Estimating the Return to Organizational Form in the California Venture Capital Industry*

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Abstract

This paper studies the gains to productivity from joint work of individuals with different levels of human capital within a firm. The analysis is based on a unique panel data-set which documents partners, investments and investment outcomes of Venture Capital firms in California during 1979-2002. I find that more successful venture capitalists recruit more new partners and that this effect increases when there is growth in the aggregate number of Venture Capital investments. Based on these findings I develop and estimate a structural model which quantifies the increase in venture capitalists' productivity through skill leverage in the firm. I find that joint work increased productivity of experienced and inexperienced partners by 8%.

1 Introduction

The role of human capital in production grew significantly in the US economy in the last decades. However, there are few quantitative analyses of the process by which multiple workers jointly use this human capital to produce goods and services. This paper focuses on a specific aspect of joint production among multiple workers. It quantifies the gains from joint work within a firm of heterogenous workers: experienced individuals with high level of human capital and inexperienced workers with low level of human capital.[1]

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[1]In their handbook chapter Lazear and Oyer (2007) emphasize the role of firms in facilitating joint work of heterogenous workers: "Perhaps the greatest value of the firm is that it provides a mechanism for people to work together and take advantage of complementarities in their skills and interests."

My analysis focuses on the Venture Capital (VC) industry. This is an attractive environment to study the synergies within groups of heterogenous workers who jointly produce services because (1) production of VC services is based purely on human capital, (2) firms are small and VC partners specialize in different fields so we can infer who works with who, and (3) there are observed measures of each worker's human capital. I constructed a unique panel data-set which documents the VC partners, their investments in portfolio companies, and the outcomes of these investments for all Venture Capital firms in California during 1979-2002.

The empirical analysis has two elements. The first element involves inferring the heterogeneity across firms in the human capital of their experienced partners. The human capital of the experienced partners in each firm is derived using information about the successful investments that they made over their career. The second element involves examining the relationship between human capital of experienced partners in each firm and the number of new partners they recruit to work (jointly) with them. I begin by presenting descriptive statistics of these two elements. I then develop and estimate a structural model of joint production by experienced and inexperienced partners. It is important to emphasize that the structural model infers the joint production function parameters from the number of new partners each firm recruits without the need to observe firms' output.[2] Based on the production function estimates I perform a counterfactual of the productivity gains from human capital leverage in the firm.

Inference about partners' human capital is based on the fact that each partner is associated with specific investments by her firm. While major decisions in a VC firm are made collectively and partners share their knowledge and experience, each partner is individually responsible for certain investments made by the firm. The partner is central to attracting and evaluating these investments as well as assisting the companies in developing their businesses. I use the number of successful investments that a partner had in each period as a measure of her performance.

Partner performance patterns suggest that in the first 10 years of their career as VCs, human capital increases with years of experience. It also implies that there is persistence in partners' performance over time. I take these two findings into account when specifying the structural model used in

[2]This approach is similar to factor demand analysis which has been used for example by Christensen and Greene (1976).

the second part of the paper.

In studying the relationship between the human capital of experienced partners in a firm and the number of new partners they recruit, I find that the recruiting ratio of the number of new partners to the number of experienced partners is higher in firms in which the experienced partners are more skilled. This implies that experienced partners with more human capital benefit more from hiring new partners. I also find that the magnitude of this effect increases with the aggregate growth of VC investments.

In the second part I develop and estimate a model of "leveraged production" in which experienced partners can leverage their human capital by recruiting new partners to their firm. Joint production within the same firm has benefits and costs. Benefits include sharing of private information between workers, a commitment to institutional investors to mentor and monitor new partners in the firm who manage part of the capital and a richer set of sustainable dynamic contracts between the firm workers. Costs include bargaining costs, incentive problems, lobbying costs and coordination costs. In the model, firms recruit more new partners (increase the leverage ratio) as long as the new partners' productivity in the firm is larger than their outside option. The model infers the production function parameters from the observed recruiting decisions.[3]

Based on model estimates, I perform a counterfactual in which I compare production when new partners jointly work with experienced partners in the firm to production when experienced partners cannot leverage their human capital and recruit new partners. I find that joint work within the firm by experienced and inexperienced partners increased California venture capitalists' productivity during 1979-2002 by 8%.

Garicano and Hubbard (2006) were the first to quantify the returns to joint work of workers with different levels of human capital by studying hierarchies in law firms. I contribute to this emerging literature in several dimensions. First, I present a fully structural model which simultaneously estimates human capital and production function parameters. While Garicano and Hubbard (2006) infer workers productivity from equilibrium wages (of partners and associates), I take a different approach.

[3]I model benefits and costs from increasing the leverage ratio (between experienced and inexperienced partners). There are patterns in the data that I discuss in Appendix B which suggest that there are also costs to increasing the absolute size of a firm. Studying these costs is not in the scope of this paper.

I use panel-data to recover partners' human capital from observed measures of their career performance. This approach allows me to exploit the mobility of workers between firms. My model also captures unobserved heterogeneity in human capital across individuals which is crucial when studying the role of organizations in production. Then, I use two sources of variation in the net benefits from leverage across firms: the human capital of the senior partners and the growth rate of the field in which the partners specialize. By using this variation together with the optimality of the recruiting decisions I can estimate the joint production function parameters without observing firm output.

In addition to specifying a fully structural model of joint work within a firm, I focus on a different industry and propose a more general interpretation of the gains to leveraging experienced workers' human capital. Garicano and Hubbard (2006) emphasize problem solving hierarchies as an important benefit from joint work of experienced and inexperienced lawyers within a law firm. According to interviews I conducted with venture capitalists, another important role of firms in the VC industry is to allow senior partners to act as intermediaries between institutional investors, entrepreneurs, and new partners. Firms allow senior partners to credibly share private information about the value of investment opportunities with new partners. They also allow them to commit to institutional investors and to entrepreneurs that new partners who manage a portion of the raised capital and deals are trained and monitored by the experienced partners.

The paper also contributes to the "insider econometrics" literature, which uses internal company data to investigate the performance gains from teamwork, incentive pay and other human resource practices.[4] My analysis differs from these papers since I do not use output and instead infer productivity gains from recruiting decisions. However, the objective, studying the effect on productivity of different aspects of teamwork, is similar.

Finally, the paper extends the work which studies the VC industry. Academic research (Kortum and Lerner (2000)) and anecdotal evidence suggest that venture capital has an important role in spurring innovation and entrepreneurship.[5] Gompers et al (2006), Hochberg et al (2007), Kaplan and

[4]For example, Boning et al (2001) study team production in the steel industry and find that productivity is higher when compensation is based on groups' performance. Mas and Moretti (2006) show that productive supermarket clerks increase the productivity of other clerks working at the same time. For review of this literature see Ichniowski and Shaw (2007).

[5]Many successful high-tech and Internet firms such as Cisco, eBay, Genentech, Google, Intel, and Microsoft started as VC backed companies.

Schoar (2005) and Sorensen (2006) have studied how different measures of experience and human capital derived from firm level (previous) investments information determine the (current) performance of VC firms. I make additional contribution to this literature by examining performance in the individual partner level. Individual level analysis is especially important in this industry due to the fact that many of the new VC firms were started by partners who worked before in other firms.

The next section presents relevant information about the Venture Capital industry. Section 3 describes the data and provides descriptive statistics. The structural model is presented in section 4. Section 5 reports the results. Finally, section 6 concludes.

2 Industry Background

Venture capitalists are financial intermediaries who work in partnerships of typically 2 to 8 partners. They raise capital from institutional investors such as university endowments and pension funds, create a deal-flow of new investment opportunities, and evaluate these potential investments. After an investment has been made, they are closely involved in the management of the company (they monitor the company's executives and assist them in developing the company's business). Performing all these activities is based on different aspects of the VC partners' human capital: knowledge about the relevant market and technology, business experience, a network of contacts inside and outside the VC industry and a proven record of success as a venture capitalist. A basic scheme of the operation of a VC firm is presented in Figure 1.

2.1 Benefits from Joint Work of Experienced and Inexperienced Partners

While some of the skills VCs need can be acquired while working in other professions, industry specific experience is very valuable in performing the work of a VC effectively. Venture capitalists emphasized in interviews that there are some aspects of human capital which can only be acquired after working as a venture capitalist for a period of three to five years. These skills include the ability to evaluate and screen investment opportunities based on interviews with entrepreneurs and on using information

from a broad network of contacts with other venture capitalists.[6,7] Similarly, partners with a proven record of success can more easily raise capital from institutional investors. By working together with experienced partners new partners can benefit from the experience and the reputation of their senior peers and receive training that will allow them to work independently in the future.[8]

The gains from joint work of experienced and inexperienced partners are particularly important because of the industry's fast growth and the massive entry of new partners. During the period studied, 1979-2002, the total number of partners in the California VC industry increased from 117 to 613.[9] A related fact which is consistent with synergies from joint work is that many of the new VC firms which were formed during this period were started by partners who had worked before as VCs. Table 1 reports that the fraction of new VC firms which had at least one partner who had worked as a VC before varies between 0.33 to 0.78 during the sample periods.[10]

2.2 Joint Work and Industry Growth

The optimal "leverage ratio", the ratio between new partners and experienced partners who work together, reflects a tradeoff between the benefits and costs of joint work. Since industry specific human capital is important and cannot be acquired instantly, in periods of industry growth we expect the net benefits from leverage to increase. First, there are more investment opportunities which need to be evaluated. Therefore, experienced partners can leverage their skill in evaluating potential investments by referring investments they screen to new partners who work with them. Second, in such period many new partners enter the industry and thus the ability of experienced partners to train and monitor new partners becomes more valuable. In the empirical analysis that follows I examine how the pace in which the aggregate level of investments grows affects the "leverage ratio".

[6]Venture capitalists pointed that only after observing the life cycle of number of ventures from the capital raising stage to the successful or unsuccessful end one can develop the required skills for screening new ventures and entrepreneurs.

[7]The case study by Glynn and Burnham (2004) describes the recruiting process of a partner from the industry and demonstrates that there are "venture capitalist specific skills" that need to be acquired even when partners have successful record in operation positions.

[8]Another potential benefit from joint work is synergies between the senior partners. However, these gains are not studied in this paper and the focus is on the benefits from leveraging senior partners' skill by joint work with new partners.

[9]Based on information about firms which are included in the sample. The sample is described in detail in section 3.

[10]Sahlman (1990) points on a similar statistical fact. He reports that "... by 1988 roughly one third of all venture capital firms had at least one partner with more than 10 years of experience, and these firms managed almost 60% of total industry capital. ...".

I use the aggregate number of investments as a proxy for aggregate demand. Demand in this context is the number of business opportunities for which venture capitalists can create value as financial intermediaries. The term "deal-flow" is used in the VC industry to describe access to investment opportunities and is another way to describe demand.

2.3 Specialization into Fields and Fields' Growth

Venture capitalists can perform their tasks more effectively when they are more knowledgable about the technology and the market conditions of the companies in which they invest. Hence, there are returns to specialization in a certain field. Based on board composition information partners can be classified into two fields of specialization: Information Technology (IT) and Life Science (LS). As demonstrated in Table 2 which describes the distribution of partners' board positions in IT and LS companies partners typically specialize in one of the two fields.

This specialization is incorporated into the empirical analysis in two ways. First, it allows me to have more refined information about who works with who. Each firm in the sample includes either one or two groups of partners.[11] Second, distinguishing between IT and LS partners allows me to exploit variation in demand over time in the field level. As demonstrated in Figure 3, each one of the fields has different trends in aggregate deal-flow. Also, according to investments' summary statistics, reported in Table 3, these variables standard deviations are large relatively to their mean. I use this variation when I examine the relationship between deal-flow growth rate and the leverage ratio in each group of partners.

3 Data and Descriptive Statistics

This section describes the dataset used in my analysis and provides descriptive statistics about partner performance and firm recruiting decisions. The dataset combines two sources. *VentureXpert* is the main source of investment information for venture capital firms, their portfolio companies and the board positions of venture capital partners in these companies. It was matched with information

[11] Firms may specialize in both fields in order to diversify risk or to exploit scale economies when accessing capital markets (raising capital or liquidating investments). Analyzing these synergies (between senior partners) is not in the scope of this paper.

about the partners in each VC firm in each period from the directory *Pratt's Guide to Venture Capital Sources*. Further details regarding data-set construction are reported in Appendix A.

The panel data includes six 4 year periods where the first period is 1979-1982 and the last period is 1999-2002. 182 Venture Capital firms in California are included in my sample. 1088 Venture Capital partners worked in these firms during the sample period and there are 1986 partner-period observations. I excluded from the sample firms which invested in less than 20 companies during the sample period as well as bank subsidiaries, corporation VC funds and firms whose main office was not in California.

3.1 Inferring Human Capital from Performance

Abundant anecdotal evidence suggests there is heterogeneity in venture capitalists' human capital. The industry is divided into tiers and partners in top tier firms consistently perform better than partners in low tier firms. Furthermore, as in sporting leagues, partners are known by their "track record": the successful investments that they have made during their career as venture capitalists and some partners persistently maintain exceptional track records.[12] In this subsection I examine how performance varies across partners and over partners' career. I show that part of the variation in performance is explained by the partners' years of experience in the VC industry. In addition, I find that there is persistence in partners' performance over time after controlling for years of experience. This is consistent with unobserved heterogeneity in partners' skill.

Due to the teamwork nature of production in Venture Capital firms, we cannot observe performance variables which can be attributed to a single partner. However, there are imperfect measures of individual human capital; each partner in a VC firm is responsible for some of the firm's portfolio companies and represents the VC firm on the companies' board of directors. The partner is usually more dominant than her peers in attracting and evaluating these investments as well as in monitoring and assisting the company. The success of these portfolio companies can be used as a proxy for the partner's human capital (in the period in which the investment was made) for two reasons. First, partners with better reputation and skill have access to and can pick better investments. Often,

[12]Typically, the web-site of each VC firm has the partners' biographies including board positions in companies which turned out to be successful investments (the partner's track record).

entrepreneurs approach a specific partner in the VC firm and better entrepreneurs approach better partners. Also, more experienced partners can evaluate and screen investment opportunities more effectively. Second, once an investment has been made, skilled partners are more able to assist the company in developing its business by using their experience and contacts inside and outside the VC industry. The partners are typically involved in finding clients for the company's products, recruiting employees for key positions in the company, raising more capital, and selling the company to the public (through an IPO) or to a different company (through M&A).

As a measure of the performance of partner i in period t, I construct the variable $Exits_{it}$ which is the number of portfolio companies in which partner i was the leading investor in period t and the company was either acquired or had a public offering.[13] The leading investor in each company is the partner that represents the VC firm which led the company's first round of investment.[14] Table 4 reports summary statistics of partners' exit events. The number of successful exits is a reasonable proxy for the returns generated by the investments made by each partner since the returns on the successful projects are typically big relative to the funds sunk in unsuccessful projects.

In the regressions that I describe below I assume that $Exits_{it} \sim Poisson(Z_{it})$ where Z_{it} is partner's i human capital at period t. I estimate different specifications, reported in Table 5, based on the equation:

$$ln(Z_{it}) = \alpha_0 + \alpha_1 Exp_{it} + \alpha_2 Exp_{it}^2 \tag{1}$$

According to the baseline specification, reported in the first column, years of experience as a venture capitalist is positively correlated, during the first 10 years of the partner's career, with her performance (based on the estimated coefficients of years of experience and years of experience squared). This is consistent with a selection process in which partners with better innate ability survive longer in the industry and with accumulation of industry specific human capital. Partners' knowledge is accumulated through different activities such as participating in board meetings and working with portfolio companies, lawyers and investment bankers. Partners who executed more deals in the past

[13] I observe exit events which occurred before the mid of 2007. The last period in human capital equation estimation ends in 2002, which implies that I make the assumption that VC investments mature (fail or succeed) in less than 5 years. This assumption is consistent with the analysis of historical investments especially considering the burst of the Internet bubble in 2000.

[14] If there is more than one partner who joined the board in the first round, I pick the partner from the firm which invested the highest amount of capital in the firm.

are more likely to have greater access to individuals and firms with whom venture capitalists do business.[15] After 10 years of experience the effect becomes negative. This may be a result of decrease in productivity or due to the fact that senior partners might become less active in investments and instead invest their time in raising capital from institutional investors. I intend to investigate this issue in future research.

The second and third columns of Table 5 report the results of estimating equation 1 with lagged performance as additional independent variables. The equation was estimated for a sub-samples which includes all the period-partner observations for partners who are observed for at least two (column 2) and three (column 3) periods in the data. I find that past performance has a positive and significant effect on the amount of the partner's successful investments.[16] I interpret the persistence in performance as evidence of unobserved heterogeneity in partners' skill. When specifying the structural model in section 4 I take into account the two findings: I use years of experience as an observed measure of performance and I allow for unobserved heterogeneity in partners' skill.

3.2 Recruiting Decisions

In this subsection, I study the recruiting patterns of new partners by experienced partners. I find that the net benefit from increasing the leverage ratio (of new to experienced partners) increases with the human capital of the experienced partners. Moreover, the magnitude of this effect is proportional to the aggregate growth in the number of investments in the field. Subsection 3.3 discusses theories about the role of firms in joint production that are consistent with these findings.

Venture capital firms regularly recruit new partners. Typically new partners are either associates who have worked in the firm (or in a different VC firm) and have been promoted to a partner status, or entrepreneurs and managers who become VC partners after retiring from a successful career in industry. Table 7 reports statistics about firm size and partner turnover for a sub sample of 278 firm-period observations for which we observe at least one additional period in the data. In each period

[15]Other scholars have found positive relationship between experience in the firm level and performance. Gompers et al (2006) find that funding by an experienced VC firm increases the probability of success, but only for entrepreneurs without a successful track record. Sorensen (2006) shows that the number of previous deals of a venture capital firm has a significant effect on the likelihood of deal success.

[16]This result is consistent with the findings in Kaplan and Schoar (2005) who study venture capitalists performance in the firm level. They find that there is persistence in returns across the sequence of funds of the same firm which is not explained by firms' observed characteristics.

there are on average 4.11 partners. About 3 of these partners are still in the firm in the next period, while on average 1.15 leave the firm. The average portion of the partners who stay in the firm in the next period is 0.75. Conditional on survival, firm size increases by 0.82 partners. To compensate for the partners who leave on average 1.97 new partners join a firm each period.

I use the following notation to describe the composition of group g (IT or LS) at period t. The variable n_{gt} is the number of new partners. The set T_{gt} and its size $|T_{gt}|$ represent the set and the number of experienced partners. Finally, $L_{gt} = \frac{n_{gt}}{|T_{gt}|}$ is the ratio between new partners and experienced partners in the group. I investigate the relationship between human capital and recruitment decision by estimating the equation:

$$L_{gt} = \beta_0 + \beta_1 \overline{\hat{Z}}_{gt} + \beta_2 D_{ft} + \beta_3 \overline{\hat{Z}}_{gt} * D_{ft} + \epsilon_{ft} \tag{2}$$

where $\overline{\hat{Z}_{gt}}$ is the average human capital of the experienced partners as predicted by the performance regression (the mean of the fitted values of the group's partners as predicted by equation 1). D_{ft} is the difference between the total number of companies which raised their first round of investment from California VCs in field f in periods t and $t-1$. $\overline{\hat{Z}_{gt}} * D_{ft}$ is the interaction between the two variables. D_{ft} and its interaction with human capital are used as regressors. As was discussed in subsection 2.2, in periods of fast growth we expect the net benefits from joint work to increase and consequently a higher "leverage ratio". Equation 2 is estimated only with group-period observations for which there is a non-negative growth rate, D_{ft}.

Table 6 reports the estimates of equation 2. We find that the interaction of the experienced partners human capital with the growth rate of the field has a positive and significant effect on the recruiting ratio and that the effect's magnitude is substantial. The sample mean of the ratio, L_{gt}, is 0.77. A one standard deviation increase in human capital, $\overline{\hat{Z}_{gt}}$, increases the ratio by 0.17 (when growth is in its mean value). A one standard deviation increase in growth rate increases the ratio by 0.24 (when skill is in its mean value).

I interpret this finding in the following way. There are benefits (for example private information sharing) and costs (for example agency costs) to joint work within the same firm, which I discuss in detail in the next subsection. The net benefits from additional new partner increase with the human capital of the experienced partners. Moreover, this effect is proportional to the aggregate growth

rate of the field. In the structural model I allow for complementarities in the "leveraged production" function between human capital (interacted with growth) and the number of new partners in the firm.

3.3 Interpretation of Empirical Findings

The complementarity between the human capital of experienced partners and the number of inexperienced partners who work with them is consistent with models of "span of control" such as Lucas (1978) and Rosen (1982). One source of complementarities in joint work within a firm is incentive problems which exist when workers who are not in the same firm collaborate (incentive problems in the spot market). A firm can alleviate these incentive problems through explicit contracts, such as the ex-ante revenue sharing contract in VC firms, or by supporting a larger set of sustainable dynamic (relational) contracts between partners (Levin 2003).

Public information about who are the senior and new partners in each firm is a commitment device. Ex-ante revenue sharing contracts which allocate to senior partners a significant portion of the profits generated by the new partners is another commitment device. These commitment devices enable senior partners to operate as intermediaries between entrepreneurs, institutional investors and new partners.

One important implication of this commitment is that senior partners can credibly share their private information with new partners. Due to their experience and reputation, senior partners have superior information about the quality of investments. They also have superior information about the quality of individuals and firms outside the venture capital industry who do business with venture capitalists or with portfolio companies. These individuals and firms include lawyers, potential customers, potential employees to key positions, firms that acquire start-ups, investment banks, etc. As I demonstrate in Appendix C the spot market cannot support efficient trade in private information due to adverse selection. This argument is explored in Garicano and Santos (2004) who show that partnerships better support private information sharing when there is tension between adverse selection on behalf of the individual who refers the task and moral hazard on behalf of the worker who executes the task.

Another aspect of intermediation is a commitment by the senior partners to institutional investors

and entrepreneurs that capital and deals are referred (when senior partners' time constraint binds) to new partners who are trained and monitored by the senior partners. Investors with capital as well as entrepreneurs prefer to work with partners with proven success as opposed to with partners without a track record. In periods of growth individuals with good track record are likely to become time constrained. The firm enables them to leverage their success by raising more capital (compared to a case when they work alone) and by hiring junior partners to whom they can refer deals. The public relationship and the ex-ante revenue sharing arrangement are a commitment of the senior partners that they will mentor and supervise the new partners who manage the deals.[17]

Consistent with the observed recruiting pattern, we expect the benefits from intermediation to increase when aggregate demand for VC services increases. First, in such periods, the senior partners expect an increase in the arrival rate of deals. Consequently, information sharing becomes more valuable as there are more tasks which require knowledge in the relevant field. Second, in such periods there is inflow of more capital into the VC industry and the institutional investors need someone who can screen and select new partners.

A different source for complementarities between experienced and new partners is "vertical specialization" within the firm. Garicano (2000) shows that hierarchies allow firms to exploit the benefits of specialization; when there is inflow of tasks with different levels of difficulty to the firm, a hierarchical structure allows less knowledgeable workers to pass the hard problems to knowledgeable workers in higher levels of the hierarchy. This improves the productivity of the workers compared to a world in which workers must reject tasks that they do not have the knowledge to execute.

While there is a rich set of theories of benefits from joint work that are consistent with the recruiting pattern, what we observe cannot be explained by risk diversification. If risk sharing across partners was the only benefit from joint work then in periods when deal flow rate grows, we do not expect the leverage ratio to increase since in such periods the average number of deals per partner increases and the risk a single partner faces decreases.[18] This result is consistent with the work of Garicano and Hubbard (2005) who find that the field composition of law firms cannot be explained

[17]Levin and Tadelis (2005) show that when clients have disadvantage in assessing the quality of employees, redistribution of profits allows firms to commit about the quality of the workers.

[18]Abramitzky (2005), Gaynor and Gertler (1995), and Lang and Gordon (1995) provide evidence for risk sharing as a benefit from forming partnerships.

only by benefits from risk sharing.

There are different costs to increasing the "leverage ratio." Recruiting of new partners requires both parties, the recruiting and the recruited, to spend efforts on gathering information about each other. In addition, there are bargaining costs for signing the firm contract. Once a new partner joins the firm there are free rider problems, lobbying costs, coordination costs and communication costs. Based on interviews with venture capitalists, incentive problems in the firm are not substantial since partners want to build good reputations. What they argue might be costly is the diversity of opinions in the firm.

4 Model

The purpose of the model is to quantify the gains to productivity from joint work of experienced and inexperienced partners within a firm. Let I_t be the set of partners in the industry in period t ($t \in \{1, .., T\}$). Each partner $i \in I_t$ is characterized by 2 dimensions. The first dimension is a field of expertise f: Information Technology (IT) or Life Science (LS). I assume that partners specialize in the same field during their career. The second dimension is human capital, Z_{it}. The aspects of human capital which are important in this industry include skill, reputation, network of contacts and knowledge about the market and the technology.

A group g_t is a subset $g_t \subseteq I_t$ of partners in the industry who work in the same firm at period t and who specialize in the same field. Let T_{gt} be the set of experienced partners in group g at period t and let $\{Z_{it}\}_{i \in T_{gt}}$ be their human capital at period t. At the beginning of each period t the experienced partners, T_{gt}, choose how many new partners to recruit.

First, the experienced partners form expectations D_{gt} about the expected level of deal-flow to the group in period t. Then, conditional on D_{gt} and $\{Z_{it}\}_{i \in T_{gt}}$, they decide how many new partners, n_{gt}, to recruit in period t. I define $V(D_{gt}, \{Z_{it}\}_{i \in T_{gt}}, n_{gt})$ to be (the portion of) the expected group output which depends on the joint work of experienced and new partners.

The analysis of the recruiting decisions in subsection 3.2 demonstrates that the marginal productivity of new partners in a group increases with the interaction of human capital and the relevant field's growth. Hence I specify a production function with complementarities between the senior part-

ners' human capital and the number of new partners who jointly work with them. In addition, I assume that the expected output can be written as a function of the average human capital of the experienced partners, $\overline{Z_{gt}}$, the number of experienced partners, $|T_{gt}|$, the number of new partners, n_{gt}, and the expected deal-flow, D_{gt}, in the following way:

$$V(D_{gt}, \{Z_{it}\}_{i \in T_{gt}}, n_{gt}) = |T_{gt}| * D_{gt} * \overline{Z_{gt}} * V(\frac{n_{gt}}{|T_{gt}|}) \tag{3}$$

Only the number of inexperienced partners in the group (and not their human capital) affects the expected group's output according to this specification. The limitations of this specifications are discussed below in subsection 4.2.

I assume there is an infinite supply of new partners and their outside "production opportunity" (when not jointly working with experienced partners) is δ. In addition, I assume that if there are gains from the match between the group and the new partner, then the two parties are able to negotiate an employment contract which splits the generated surplus between them. Experienced partners recruit new partners as long as there are productivity gains from the match:

$$V(D_{gt}, \{Z_{it}\}_{i \in T_{gt}}, n_{gt} + 1) \geq V(D_{gt}, \{Z_{it}\}_{i \in T_{gt}}, n_{gt}) + \delta$$

The recruiting decisions are "efficient" in the sense that whenever there is surplus created from joint work a group hires an additional partner. Therefore, the number of new partners that the group recruits, n^*_{gt}, maximizes the "joint surplus":

$$n^*_{gt} = argmax_{\ n} \ \{|T_{gt}| * D_{gt} * \overline{Z_{gt}} * V(\frac{n}{|T_{gt}|}) - n * \delta\}$$

In addition, I allow for the marginal productivity from new partners to be decreasing. The parameter θ $(0 < \theta < 1)$ reflects the degree to which the experienced partners can effectively leverage their human capital when the number of new partners increases. The difference between the increase in productivity when recruiting an additional partner and the outside option, δ, is monotonically decreasing. Therefore, above a certain number of new partners the difference becomes smaller than δ. The recruiting problem can be rewritten as:

$$n^*_{gt} = argmax_{\ n} \ \{|T_{gt}| * D_{gt} * \overline{Z_{gt}} * (1 + \frac{n}{|T_{gt}|})^{\theta} - n * \delta\}.$$

The intuition is illustrated in Figure 4. The optimal number of new partners, n^*_{gt}, is the largest n for which the marginal productivity of the n_{th} new partner is higher than δ (if for $n = 1$ the marginal productivity is below δ then the optimal n is $n = 0$)

$$n^*_{gt} = Max\{n \in N^+ \mid |T_{gt}| * D_{gt} * \overline{Z_{gt}} * [(1 + \frac{n}{|T_{gt}|})^\theta - (1 + \frac{n-1}{|T_{gt}|})^\theta] \geq \delta\} \tag{4}$$

where N^+ is the set of nonnegative integers.

4.1 Econometric Model

The econometric model combines the two elements described in Section 3, partners' performance and the recruiting decisions, in order to estimate the "leveraged production" function. It includes two equations: a performance equation and an optimal recruiting equation which are estimated simultaneously.

4.1.1 Performance Equation

Building on the findings in subsection 3.1, I specify a performance equation which uses years of experience as a venture capitalist, Exp_{it}, as an observed measure of human capital and allows for unobserved heterogeneity in ability across partners. For each partner there is a component of her human capital, ν_i, which is not observed by the econometrician where $\nu_i \sim N(0, \sigma_\nu)$. I assume that the number of successful investments that partner i made in period t, $Exits_{it} \sim Poisson(Z_{it})$:

$$P(Exits_{it} = k | Exp_{it}, \nu_i) = \frac{e^{-Z_{it}} * (Z_{it})^k}{k!}$$

where the mean of the Poisson distribution, Z_{it}, is defined by

$$ln(Z_{it}) = \alpha_0 + \alpha_1 Exp_{it} + \alpha_2 Exp^2_{it} + \nu_i \tag{5}$$

I also assume that the random effect ν_i is independent of the Poisson error.

4.1.2 Optimal Recruiting Equation

I assume that senior partners in group g at period t form expectations about the group's deal-flow, D_{gt}. I also assume that the mean of D_{gt} across all the groups which specialize in the same field (IT or LS) in period t is proportional to the actual increase in aggregate deal flow in the field, D_{ft}, (which

I observe). This allows me to specify D_{gt} as the sum of D_{ft} and a group-period shock to demand, ψ_{gt}, where $\psi_{gt} \sim N(0, \sigma_\psi)$. This shock represents group-period expectations which are unobserved to the econometrician (for example the experienced partners over estimate the expected growth in their field)

$$D_{gt} = D_{ft} + \psi_{gt} \tag{6}$$

After substituting D_{gt} into equation 4 we get that under optimal recruiting

$$|T_{gt}| * (D_{ft} + \psi_{gt}) * \overline{Z_{gt}} * [(1 + \frac{n_{gt}}{|T_{gt}|})^\theta - (1 + \frac{n_{gt} - 1}{|T_{gt}|})^\theta] \geq \delta$$

$$|T_{gt}| * (D_{ft} + \psi_{gt}) * \overline{Z_{gt}} * [(1 + \frac{n_{gt} + 1}{|T_{gt}|})^\theta - (1 + \frac{n_{gt}}{|T_{gt}|})^\theta] < \delta$$

if $n_{gt} > 0$ and

$$|T_{gt}| * (D_{ft} + \psi_{gt}) * \overline{Z_{gt}} * [(1 + \frac{1}{|T_{gt}|})^\theta - 1] < \delta$$

if $n_{gt} = 0$. Using these conditions the production function parameters are inferred without the need to observe output.

The likelihood function is the joint probability of observing exit events, $\{Exits_{it}\}$, and recruiting decisions, $\{n_{gt}\}$, conditional on experienced partners grouping at the beginning of each period, $\{T_{gt}\}$, their observed years of experience, $\{Exp_{it}\}$, aggregate changes in deal-flow, $\{D_{ft}\}$, and model parameters.

4.2 Model Assumptions

In the model only the number of inexperienced partners in the group and not their level of human capital affects the expected group's output (as stated in equation 3). One assumption consistent with only the number of new partners entering the production function is that all the new partners have the same level of human capital. As was discussed in subsection 2.1 venture capitalists described in interviews that many of the abilities required in their profession are unique and that it may take three to five years to acquire these skills.[19] Therefore, in their first period in the sample (which

[19]The analysis in Oyer (2007) also suggests that in human capital intensive industries on the job training has substantial effect on productivity. He finds that starting a career in Wall Street as an investment banker makes individuals more likely to work in Wall street later in their career (when controlling for skill).

lasts maximum 4 years) there may be relatively small variation in their VC related skills. Another sufficient assumption would be if the senior partners could not assess the skills of new partners. Since the venture capitalists' job requires unique skills, previous track record in other professions may not be informative about the future success as a venture capitalist. Many times individuals with exceptional success in other industries turn out to not perform well as venture capitalists.

Even without these assumptions (when there is observed heterogeneity in new partners' skill) there are certain assignment patterns which are consistent with the specification in equation 3. Obviously, a richer specification with more parameters (and more data) can fully capture the heterogeneity across new partners, and can provide us with more refined measurement. However, the homothetic function allows me to capture the synergy between experienced and inexperienced partners with a parsimonious and estimable model and to make a first step in quantifying the gains from these synergies. If in fact there is significant variation in new partners' skill and there are significant complementarities between the skill of new partners and experienced partners then this would increase the returns from joint production. In this case my estimation of the gains from joint work would be a lower bound on the return from joint work in the VC industry.

Unobserved heterogeneity is modeled by the unobserved component of human capital, ν_i, which appears in both the partner's performance equation and the optimal recruiting equation. It represents information about partners' human capital other than years of experience. The model infers the unobserved component of human capital of each partner using her successful exit events and the extent to which the partner is "leveraged". Thus, ν_i may represent a component of human capital which is observed by other partners but not by the econometrician. For example, partner's positions before becoming a venture capitalists.

As described in subsection 2.1, many of the new firms in the VC industry were started by partners who worked before in other firms. Another feature of the model is that it uses information about performance at the individual level as opposed to performance at the firm (or group) level. This allows me to exploit information about partners' performance using their entire career investment outcomes (and leverage ratio).

4.3 Identification

To my best knowledge, this is the second paper quantifying the benefits from joint work in human capital intensive industries. Garicano and Hubbard (2006) were the first to address this question. They identify the production function using wage data as a measure of productivity. Wages may not be equal to workers' marginal productivity when part of workers' remuneration is investment in their human capital. Therefore, I propose a different approach and identify the production function parameters from the optimality of the recruiting decisions without the need to observe firm output. I use observed measures of partners' performance over their career together with aggregate shifts in demand for venture capital services as sources of variation in the net benefits from human capital leverage within the firm.

The human capital parameters α and σ_ν are identified by the extent to which observed heterogeneity in years of experience explains the variation in partners' performance (measured by number of successful investments in each period) and the leverage of the groups to which they belong over their career.

The parameters which describe the "joint production technology" are θ and δ. The parameter θ represents the extent to which the returns to leveraging senior partners' human capital are diminishing with the ratio between the number of new partners and senior partners in the group. The parameter δ reflects the productivity of new partners when they do not work jointly with senior venture capitalists. The identification of δ seems counterintuitive, how can the model infer the output of new partners when they work independently if they are not part of the sample?

The identification of the outside option, δ, is based on the assumption about diminishing returns in the productivity of the new partners. Since there are diminishing returns in the productivity of new partners we can use the productivity of the last new partner in a group as an upper bound on the outside option, δ. In addition, the diminishing returns parameter, θ, allows us to calculate the productivity of an additional (hypothetical) new partner. This productivity puts a lower bound on the outside option, δ.

The parameters θ and δ are jointly identified since we have variation across groups of senior partners in the extent to which they can make the new partners more productive. The basic concept

behind the "joint production technology" is that by leveraging their human capital senior partners make inexperienced partners more productive. The model assumes that the magnitude of these productivity gains varies across groups of senior partners. For example, everything else equal, the marginal increase in group's productivity from recruiting the first new partner are higher in a group in which the experienced partners have more human capital (higher $\overline{Z_{gt}}$). Similarly, in a group which expects more deal-flow per partner (higher D_{ft}) the expected productivity of the first new partner is higher. The different patterns in the trend of the aggregate deal-flow, D_{ft}, of each one of the two fields (IT and LS) create variation which is independent of the variation in the human capital of the experienced partners, $\overline{Z_{gt}}$.

By using the relationship between this variation and the optimal number of new partners recruited to each group, we can identify both, θ and δ. Figure 5 provides a technical explanation for the joint identification of θ and δ. There might be multiple combinations of θ and δ which predict the same number of new partners, n, for given human capital and field-growth, $D * \overline{Z}$. However, due to the variation in both $\overline{Z}$ and D we can find the θ and δ which best explain the observed triples $D, \overline{Z}$ and n.

5 Results

5.1 Estimation

The likelihood function of my model depends on the distribution of the unobserved components of human capital, σ_ν. Calculating this likelihood requires to integrate over all possible combinations of ν_i for each partner. However, the joint decisions of the senior partners about the number of new partners they recruit to their group creates numerical difficulties in estimation. If the recruiting decisions were not made jointly then the likelihood to observe recruiting decisions and exit events which are related to each partner would be independent of the likelihood to observe the dependent variables which are related to her peer partners. In this case the integration in the likelihood function over the unobserved components of human capital, ν_i, could be factored into a product of low dimensions integrals. Due to the joint decision made by experienced partners the integral does not factor out. As a result of the mobility of partners and their diffusion in the industry the dependency is not only between partners who work together but also between partners and the partners who work with their peers in other

periods. Consequently, evaluation of the likelihood function requires integrating over hundreds of dimensions. This makes maximum likelihood estimation computationally intractable.

Bayesian estimation is an attractive method to deal with these difficulties. Bayesian methods use an iterative process that integrates over draws of the latent state variables from the correct posterior distribution. By treating the random effects, ν_i, as latent state variables the process spends more time on the ν_i which are more likely conditional on observed outcomes.

The challenge with the Bayseian procedure is to generate draws which converge to the posterior distribution of the model parameters. Gibbs sampling is a specific method for generating a Monte Carlo Markov Chain (MCMC) which converges to the posterior distribution. It exploits the fact that while it is computationally hard to draw from the joint posterior of ν_i, it is very easy to draw a single ν_i conditional on all $\nu_{j\neq i}$. The process converges to draws from the joint density of the posterior. I use the mean of the posterior distribution of each ν_i when performing the counterfactual simulation.

I estimate the model by setting a flat prior for the parameters. The model parameters are drawn from their conditional distribution using the Metropolis Hastings algorithm. The structural model estimates are reported in Table 8.

5.2 Counterfactual Simulation

The parameter δ represents the outside option of the new partners. It should be interpreted as the output generated by a potential new partner when not working together with experienced partners in the same venture capital firm. It can reflect the productivity when working as a venture capitalist independently (without experienced partners) or the productivity in a different industry (for example as an investment banker). Groups in the model recruit an additional new partner if the joint expected output generated by the extended group is larger than the sum of the group's output without the new partner and the new partner's outside option, δ. Therefore, the productivity gains calculated below reflect the value which is created by joint work within the firm.

While in the model the groups' recruiting decisions are for a single period, the results can be interpreted in a broader dynamic context. For each party, the group and the new partner, there are values associated with the match and with the outside option. These values equal to the discounted

value of future payoffs conditional on each option. For example, part of the future returns a new partner gets from working together with senior partners are due to accumulation of human capital through the apprenticeship.[20] Similarly, as described in O'Flaherty and Siow (1992), a group may recruit a new partner in order the learn about her ability and promote the partner in the future if she turns out to be skilled enough. In this case the group's gains from the match are realized in a future period.

To sum up, there are operational gains as well as long term gains from joint work within a firm of experienced and inexperienced partners. The first include for example private information sharing in the firm between senior and new partners and the firm's support in a larger set of sustainable dynamic contracts between workers. Long term gains include human capital accumulation by the new partners and revelation of information about new partners' skill.

Using the model estimates I calculate the output of joint work of inexperienced and experienced partners. Since the recruiting decisions are based on expectations, groups may recruit a number of new partners which is suboptimal ex-post. For each group-period observation I find the optimal number of new partners, n^*_{gt}, given the realized change in aggregate deal-flow in each field, D_{ft}. Then, I sum up the output for all group-period observations when new partners work jointly with senior partners

$$Y_{joint} = \sum_{g_t} \{|T_{gt}| * D_{ft} * \overline{Z_{gt}} * (1 + \frac{n^*_{gt}}{|T_{gt}|})^{\theta}\}$$

I compare it to the output when new partners cannot join experienced partners and instead produce their outside option δ

$$Y_{separated} = \sum_{g_t} \{|T_{gt}| * D_{ft} * \overline{Z_{gt}} + n^*_{gt} * \delta\}$$

Figure 6 illustrates how the gains are calculated using the model estimates. The shaded area which reflects the gains equals to the area between the new-partners marginal productivity curve and their outside option. I find that joint work increases productivity by 8%. I use a simulation process in order to calculate the standard deviation of the gains. I calculate $Y_{joint}/Y_{separated}$ using 1000 draws

[20] In addition to learning from the senior partners about the process in which investments are selected and executed, by being introduced to the network of contacts of the senior partners the new partner creates new contacts inside and outside the VC industry. Based on interviews with venture capitalists such contacts are critical for the work of venture capitalists.

from the posterior distribution of the model parameters. I find that the standard deviation is 0.2%.

6 Conclusions

This paper studies the gains from joint work within a firm of workers with different levels of human capital. The analysis is based on a unique data-set that combines information on the composition of venture capital firms over two decades together with venture capitalists' investments and the associated outcomes. I develop and estimate a structural model which estimates the returns from leveraging senior partners' human capital through joint work with inexperienced partners. I find that the gains to productivity due to joint work of California venture capitalists during the sample period are 8%. Based on interviews with venture capitalists I conclude that a major source of these gains is the role of firms as a commitment device which enables senior partners to leverage different dimensions of their human capital: their access to high quality investment opportunities, their ability to raise capital from institutional investors based on previous track record and their ability to train and monitor new partners.

The paper makes several important contributions to the work of Garicano and Hubbard (2006) which quantifies the returns to joint work of workers with different levels of human capital in law firms. It measures these gains in the venture capital industry for which institutional details suggest that an important role of joint work within a firm is to alleviate incentive problems: sharing of private information between workers and providing private information to individuals outside the venture capital industry. It also provides a more general interpretation for the measured productivity gains. Another contribution is specifying a fully structural model which infers production function parameters from the optimality of the recruiting decisions without the need to observe firm output. The model exploits different sources of variation (observed measures of partners' performance over their career as well as aggregate shifts in demand) to estimate the returns to human capital leverage.

The comprehensive panel data collected for this paper is informative about the growth of firms as well as the separation between partners (many venture capital firms were founded by partners who split apart from other partners). By modeling the equilibrium in the entire labor market for venture capitalists we can shed light on two theoretical issues. One involves the limitations on the

size of a firm or on the type of workers who can benefit from working together. This can explain the separation between partners. Another issue is the dynamic considerations involved in the planning of an individual's career path which are affected by investment in human capital accumulation through joint work. I hope to investigate these questions in future work.

7 References

Abramitzky Ran (2005) "The Limits of Equality: Insights From the Israeli Kibbutz" Manuscript, Stanford University

Boning Brent, Casey Ichniowski, and Kathryn Shaw (2007) "Opportunity Counts: Teams and the Effectiveness of Production Incentives," Journal of Labor Economics, forthcoming.

Chen Joseph, Harrison Hong, Ming Huang and Jeffrey D. Kubik (2004) "Does Fund Size Erode Mutual Fund Performance? The Role of Liquidity and Organization" The American Economic Review, Vol. 94, No. 5. , pp. 1276-1302.

Christensen R. Laurits and William H. Greene (1976) "Economies of Scale in U.S. Electric Power Generation," The Journal of Political Economy, Vol. 84, No. 4, Part 1. , pp. 655-676.

Farrell Joseph and Scotchmer Suzanne (1988) "Partnerships" The Quarterly Journal of Economics, Vol. 103, No. 2. pp. 279-297.

Franco April Mitchell and Filson Darren (2005) "Spin-outs: Knowledge Diffusion through Employee Mobility", Rand Journal of Economics, forthcoming

Garicano Luis (2000) "Hierarchies and the Organization of Knowledge in Production" Journal of Political Economy, volume 108, pages 874-904

Garicano Luis and Santos Tano (2004) "Referrals" *American Economic Review,* June 2004, v. 94, iss. 3, pp. 499-525

Garicano Luis and Hubbard Thomas (2005) "Specialization, Firms, and Markets: The Division of Labor Within and Between Law Firms" Northwestern University Working paper

Garicano Luis and Hubbard Thomas (2006) "The Return to Knowledge Hierarchies" Northwestern University Working paper

Gaynor Martin and Gertler Paul (1995) "Moral Hazard and Risk Spreading in Partnerships" The RAND Journal of Economics, Vol. 26, No. 4, pp. 591-613.

Glynn John and Mary Moon Burnham (2004) "Peter Levine" Case Study Number E166, Stanford Graduate School of Business

Gompers Paul, Kovner Anna, Lerner Josh, and Scharfstein David (2006) "Skill vs. Luck in Entrepreneurship and Venture Capital: Evidence from Serial Entrepreneurs" NBER Working Paper No. 12592

Gompers Paul and Josh Lerner (1999) "The Venture Capital Cycle," MIT Press

Gompers Paul and Josh Lerner (2002) "Short-Term America Revisited? Boom and Bust in the Venture Capital Industry and the Impact on Innovation" Innovation Policy and the Economy, Volume 3, 2002

Gupta Udayan (2000) "Done Deals: Venture Capitalists Tell Their Stories," Harvard Business School Press

Hart Oliver (1995) "Firms, Contracts, and Financial Structure," Oxford University Press, USA

Holmstrom Bengt (1982) "Moral Hazard in Teams" The Bell Journal of Economics, Vol. 13, No. 2, pp. 324-340.

Hochberg Yael, Alexander Ljungqvist, and Yang Lu (2007) "Whom You Know Matters: Venture Capital Networks and Investment Performance," Journal of Finance.

Ichniowski Casey, and Kathryn Shaw (2007) "Insider Econometrics," in Handbook of Organizational Economics, eds. Robert Gibbons and D. John Roberts. Princeton: Princeton University Press

Kaplan Steven N., and Antoinette Schoar (2005), "Private equity returns: Persistence and capital flows," Journal of Finance 60, pp. 1791-1823.

Kortum Samuel and Josh Lerner (2000) "Assessing the Contribution of Venture Capital to Innovation," The RAND Journal of Economics, Vol. 31, No. 4., pp. 674-692.

Lang Kevin and Gordon Peter-John (1995), "Partnerships as Insurance Devices: Theory and Evidence" The RAND Journal of Economics, Vol. 26, No. 4, pp. 614-629.

Lazear Edward and Paul Oyer (2007) "Personnel Economics" draft chapter for *Handbook of Organizational Economics*, Stanford University

Levin Jonathan (2003) "Relational Incentive Contracts" The American Economic Review, Vol. 93, No. 3. pp. 835-857.

Levin Jonathan and Tadelis Steven (2005) "Profit Sharing And The Role Of Professional Partnerships" The Quarterly Journal of Economics, Vol. 120, No. 1, Pages 131-171

Lucas Robert (1978) "On the Size Distribution of Business Firms", The Bell Journal of Economics, Vol. 9, No. 2, pp. 508-523.

Mas Alexandre and Enrico Moretti (2006) "Peers at Work," U.C. Berkeley Working paper

O'Flaherty Brendan and Aloysius Siow (1992) "On the Job Screening, up or Out Rules, and Firm Growth" The Canadian Journal of Economics,Vol. 25, No. 2., pp. 346-368.

Oyer Paul (2007) "The Making of an Investment Banker: Macroeconomic Shocks, Career Choice, and Lifetime Income" Forthcoming, Journal of Finance

Rosen Sherwin (1982) "Authority, Control, and the Distribution of Earnings", The Bell Journal of Economics, Vol. 13, No. 2, pp. 311-323.

Sahlman, W. (1990) "The Structure and Governance of Venture Capital Organizations," Journal of Financial Economics, 27, 473-521.

Sorensen Morten (2006), "How smart is smart money? An empirical two-sided matching model of venture capital," Journal of Finance (forthcoming).

Wasserman Noam (2005) "Upside-down Venture Capitalists and the Transition Toward Pyramidal Firms: Inevitable Progression, or Failed Experiment" Entrepreneurship, Research in the Sociology of Work, Volume 15, 151-208.

A Data-set Construction

The commercial database *VentureXpert* is the source of information about funds raised, rounds of investments, and portfolio company exit events. It was matched with the directory *Pratt's Guide to Venture Capital Sources* which documents all the venture capital firms in the United States and has been published since 1970.[21] For each firm, the directory typically reports firm name, firm contact information, names of individual venture capitalists, their title (for example managing partner, partner, principle) and firm's preferences in terms of stage of investment, geography and industry. I collected information for every firm in California from the directory every four years, from 1982 to 2002. I have constructed a data-set that includes, for each year, the firms, the names of the venture capitalists as well as the individual venture capitalists' titles.

In order to examine the comprehensiveness of *Pratt's Guide* directory, I have cross checked the match partner-firm-year for a sub sample by comparing it with the information from prospectuses filed by portfolio companies. In these prospectuses, the companies report for each venture capitalist in the board, the VC firm she works as well as short biography that often includes previous positions in VC firms. I also cross referenced a sub sample with the Secretary of State Filing. I compared partners' names for firms which were registered as limited partnership, and also verified for the years in which firms were active and raised new funds. A similar comparison was made with VentureXpert data about years of fund raising. In general, I did not find any major discrepancy between *Pratt's Guide* and the other sources. The most common inconsistency is firms sometimes appear in the directory only few years after their founding.

I create the sample I use in the analysis following two criteria. There are two types of venture

[21] There are four editions between 1970 and 1977, and since 1981 the directory has been published every year.

capitalists: associates and partners.[22] Associates typically do not have extensive working experience and they are many times Business School graduates in the beginning of their career. Due to their short career their network of contacts and the access they have to new opportunities inside and outside the VC industry is relatively small. Associates' share in the firm profits is usually negligible, less than 1%. Partners, on the other hand, typically have a significant part in the profits, more than 1%. They have longer working experience; either as associates for 3-5 years or as entrepreneurs or senior managers outside the VC industry. I use only partners in my analysis.

The second restrictions on the sample is regarding the definition of firms as VC firms. The two sources, *VentureXpert* and *Pratt's Guide*, include information also about banks subsidiaries and corporations VC funds which make VC investments. Since such firms may differ from independent firms in terms of inflow of opportunities, and I also suspect that *Pratt's Guide* may not report accurately all the venture capitalists in their stuff, I exclude them from the sample. I only include firms which are defined as "Private equity firm investing its own capital". I also exclude firms which invested in less than 20 companies during the sample period.

B Limits on Firms' Size

While this paper does not study the limits on firms' size this issue is indirectly related. As reported in Table 1 many of the new firms were started by partners who split from their peers.[23] The existence of costs to increasing the organization size is consistent with the pattern in Figure 2. The growth in the total number of partners in the industry was much faster than the growth in the average number of partners in a firm and therefore the total number of firms grew significantly during the sample period.

The organizational diseconomies which induce the separation of partners can result from for ex-

[22] VC firms often make a more refined separation within these two layers, however the distinction between partners and associates is, in general, consistent across all firms.

[23] There is also an anecdotal evidence which is consistent with these findings. When describing the cyclical nature of the venture industry in Gompers and Lerner (2002) the authors argue: "An essential characteristic of venture capital organizations has been the speed with which decisions can be made and the parallel incentives that motivate the parties. An expansion of the fund can lead to a fragmentation of the bonds that tie the partnership into a cohesive whole. ...But as the venture organization grew, substantial management challenges emerged. In particular, it became increasingly difficult to monitor the investment activities of each of the groups... In short, rapid growth puts severe pressures on venture capital organizations."

ample from the inability of firms to have significant inequality across partners in the revenue sharing arrangement. Another reason for separation may be disagreements between partners about the skill of their peers or about the expected returns of different investment opportunities. Another potential diseconomy is "hierarchy cost". When information cannot be verified by people other than the agent who produces it, the process of agents fighting for implementing their ideas may affect the type of projects they can work on. Chen et al (2004) provide evidence that "hierarchy cost" induce organizational diseconomies in mutual fund management firms.

C Example of Referrals in the Market and Referrals in the Firm

Consider a case when individuals have private information about the probability of success of opportunities and the outcome, y, of all opportunities is either success or failure, $y \in \{0, 1\}$. There are two types of opportunities, high and low value, where high value are more likely to succeed: $0 \leq p_L < p_H \leq 1$. Also, assume that individuals have an outside option for using their time, $\bar{y}$, where $p_L < \bar{y} < p_H$ and therefore their willingness to pay for low value opportunities is 0. Individuals who are time constrained can sell an opportunity in the spot market, and offer an output based contract in which their payment $s(y)$ is contingent on the project outcome. I assume that the selling individual has limited liability and therefore the payments are non-negative $s(0), s(1) \geq 0$. The profit of the individual who buys the opportunity is $y - s(y)$.

The spot market supports an efficient trade in private information if a separating equilibrium exists. In such an equilibrium an individual who sells a high value opportunity offers a different contract than an individual who sells a low value opportunity. An agent with a low value opportunity does not benefit from deviating and pretending to offer a high value project. However, this incentive constraint never holds; since the contingent payments $s(y)$ are non-negative, the expected profit of a seller with a low value opportunity who pretends to sell a high value opportunity is larger than zero. Therefore, a separating equilibrium does not exist and private information cannot be sold in the spot market.[24]

[24]Existence of pooling equilibria depends on opportunity proportions. If a portion π of the opportunities are low value and a portion $1 - \pi$ are high value, as long as there are enough low value projects, a pooling equilibrium does

The failure of the market to support trade in information results in inefficient matches between opportunities and skill. Consider a case when there is a continuum of opportunity qualities, p_i, and a continuum of agents skill, θ_j. Also, the quality of an opportunity and skill are complementary: projects succeed in probability π, where $\pi = p_i\theta_j$. Individuals who have information about the value of an opportunity and cannot execute it by themselves due to time constraints, are not able to share this information with individuals with available time. Therefore, these opportunities may end up randomly assigned to individuals whose skill may not fit the opportunity value.

Agents mitigate the inefficiency of the spot market by forming firms. A firm is an ex-ante contract in which they agree on the distribution of future revenue. For example consider a venture capital firm with 2 senior and 2 junior partners. Each junior i gets a portion $0 \leq r \leq 1$ of her own output, Y_i, and shares equally between the seniors $(1-r)$ of her output.[25] Since each senior partner receives $\frac{(1-r)}{2}$ of the revenue generated by each one of the juniors, she benefits from increasing their productivity. In the case discussed above when there are only two types of opportunities, $0 \leq p_L < \bar{y} < p_H \leq 1$, it is optimal for for the seniors to refer only high value opportunities, since the low value opportunities decrease the juniors' output.

not exists, $\pi p_L + (1-\pi)p_H < \bar{y}$. When it exists, the pooling equilibria is inefficient.

[25]The output, Y_i, is not necessarily entirely monetary. Especially for junior partners, part of the output and the compensation in the beginning of their career is the human capital that they accumulate.

D Tables and Figures

Table 1: New Firms in California Statistics

	1983-1986	1987-1990	1991-1994	1995-1998	1999-2002
Number of New Firms in CA	33	16	9	35	53
Number of "Mixed" New Firms in CA	11	11	7	17	22
Ratio	0.33	0.69	0.78	0.49	0.42

Unit of observation is a 4 year period. The statistics are based on previous partner positions in VC firms also in states other than California. "Mixed" firms are defined as firms with at least one partner who worked before as a partner in a different VC firm.

Table 2: Board Positions in IT and Life Science Companies

		Life Science				
		0-3	4-7	8-11	12-	Total
IT	0-3	696	42	18	7	763
	4-7	170	4	2	1	177
	8-11	76	4	0	0	78
	12-15	39	0	1	0	40
	16-19	12	0	0	0	12
	20-	14	0	0	0	14
	Total	1,007	48	21	8	1,084

Unit of observation is a partner. Each cell reports the number of partners with the relevant combination of IT and Life Science board memberships. The board positions include companies with and without an exit event.

Table 3: Industry Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Number of partners	6	331	163.93	117	613
Number of firms	6	76.67	28.26	36	119
IT Investments	6	1155.33	929.7	456	2896
Life Science Investments	6	258.33	107	103	407
Investments (IT and LS)	6	1423.67	967.04	559	3176

Unit of observation is a 4 year period. IT investments are investments in companies which are classified in *VentureXpert* as Media, Computer Related or Semiconductors/Other Elect. Life Sience investments are in companies classified as Biotechnology or Medical/Health/Life Science.

Table 4: Partners Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
Experience	1986	3.85	5.12	0	20
Experience Sq.	1986	41.11	78.58	0	400
Exits	1986	0.34	0.76	0	6

The unit of observation is partner-period. The variable Exits equals to the number of successful exit events of companies in which the partner was the leading investor.

Table 5: Measuring Partners' Human Capital

	(1)		(2)		(3)	
	Coef.	SE	Coef.	SE	Coef.	SE
Exp.	.101***	.023	.014	.052	–0.02	.123
Exp Sq.	–.006***	.001	–.002	.002	–.0006	.005
$Exits_{i,t-1}$			.845***	.099	0.673***	.133
$Exits_{i,t-2}$					0.763***	.153
Constant	-2.27***	.288	–1.29***	.238	–1.05	.702
Year F.E.	Yes		Yes		Yes	
$PseudoR^2$	.06		.078		.10	
N	1986		902		474	

Poisson regression. The dependent variable is $Exits_{i,t}$. The unit of analysis is partner-period. Columns (2) and (3) report the regression estimates for a sub sample which includes only observation of partners which are observed at least (2) and (3) periods respectively. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 6: Recruiting Decisions

	Coef.	SE
$\hat{Z}_{gt}$	−.202	.261
D_{ft}	.030	.122
$\hat{Z}_{gt} * D_{ft}$	.373**	.162
Constant	.63***	.186
R^2	.06	
N	273	

OLS regression. The dependent variable, L_{gt}, is the ratio between new and experienced partners in the group. Unit of analysis: group-period. Sub-sample of group-period observations for which the group's field has positive growth rate at period t. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 7: Summary Statistics Firm Dynamics

Variable	Observations	Mean	Std. Dev.	Min	Max
Number of Partners	274	4.11	2.61	1	18
Staying Partners	274	2.95	1.93	0	11
Leaving Partners	274	1.15	1.64	0	14
Change Num Partners	274	0.82	2.33	-8	12
Next pd. new partners	274	1.97	2.43	0	17
Stay Ratio	274	0.75	0.26	0	1

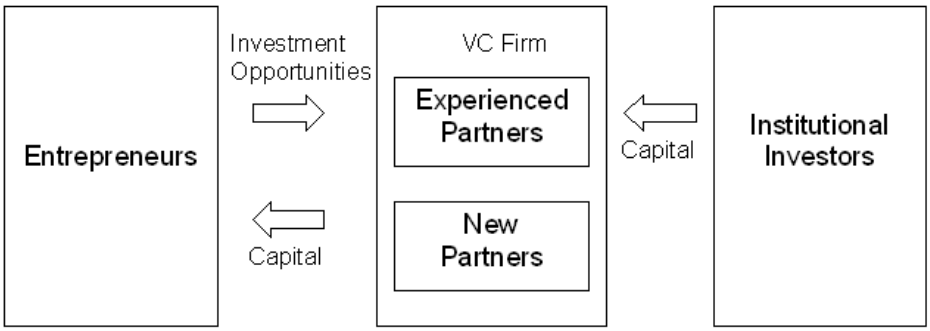
Unit of observation is firm-period. The sub sample includes only firm-period observations for which the firm is observed also in the next period.

Table 8: Structural Model Estimates

Coefficient	Mean	Std. Dev.
Human Capital *Constant*	-1.72	0.07
Human Capital Exp	0.14	0.008
Human Capital Exp^2	-0.007	0.0008
Human Capital σ_ν	1.1	0.14
Leverage Technology θ	0.4	0.03
Outside Option δ	1.3	0.22

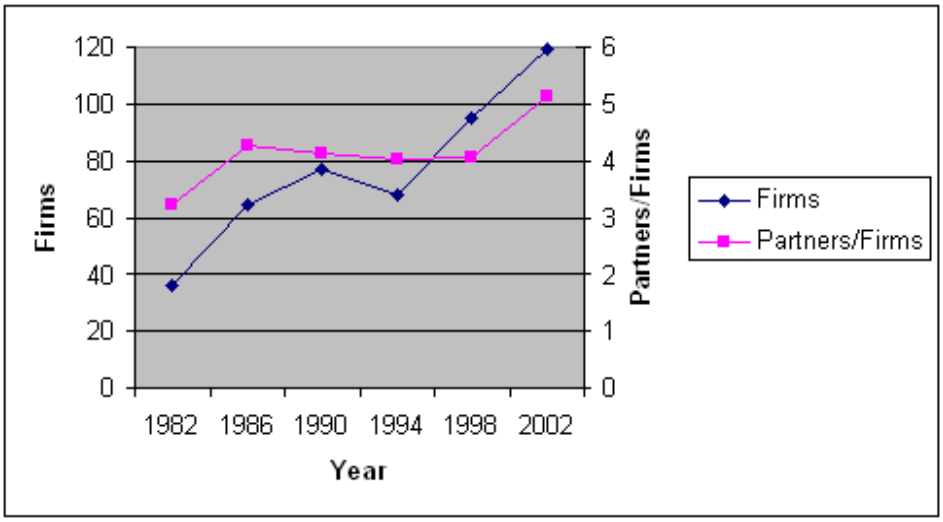
The reported statistics are calculated from the simulated posterior distribution of the parameters. The posterior is derived from Bayesian estimation of the two equations in the structural model. In the performance equation the dependent variable is the number of successful investments a partner made in a period. In the optimal recruiting equation the dependent variable is the latent marginal productivity of an additional new partner.

Figure 1: Intermediation by Venture Capital Firms



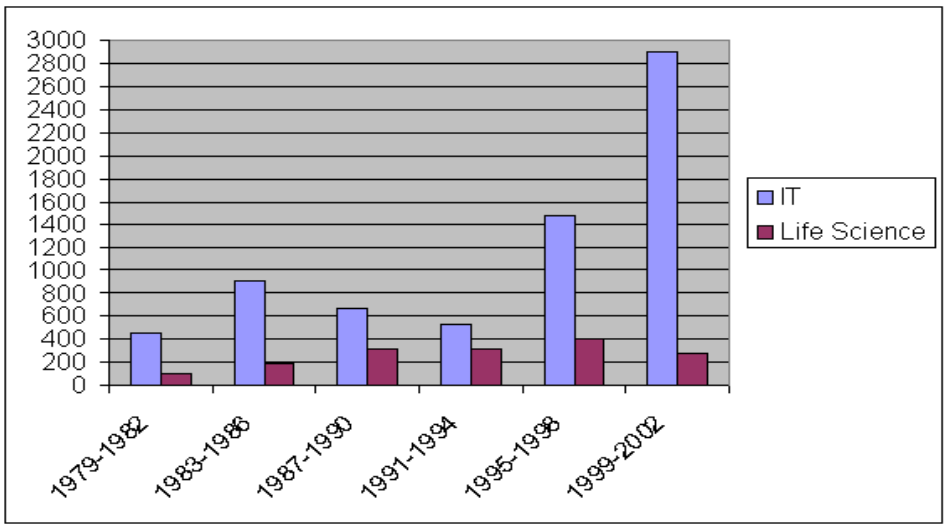
As financial intermediaries venture capitalists raise capital from institutional investors and invest this capital in companies which they carefully select. Joint work of experienced and inexperienced partners in the same firm allows successful venture capitalist to "leverage" their human capital.

Figure 2: Industry Growth



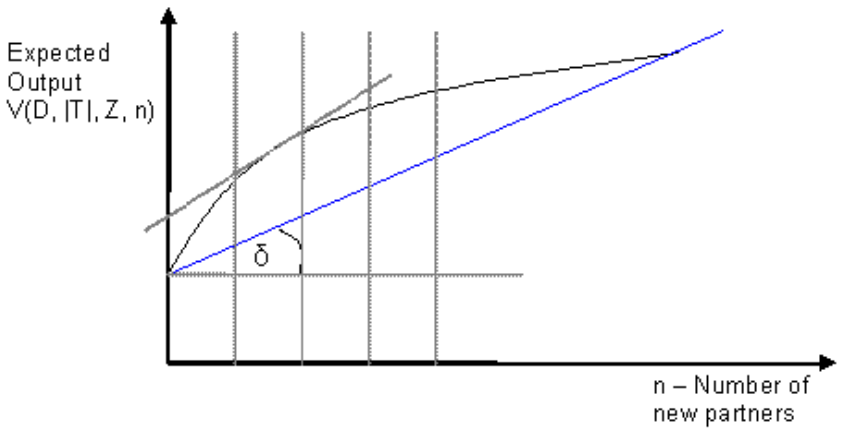
The total number of partners in the sample increased from 117 in 1982 to 613 in 2002. The sample includes Venture Capital firms which had all their offices in California or had their main office in California according to *Pratt's Guide to Venture Capital Sources*. Firms with less than 20 investments during the sample period as well as bank subsidiaries and corporation VC funds were excluded.

Figure 3: Investments by Field



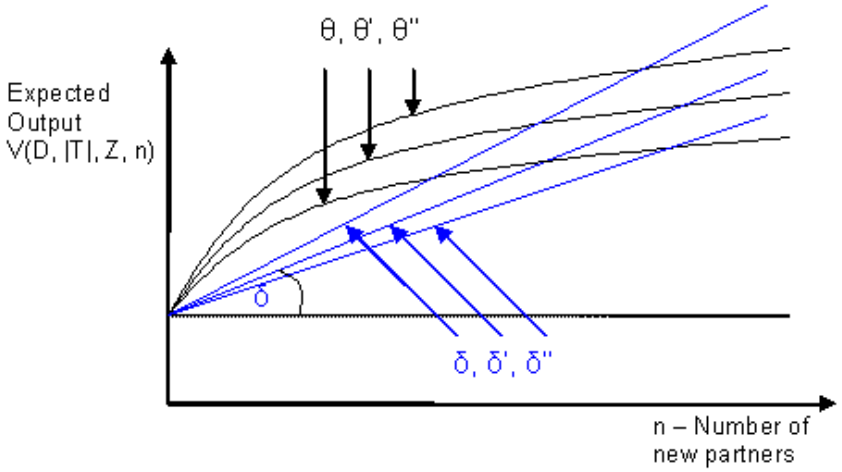
Investment is defined as a company which raises its first round of investment from a California VC firm in the relevant period. IT investments are investments in companies which are classified in *VentureXpert* as Media, Computer Related or Semiconductors/Other Elect. Life Science investments are in companies classified as Biotechnology or Medical/Health/Life Science.

Figure 4: New Partners Recruiting Problem



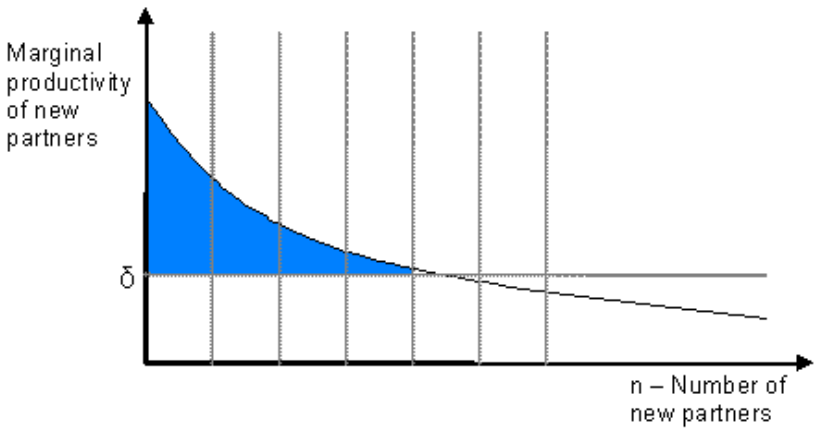
The vertical axis is the group's output. The horizonal axis is the number of new partners, n. The group recruits partners as long as their marginal productivity is higher than their outside option δ. Since the marginal productivity in this figure equals δ for $1 < n < 2$ the optimal number of new partners in this case is either one or two (depending on the parameter values).

Figure 5: Identification



There might by multiple combinations of θ and δ which predict the same n, for given human capital, Z, and deal-flow, D. However, due to the variation in Z and D we can find the θ and δ which best explain the observed D, Z, n.

Figure 6: Counterfactual



The shaded area is the benefits from joint work of experienced and new partners. It is the difference between the new partners productivity when jointly working with senior partners and their outside option δ.