Variable Definitions

Variable Name	Definition
HERFINDAHL-HIRSCHMAN INDEX (HHI)	The sum of the squares of percentage of all investments in each area (industry, stage or state) by a venture capital fund.
INDUSTRY HHI	Industry specialization, calculated using Herfindahl-Hirschman Index, for VentureXpert industry classification of 9-minor industry groups.
STAGE HHI	Stage specialization, calculated using Herfindahl-Hirschman Index, for VentureXpert classification of Stage Level Three.
GEOGRAPHY HHI	Geography specialization, calculated using Herfindahl-Hirschman Index, for VentureXpert classification of 50 states.
FOCUS AREA	The particular area (industry, stage or state) with the largest number of investments in a venture fund.
FOCUS AREA CONCENTRATION RATIO (CTR)	Focus area concentration ratio, calculated as the number of investments in the focus area (industry, stage, or state) divided by the total number of investments in a venture capital fund.
INDUSTRY CTR	Industry specialization, calculated as focus industry concentration ratio, for VentureXpert industry classification of 9-minor industry groups.
STAGE CTR	Stage specialization, calculated as focus stage concentration ratio, for VentureXpert classification of Stage Level Three.
GEOGRAPHY CTR	Geography specialization, calculated as focus stage concentration ratio, for VentureXpert classification of 50 states.
SIZE	The total amount of capital committed by limited and general partners of a fund.
AGE	The difference between the date of a fund's last distributed investment and the time of a venture capital management firm's first investment.
CAPITAL	The total amount of capital under management by venture capital firms.
INUDSTRY SPECIAL TALENT	The number of company investments the venture capital management firm has made in the focus industry before this venture fund.
STAGE SPECIAL TALENT	The number of company investments the venture capital management firm has made in the focus stage before this venture fund.
GEOGRAPHY SPECIAL TALENT	The number of company investments the venture capital management firm has made in the focus state before this venture fund.
GENERAL TALENT	The total number of company investments the venture capital management firm has ever made before this venture fund.

(~ To Be Continued ~)

Appendix G: Summary of Variable Definitions (~ Continued ~)

Variable Name	Definition
IPORATE	The fraction of firms that went public or were in registration for an offering in a venture portfolio.
IPOARATE	The fraction of firms that were acquired, merged, went public, or in registration for an offering in a venture portfolio.
FOCUS INDUSTRY DUMMIES	Focus industry dummies, taking the value of 1 for a particular industry group, otherwise 0. There are 9 dummies denoting each industry.
FOCUS STAGE DUMMIES	Focus stage dummies, taking the value of 1 for some particular stages of company development, otherwise 0. There are 8 dummies denoting whether the portfolio company is in "seed stage", "startup stage", "first stage", "early stage ", "second stage", "third stage", "expansion stage ", or "other later stage".
FOCUS GEOGRAPHY DUMMIES	Focus geographic dummies, taking the value of 1 for a particular geographic region, otherwise 0. There are 4 dummies denoting whether the portfolio company is located in "New York", "Massachusetts", "California", or "Texas".
FUND YEAR	Fund initial closing year.
FUND YEAR DUMMIES	Binary variables, taking the value of 1 for a particular fund year, otherwise 0.

Table 1: Summary Statistics

This table reports the mean, standard deviation and quartiles of key variables for the sample of 1586 VC funds collected from VentureXpert database. The classifications of 9 minor industry groups, Stage Level Three, and 50 states are used in calculating industry, stage, and geography specialization, respectively. The variables INDUSTRY HHI, STAGE HHI, and GEOGRAPHY HHI are the specialization measures using Herfindahl-Hirschman Index (HHI). The variables INDUSTRY CTR, STAGE CTR, and GEOGRPAHY CTR are alternative specialization measures, calculated as the fraction of portfolio companies in the focus area (industry, stage, or state). The focus area refers to the particular industry, stage, or state with the highest number of companies in a venture portfolio. The varialbles INDUSTRY SPECIAL TALENT, STAGE SPECIAL TALENT, and GEOGRAPHY SPECIAL TALENT are measured as the number of company investments the VC management firm has made in the focus industry, stage, or state before this fund. The GENERAL TALENT is measured as the total number of company investments the VC management firm has ever made before this fund. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions.CAPITAL is the total amount of capital under management by a VC management firm. IPORATE is the fraction of firms that went public or in registration for an IPO in a VC fund, and IPOARATE is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund.

Variable	No. of Funds	Mean	Standard Deviation	Q1	Median	Q3
INDUSTRY HHI	1586	0.3614	0.2278	0.2066	0.2854	0.4303
STAGE HHI	1586	0.3082	0.2256	0.1736	0.2244	0.3333
GEOGRAPHY HHI	1586	0.4635	0.2745	0.2346	0.3956	0.6296
INDUSTRY CTR	1586	0.4581	0.2145	0.3043	0.4000	0.5333
STAGE CTR	1586	0.4016	0.2083	0.2667	0.3333	0.5000
GEOGRAPHY CTR	1586	0.5837	0.2485	0.3750	0.5556	0.7778
INDUSTRY SPECIAL TALENT	1586	15.4729	35.3010	0.0000	2.0000	15.0000
STAGE SPECIAL TALENT	1586	13.8701	30.8238	0.0000	2.0000	12.0000
GEOGRAPHY SPECIAL TALENT	1586	47.6129	120.7104	0.0000	3.0000	34.0000
GENERAL TALENT	1586	95.6961	213.3648	0.0000	13.0000	83.0000
AGE (Years)	1586	14.3567	10.3863	6.3333	11.7500	19.9167
SIZE (1000 mils)	1581	0.1054	0.1890	0.0170	0.0450	0.1065
CAPITAL (1000 mils)	1527	1.0540	2.1082	0.0840	0.3000	1.1000
IPORATE	1586	0.2146	0.2212	0.0000	0.1667	0.3333
IPOARATE	1420	0.4732	0.2424	0.2667	0.4783	0.6448

Table 2: Median Fund Specialization By Year

This table reports the median value of cross-sectional fund specialization, for each year from 1978 to 2000. The VentureXpert classifications of 9 minor industry groups, Stage Level Three, and 50 states are used in calculating industry specialization, stage specialization, and geography specialization, respectively. Two measures of fund specialization are used. The first specilaization measure uses the Herfindahl-Hirschman Index. An alternative measure uses the fraction of portfolio companies in the focus area (industry, stage, geography), called the Focus Area Concentration Ratio. The focus area is defined as the particular industry, stage, or state with the highest number of companies in a venture portfolio. Fund year refers to the initial closing year of a venture capital fund.

		Herfindahl-Hirschman Index			Focus Area Concentration Ratio		
Fund Year	No. of Funds	Industry	Stage	Geography	Industry	Stage	Geography
1978	10	0.18	0.16	0.23	0.33	0.24	0.40
1979	10	0.20	0.18	0.35	0.32	0.29	0.56
1980	25	0.20	0.18	0.38	0.32	0.27	0.50
1981	39	0.21	0.17	0.30	0.35	0.29	0.47
1982	45	0.21	0.20	0.47	0.31	0.30	0.67
1983	61	0.21	0.18	0.36	0.32	0.28	0.50
1984	64	0.20	0.17	0.36	0.30	0.27	0.51
1985	44	0.25	0.20	0.47	0.33	0.32	0.67
1986	48	0.25	0.20	0.37	0.33	0.32	0.50
1987	58	0.23	0.18	0.38	0.33	0.29	0.56
1988	52	0.24	0.23	0.39	0.34	0.33	0.52
1989	60	0.28	0.19	0.38	0.38	0.29	0.56
1990	34	0.29	0.22	0.37	0.39	0.32	0.50
1991	23	0.46	0.33	0.56	0.50	0.36	0.67
1992	40	0.27	0.25	0.46	0.41	0.33	0.57
1993	43	0.35	0.21	0.41	0.44	0.30	0.54
1994	74	0.29	0.22	0.45	0.39	0.34	0.62
1995	75	0.33	0.24	0.48	0.43	0.36	0.56
1996	91	0.31	0.21	0.39	0.44	0.33	0.56
1997	117	0.33	0.23	0.39	0.44	0.33	0.55
1998	140	0.36	0.24	0.40	0.50	0.36	0.56
1999	189	0.33	0.26	0.44	0.46	0.39	0.60
2000	244	0.30	0.25	0.43	0.43	0.36	0.57

Table 3: The Effect of Size, Age, and Talent on Fund Specialization

The table reports the ordinary least squares regression results for two specialization measures. The VentureXpert classifications of 9 minor industry groups, Stage Level Three, and 50 states are used in calculating industry, stage and geography specialization, respectively. In Panel A, fund specilaization is measured using Herfindahl-Hirschman Index. In Panel B, specialization is measured as the fraction of portfolio companies in the focus area (industry, stage, geography), called the Focus Area Concentration Ratio. The focus area is defined as the particular industry (stage, or state) with the highest number of companies in a venture portfolio. The explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus area (industry, stage, geography) dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

Panel A: Measuring Specialization by Herfindahl-Hirschman Index (HHI)

	Industry HHI			Stage HHI			Geography HHI		
SIZE	-0.1491	-0.1365	-0.1494	-0.1758	-0.1616	-0.1767	-0.2759	-0.2651	-0.2571
	(-4.48)	(-4.16)	(-4.49)	(-5.18)	(-4.84)	(-5.20)	(-6.78)	(-6.42)	(-6.29)
AGE	-0.0045	-0.0045	-0.0045	-0.0042	-0.0040	-0.0041	-0.0051	-0.0048	-0.0042
	(-7.28)	(-6.83)	(-6.92)	(-6.38)	(-5.98)	(-6.15)	(-6.50)	(-5.78)	(-5.09)
SPECIAL TALENT	0.0006		0.0005	0.0008		0.0011	0.0004		0.0010
	(2.99)		(2.12)	(3.51)		(2.36)	(6.55)		(6.10)
GENERAL TALENT		0.0001	0.0000		0.0001	0.0000		0.0002	-0.0004
		(2.11)	(0.15)		(2.69)	(-0.69)		(4.41)	(-3.72)
CAPITAL	-0.0026	-0.0028	-0.0027	-0.0018	-0.0018	-0.0016	-0.0090	-0.0104	-0.0050
	(-0.90)	(-0.95)	(-0.91)	(-0.62)	(-0.59)	(-0.53)	(-2.52)	(-2.82)	(-1.33)
Focus Area Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.14	0.14	0.14	0.11	0.11	0.11	0.11	0.09	0.12
Number of Funds	1525	1525	1525	1525	1525	1525	1525	1525	1525

(To be continued on next page.)

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Panel B: Measuring Specialization by Focus Area Concentration Ratio (CTR)

	Industry CTR			Stage CTR			Geography CTR		
SIZE	-0.1240	-0.1058	-0.1224	-0.1465	-0.1334	-0.1478	-0.2118	-0.1966	-0.1871
	(-3.95)	(-3.42)	(-3.90)	(-4.63)	(-4.29)	(-4.67)	(-5.69)	(-5.19)	(-5.04)
AGE	-0.0040	-0.0037	-0.0038	-0.0038	-0.0036	-0.0037	-0.0043	-0.0037	-0.0030
	(-6.82)	(-6.00)	(-6.13)	(-6.24)	(-5.79)	(-5.96)	(-5.90)	(-4.92)	(-4.04)
SPECIAL TALENT	0.0005		0.0007	0.0007		0.0010	0.0004		0.0012
	(3.04)		(2.89)	(3.06)		(2.40)	(7.28)		(7.90)
GENERAL TALENT		0.0000	0.0000		0.0001	-0.0001		0.0002	-0.0005
		(1.33)	(-0.94)		(2.14)	(-1.00)		(4.41)	(-5.35)
CAPITAL	-0.0033	-0.0030	-0.0029	-0.0013	-0.0011	-0.0010	-0.0085	-0.0096	-0.0032
	(-1.21)	(-1.09)	(-1.04)	(-0.47)	(-0.41)	(-0.35)	(-2.60)	(-2.84)	(-0.94)
Focus Area Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.15	0.15	0.15	0.10	0.10	0.11	0.10	0.08	0.11
Number of Funds	1525	1525	1525	1525	1525	1525	1525	1525	1525

Table 4: The Effect of Specialized Area Risk on Industry Specialization

The table shows how focus industry risk affects fund specialization. The focus industry is defined as the particular industry with the highest number of companies in a venture portfolio. The VentureXpert classification of 9 minor industry groups is used. Two measures of industry specialization are considered: the Herfindahl-Hirschman Index (HHI), and the focus industry concentration ratio (CTR) measured as the fraction of portfolio companies in the focus industry. There are two proxies for focus industry risk: the return standard deviation of publicly traded stocks matched by the SIC codes with VentureXpert industry classifications, and the return residual volatility from the Fama-French three-factor model of matched publicly traded stocks. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus industry dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Industry HHI				Focus Industry CTR			
RETURN VOLATILITY	-0.9513 (-5.22)	-0.9648 (-5.29)			-0.8434 (-4.85)	-0.8659 (-5.00)		
RESIDUAL VOLATILITY			-1.1111 (-5.03)	-1.1283 (-5.11)			-0.9620 (-4.56)	-0.9905 (-4.71)
SIZE	-0.1587 (-3.79)	-0.1574 (-3.76)	-0.1585 (-3.78)	-0.1572 (-3.75)	-0.1392 (-3.48)	-0.1370 (-3.44)	-0.1387 (-3.47)	-0.1366 (-3.43)
AGE	-0.0052 (-7.43)	-0.0048 (-6.56)	-0.0052 (-7.42)	-0.0048 (-6.55)	-0.0047 (-6.95)	-0.0040 (-5.71)	-0.0047 (-6.94)	-0.0040 (-5.70)
SPECIAL TALENT	0.0006 (2.99)	0.0011 (3.30)	0.0006 (3.00)	0.0011 (3.31)	0.0006 (3.04)	0.0015 (4.52)	0.0006 (3.04)	0.0015 (4.51)
GENERAL TALENT		-0.0001 (-1.93)		-0.0001 (-1.93)		-0.0002 (-3.38)		-0.0002 (-3.37)
CAPITAL	-0.0026 (-0.78)	-0.0016 (-0.46)	-0.0028 (-0.83)	-0.0018 (-0.51)	-0.0031 (-0.96)	-0.0013 (-0.41)	-0.0033 (-1.02)	-0.0015 (-0.46)
Focus Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.15	0.16	0.15	0.16	0.14	0.15	0.14	0.15
Number of Funds	1230	1230	1230	1230	1230	1230	1230	1230

Table 5: The Effect of Specialized Area Risk on Stage Specialization

The table shows how focus stage risk affects fund specialization. The focus stage is defined as the particular stage with the highest number of companies in a venture portfolio. The VentureXpert classification of Stage Level Three is used. Two measures of industry specialization are considered: the Herfindahl-Hirschman Index (HHI), and the focus stage concentration ratio (CTR) measured as the fraction of portfolio companies in the focus stage. The stage risk rank is an ordered number denoting the degree of riskiness for each stage, ranging from 1 to 8. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus stage dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Stage HHI			Focus Stage CTR		
STAGE RISK RANK	-0.0092	-0.0090	-0.0092	-0.0044	-0.0041	-0.0044
	(-3.68)	(-3.60)	(-3.68)	(-1.88)	(-1.77)	(-1.88)
SIZE	-0.1803	-0.1699	-0.1796	-0.1482	-0.1362	-0.1488
	(-5.30)	(-5.09)	(-5.27)	(-4.68)	(-4.38)	(-4.69)
AGE	-0.0043	-0.0042	-0.0043	-0.0039	-0.0038	-0.0039
	(-6.50)	(-6.36)	(-6.47)	(-6.44)	(-6.11)	(-6.27)
SPECIAL TALENT	0.0008		0.0006	0.0007		0.0008
	(3.29)		(1.39)	(3.07)		(1.92)
GENERAL TALENT		0.0001	0.0000		0.0001	0.0000
		(3.01)	(0.40)		(2.42)	(-0.37)
CAPITAL	-0.0017	-0.0019	-0.0018	-0.0011	-0.0011	-0.0010
	(-0.57)	(-0.65)	(-0.61)	(-0.40)	(-0.40)	(-0.35)
Focus Stage Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.10	0.10	0.10	0.09	0.09	0.09
Number of Funds	1525	1525	1525	1525	1525	1525

Table 6: The Effect of Industry Specialization on Fund Performance

The table reports the OLS regression results regarding the effect of industry specialization on fund performance. The dependent variable is the proxy for fund performance. Two proxies are used. One is the fraction of firms that went public or in registration for an IPO in a VC fund, and the other is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund. The industry specialization is measured using Herfindahl-Hirschman Index, for the VentureXpert classification of 9 minor industry groups. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus industry dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus industry denotes the particular industry with the highest number of portfolio companies in a venture fund. Fund year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Performance (IPO)				Performance (IPO&Acquisition)			
INDUSTRY HHI	0.0765	0.1182	0.1188	0.1180	0.3351	0.3636	0.3636	0.3637
	(3.69)	(5.43)	(5.48)	(5.43)	(13.75)	(14.29)	(14.34)	(14.33)
SIZE		0.0372	0.0371	0.0337		0.0042	-0.0012	-0.0004
		(1.32)	(1.34)	(1.20)		(0.15)	(-0.04)	(-0.01)
AGE		0.0010	0.0005	0.0005		0.0006	0.0001	0.0001
		(1.83)	(0.98)	(0.94)		(1.13)	(0.12)	(0.13)
SPECIAL TALENT		0.0005		0.0001		0.0004		0.0000
		(3.05)		(0.66)		(2.46)		(-0.13)
GENERAL TALENT			0.0001	0.0001			0.0001	0.0001
			(3.84)	(2.42)			(3.88)	(2.99)
CAPITAL		0.0054	0.0045	0.0045		0.0046	0.0035	0.0035
		(2.25)	(1.82)	(1.83)		(1.93)	(1.45)	(1.45)
Focus Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.35	0.39	0.39	0.39	0.52	0.54	0.54	0.54
Number of Funds	1586	1525	1525	1525	1420	1371	1371	1371

Table 7: The Effect of Stage Specialization on Fund Performance

The table reports the OLS regression results regarding the effect of stage specialization on fund performance. The dependent variable is the proxy for fund performance. Two proxies are used. One is the fraction of firms that went public or in registration for an IPO in a VC fund, and the other is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund. The stage specialization is measured using Herfindahl-Hirschman Index, for the VentureXpert classification of Stage Level Three. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus stage dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus stage denotes the particular stage with the highest number of portfolio companies in a venture fund. Fund year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Performance (IPO)				Performance (IPO&Acquisition)			
STAGE HHI	0.0420	0.0713	0.0688	0.0732	0.3589	0.3827	0.3814	0.3833
	(1.98)	(3.23)	(3.13)	(3.34)	(13.62)	(14.15)	(14.15)	(14.23)
SIZE		0.0405	0.0277	0.0464		0.0084	0.0002	0.0132
		(1.39)	(0.97)	(1.60)		(0.29)	(0.01)	(0.45)
AGE		0.0011	0.0005	0.0007		0.0004	0.0000	0.0001
		(2.02)	(0.91)	(1.18)		(0.78)	(-0.01)	(0.15)
SPECIAL TALENT		0.0003		-0.0013		0.0004		-0.0008
		(1.58)		(-3.30)		(1.89)		(-2.03)
GENERAL TALENT			0.0001	0.0003			0.0001	0.0002
			(3.75)	(4.75)			(3.42)	(3.50)
CAPITAL		0.0038	0.0026	0.0024		0.0041	0.0032	0.0031
		(1.53)	(1.02)	(0.95)		(1.69)	(1.30)	(1.27)
Focus Stage Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.32	0.35	0.36	0.36	0.50	0.53	0.53	0.53
Number of Funds	1586	1525	1525	1525	1420	1371	1371	1371

Table 8: The Effect of Geography Specialization on Fund Performance

The table reports the OLS regression results regarding the effect of geography specialization on fund performance. The dependent variable is the proxy for fund performance. Two proxies are used. One is the fraction of firms that went public or in registration for an IPO in a VC fund, and the other is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund. The geography specialization is measured using Herfindahl-Hirschman Index, for the classification of 50 states. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus stage dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus state denotes the particular state with the highest number of portfolio companies in a venture fund. Fund year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Performance (IPO)				Performance (IPO&Acquisition)			
GEOGRAPHY HHI	-0.0036	0.0052	0.0082	0.0065	0.1240	0.1300	0.1311	0.1350
	(-0.22)	(0.30)	(0.47)	(0.37)	(6.54)	(6.51)	(6.64)	(6.72)
SIZE		0.0090	0.0065	0.0067		-0.0049	-0.0118	-0.0126
		(0.32)	(0.23)	(0.23)		(-0.17)	(-0.40)	(-0.42)
AGE		0.0003	0.0001	0.0002		-0.0003	-0.0006	-0.0006
		(0.54)	(0.24)	(0.30)		(-0.56)	(-0.99)	(-1.08)
SPECIAL TALENT		0.0001		0.0001		0.0001		-0.0001
		(3.16)		(0.61)		(1.91)		(-1.05)
GENERAL TALENT			0.0001	0.0001			0.0001	0.0001
			(3.20)	(0.76)			(2.52)	(1.95)
CAPITAL		0.0025	0.0016	0.0019		0.0035	0.0026	0.0020
		(1.01)	(0.62)	(0.74)		(1.39)	(1.03)	(0.75)
Focus State Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.33	0.36	0.36	0.36	0.47	0.48	0.49	0.49
Number of Funds	1586	1525	1525	1525	1420	1371	1371	1371

Table 9: The Effect of Industry, Stage, and Geography Specializations on Fund Performance

The table reports the OLS regression results when simultaneously considering the effect of industry (ind.), stage (stg.), and geography (geo.) specialization on fund performance. The dependent variable is the proxy for fund performance. Two proxies are used. One is the fraction of firms that went public or in registration for an IPO in a VC fund, and the other is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund. Fund specialization is measured using Herfindahl-Hirschman Index, for the VentureXpert classifications of 9 minor industry groups, Stage Level Three, and 50 states, respectively. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus area dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus area (industry, stage, geography) denotes the particular area with the highest number of portfolio companies in a venture fund. Fund year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	Performance (IPO)				Performance (IPO&Acquisition)			
INDUSTRY HHI	0.0691	0.1028	0.1055	0.1013	0.1961	0.2104	0.2116	0.2092
	(2.30)	(3.34)	(3.44)	(3.28)	(6.36)	(6.59)	(6.68)	(6.54)
STAGE HHI	0.0505	0.0490	0.0359	0.0478	0.2505	0.2541	0.2466	0.2533
	(1.56)	(1.52)	(1.12)	(1.48)	(7.15)	(7.15)	(6.99)	(7.12)
GEOGRAPHY HHI	-0.0507	-0.0483	-0.0399	-0.0456	-0.0132	-0.0041	0.0009	-0.0023
	(-2.49)	(-2.36)	(-1.97)	(-2.21)	(-0.65)	(-0.20)	(0.04)	(-0.11)
SIZE		0.0305	0.0201	0.0324		0.0030	0.0000	0.0039
		(1.08)	(0.73)	(1.14)		(0.10)	(0.00)	(0.14)
AGE		0.0008	0.0004	0.0007		0.0003	0.0001	0.0002
		(1.41)	(0.78)	(1.17)		(0.53)	(0.24)	(0.40)
IND. SPECIAL TALENT		0.0002		0.0002		0.0002		0.0002
		(1.22)		(0.89)		(0.87)		(0.69)
STG. SPECIAL TALENT		-0.0009		-0.0011		-0.0003		-0.0004
		(-2.73)		(-2.94)		(-0.98)		(-1.18)
GEO. SPECIAL TALENT		0.0003		0.0002		0.0002		0.0001
		(3.88)		(1.80)		(2.21)		(0.96)
GENERAL TALENT			0.0001	0.0001			0.0001	0.0001
			(3.33)	(1.17)			(2.97)	(0.67)
CAPITAL		0.0046	0.0030	0.0039		0.0035	0.0025	0.0031
		(1.91)	(1.23)	(1.55)		(1.49)	(1.08)	(1.27)
R-Square	0.38	0.42	0.42	0.42	0.56	0.58	0.58	0.58
Number of Funds	1586	1525	1525	1525	1420	1371	1371	1371

Table 10: Small Business Investment Companies (SBICs) and Fund Specialization

The table shows the relationship between Small Business Investment Companies and VC fund specialization. The fund specilaization is measured using Herfindahl-Hirschman Index, for VentureXpert classifications of 9 minor industry groups, Stage Level Three, and 50 states, respectively. The SBIC DUMMY is a binary variable, equal to 1 if the VC fund is registered as a SBIC, otherwise 0. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus area (industry, stage, geography) dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus area is defined as the particular industry (stage, or state) with the highest number of companies in a venture portfolio. Focus year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

	INDUSTRY HHI			STAGE HHI			GEOGRAPHY HHI		
SBIC DUMMY	-0.0673	-0.0672	-0.0672	-0.0257	-0.0254	-0.0259	0.0123	0.0104	0.0138
	(-2.66)	(-2.65)	(-2.65)	(-1.00)	(-0.99)	(-1.01)	(0.39)	(0.33)	(0.44)
SIZE	-0.1525	-0.1398	-0.1527	-0.1773	-0.1631	-0.1783	-0.2753	-0.2646	-0.2564
	(-4.59)	(-4.27)	(-4.59)	(-5.22)	(-4.87)	(-5.24)	(-6.76)	(-6.40)	(-6.27)
AGE	-0.0045	-0.0045	-0.0046	-0.0042	-0.0040	-0.0041	-0.0051	-0.0048	-0.0042
	(-7.33)	(-6.87)	(-6.96)	(-6.39)	(-5.99)	(-6.16)	(-6.50)	(-5.78)	(-5.08)
SPECIAL TALENT	0.0006		0.0005	0.0008		0.0011	0.0004		0.0010
	(2.97)		(2.12)	(3.51)		(2.37)	(6.56)		(6.10)
GENERAL TALENT		0.0001	0.0000		0.0001	0.0000		0.0002	-0.0004
		(2.08)	(0.12)		(2.68)	(-0.71)		(4.42)	(-3.72)
CAPITAL	-0.0031	-0.0033	-0.0032	-0.0020	-0.0019	-0.0018	-0.0090	-0.0103	-0.0049
	(-1.08)	(-1.12)	(-1.08)	(-0.69)	(-0.65)	(-0.59)	(-2.49)	(-2.80)	(-1.30)
Focus Area Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.15	0.15	0.15	0.11	0.11	0.12	0.11	0.09	0.12
Number of Funds	1525	1525	1525	1525	1525	1525	1525	1525	1525

Table 11: Small Business Investment Companies (SBICs) and Fund Performance

The table shows the relationship between SBICs and fund performance. In Panel A, the three types of fund specialization (industry, stage and geography) are considered separately, while in Panel B, they are considered simultaneously. The dependent variable is the proxy for fund performance. Two proxies are used. One is the fraction of firms that went public or in registration for an IPO in a VC fund, and the other is the fraction of firms that were acquired, merged, went public or in registration for an IPO in a VC fund. The SBIC DUMMY is a binary variable, equal to 1 if the VC fund is registered as a SBIC, otherwise 0. Fund specilaization is measured using Herfindahl-Hirschman Index, for VentureXpert classifications of 9 minor industry groups, Stage Level Three, and 50 states, respectively. Other explanatory variables include fund size, VC management firm age, the amount of specialized talent, the amount of general talent, and the total managed capital of the VC firm, focus industry dummies, and fund year dummies. Fund SIZE is the total amount of capital committed by limited and general partners of a fund, in $1000 millions. AGE is the difference between the date of a fund's last distributed investment and the time of a VC management firm's first investment. The amount of specialized talent is measured as the number of company investments the VC management firm has made in the focus area before this fund. The amount of general talent is measured as the total number of company investments the VC management firm has ever made before this fund. CAPITAL is the total amount of capital under management by a VC management firm. Focus area denotes the particular industry (stage, geography) with the highest number of portfolio companies in a venture fund. Fund year dummies are a set of dummies variables denoting the intitial closing date of a fund. The T-statistics are in parenthesis under parameter estimates.

Panel A: Considering Specialization Separately

Dependent Variable	Performance (IPO)			Performance (IPO&Acquisition)		
Type of Specialization	Industry	Stage	Geography	Industry	Stage	Geography
SBIC DUMMY	-0.0489	-0.0675	-0.0571	-0.0629	-0.0856	-0.0860
	(-2.29)	(-3.11)	(-2.64)	(-2.93)	(-3.98)	(-3.81)
SPECIALIZATION BY HHI	0.1146	0.0714	0.0071	0.3587	0.3807	0.1371
	(5.27)	(3.26)	(0.40)	(14.14)	(14.2)	(6.86)
SIZE	0.0307	0.0421	0.0038	-0.0049	0.0067	-0.0182
	(1.09)	(1.45)	(0.13)	(-0.17)	(0.23)	(-0.62)
AGE	0.0005	0.0007	0.0002	0.0000	0.0000	-0.0007
	(0.90)	(1.15)	(0.28)	(0.02)	(0.05)	(-1.16)
SPECIAL TALENT	0.0001	-0.0013	0.0001	0.0000	-0.0008	-0.0001
	(0.66)	(-3.28)	(0.56)	(-0.12)	(-1.99)	(-1.11)
GENERAL TALENT	0.0001	0.0003	0.0001	0.0001	0.0002	0.0001
	(2.40)	(4.72)	(0.80)	(2.98)	(3.46)	(2.01)
CAPITAL	0.0041	0.0019	0.0015	0.0030	0.0025	0.0014
	(1.68)	(0.75)	(0.58)	(1.25)	(1.03)	(0.54)
Focus Area & Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.40	0.36	0.36	0.55	0.54	0.49
Number of Funds	1525	1525	1525	1371	1371	1371

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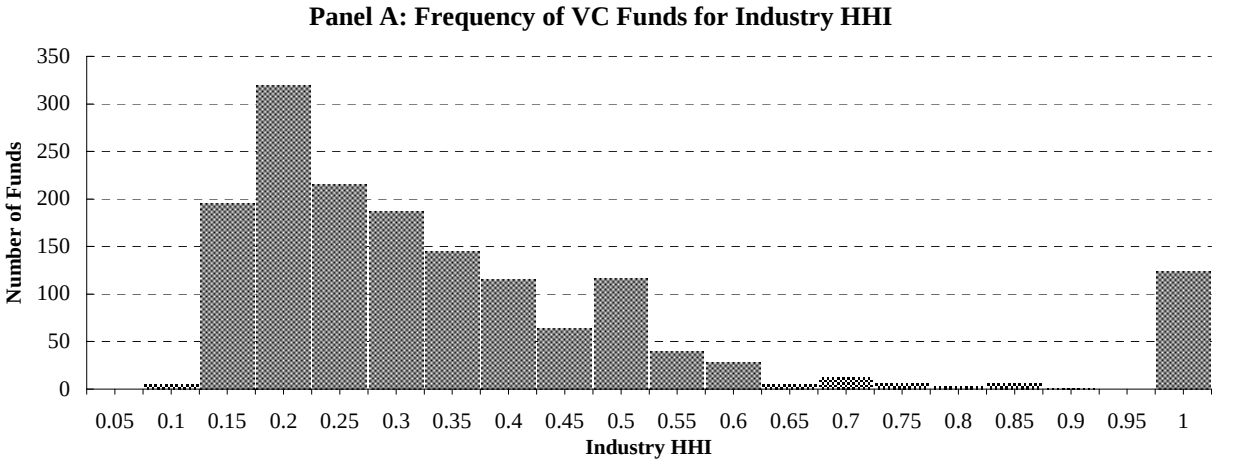
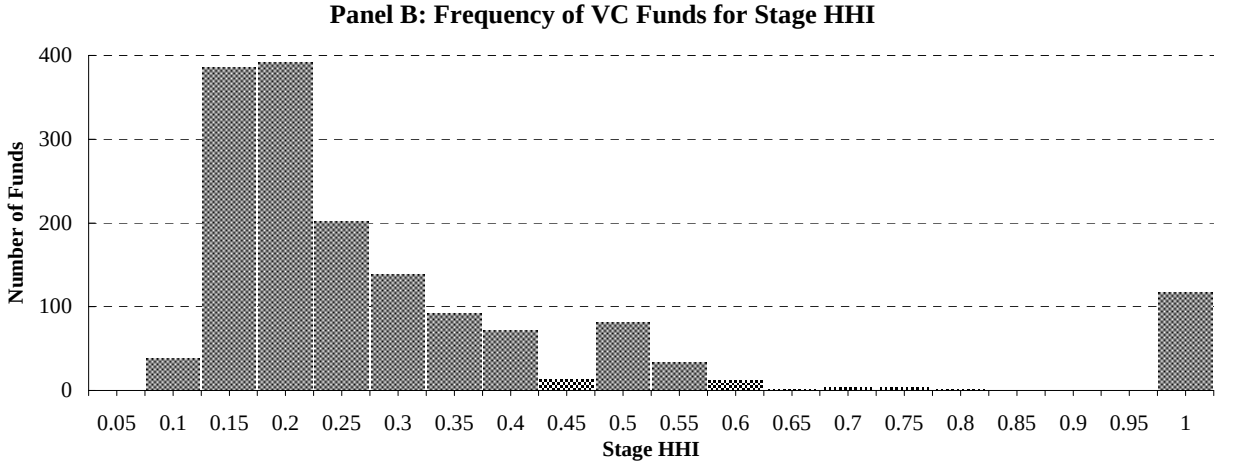
Panel B: Considering Specialization Simultaneously

	Performance (IPO)			Performance (IPO&Acquisition)		
SBIC DUMMY	-0.0465	-0.0478	-0.0468	-0.0624	-0.0627	-0.0625
	(-2.21)	(-2.27)	(-2.23)	(-2.98)	(-3.00)	(-2.99)
INDUSTRY HHI	0.0973	0.1000	0.0957	0.2025	0.2038	0.2012
	(3.15)	(3.26)	(3.10)	(6.34)	(6.43)	(6.29)
STAGE HHI	0.0502	0.0372	0.0490	0.2556	0.2480	0.2547
	(1.56)	(1.16)	(1.52)	(7.22)	(7.05)	(7.19)
GEOGRAPHY HHI	-0.0466	-0.0383	-0.0437	-0.0012	0.0035	0.0007
	(-2.27)	(-1.89)	(-2.12)	(-0.06)	(0.17)	(0.03)
SIZE	0.0278	0.0176	0.0298	-0.0017	-0.0042	-0.0007
	(0.98)	(0.64)	(1.05)	(-0.06)	(-0.15)	(-0.03)
AGE	0.0008	0.0004	0.0006	0.0002	0.0001	0.0002
	(1.38)	(0.76)	(1.14)	(0.44)	(0.16)	(0.31)
IND. SPECIAL TALENT	0.0003		0.0002	0.0002		0.0002
	(1.26)		(0.92)	(0.94)		(0.75)
STG. SPECIAL TALENT	-0.0009		-0.0011	-0.0003		-0.0004
	(-2.71)		(-2.94)	(-0.96)		(-1.18)
GEO. SPECIAL TALENT	0.0003		0.0002	0.0002		0.0001
	(3.82)		(1.73)	(2.14)		(0.90)
GENERAL TALENT		0.0001	0.0001		0.0001	0.0001
		(3.31)	(1.20)		(2.97)	(0.70)
CAPITAL	0.0043	0.0026	0.0035	0.0030	0.0021	0.0026
	(1.76)	(1.09)	(1.40)	(1.30)	(0.90)	(1.08)
Focus Area & Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-Square	0.43	0.42	0.43	0.58	0.58	0.58
Number of Funds	1525	1525	1525	1371	1371	1371

Figure 1: Frequency of VC Funds (Measuring Specialization by Herfindahl-Hirschman Index)

The following figure plots the frequency of VC funds for different levels of specialization, measured using Herfindahl-Hirschman Index, for VentureXpert classifications of 9 industry minor groups (Panel A), Stage Level Three (Panel B), and 50 states (Panel C), respectively. The sample has 1586 VC funds from 1978 to 2000, collected from VentureXpert database.





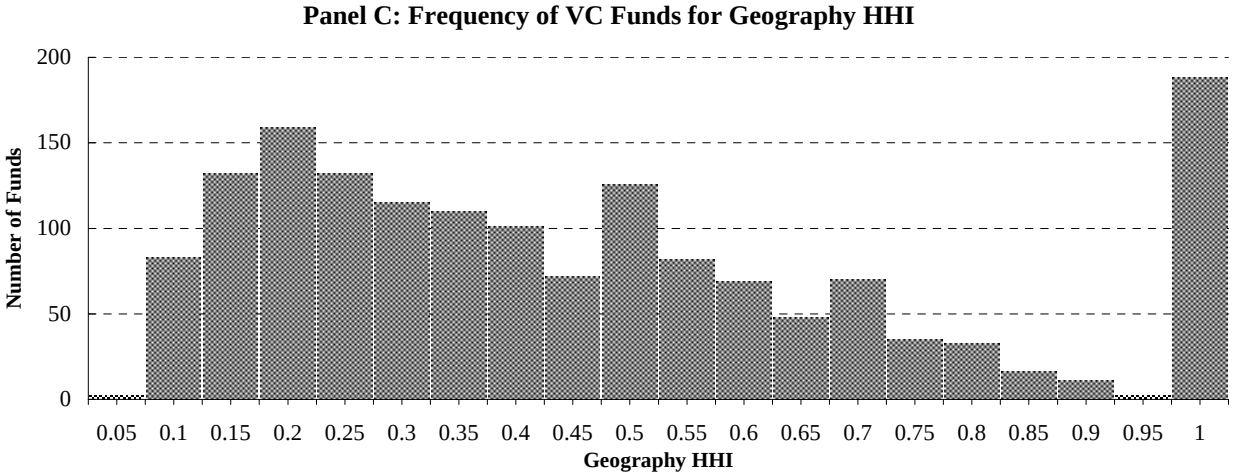
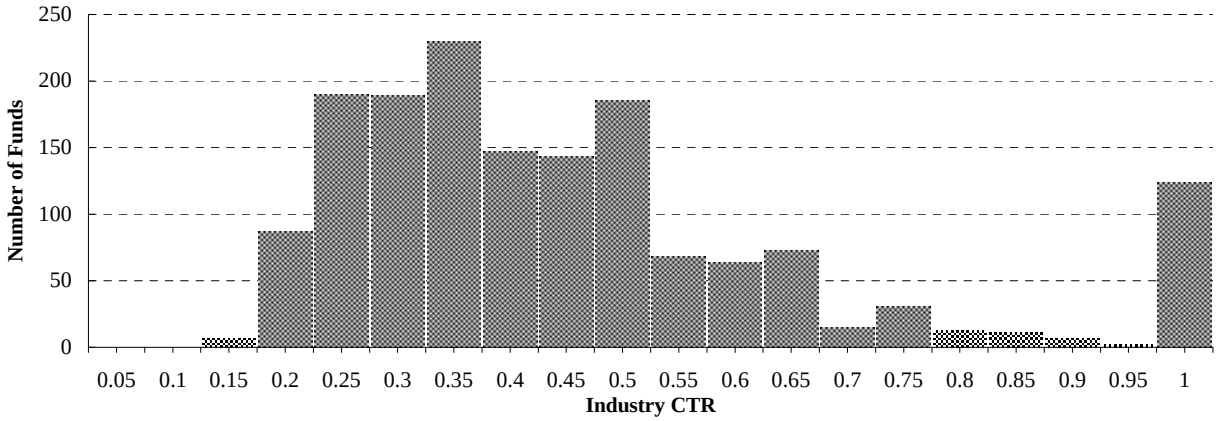


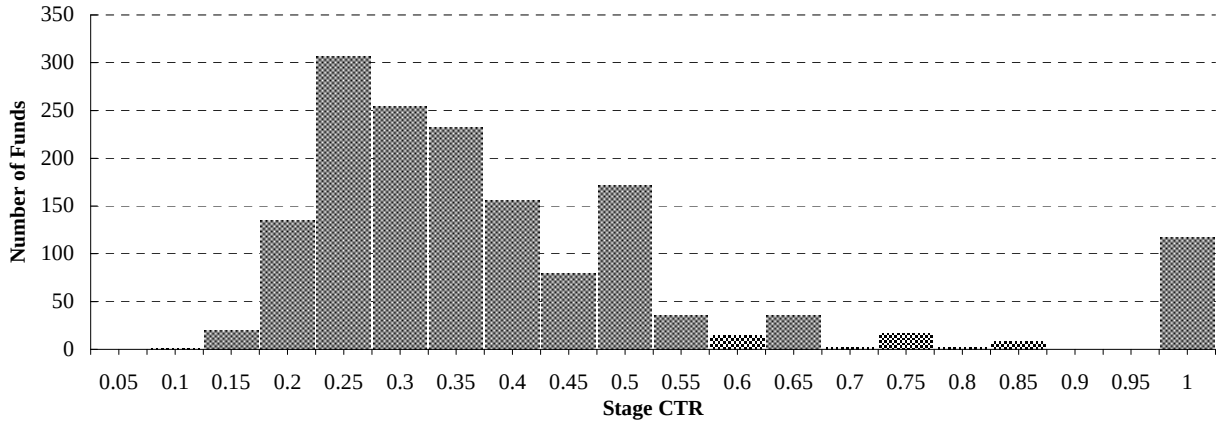
Figure 2: Frequency of VC Funds (Measuring Specialization by Focus Area Concentration Ratio)

The following figure plots the frequency of VC funds for different levels of specialization, measured as the fraction of portfolio compaines in the focus area, called Focus Area Concentration Ratio (CTR), for VentureXpert classifications of 9 industry minor groups (Panel A), Stage Level Three (Panel B), and 50 states (Panel C), respectively. The sample has 1586 VC funds from 1978 to 2000, collected from VentureXpert database.

Panel A: Frequency of VC Funds for Industry CTR



Panel B: Frequency of VC Funds for Stage CTR



Panel C: Frequency of VC Funds for Geography CTR