

Venture Capital Investment under Private Information

by

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Many venture capitalists (VCs) use the “VC method” of valuation where they use judgment to estimate a probability of successful exit while determining the ownership share to demand in exchange for investing in a venture. However, prior models are not aligned with the “VC method” because they do not consider private information about entrepreneurial characteristics, the primary drivers of the above probability, and consequently do not model judgment. The three main chapters of this thesis—one theoretical, one simulation, and one empirical study—examine the venture capital deal process in sync with the “VC method.”

Chapter 2 is theoretical and develops a principal-agent model of venture capital deal process incorporating double-sided moral hazard and one-sided private information. The VC is never fully informed about the entrepreneur’s disutility of effort in spite of due diligence checks, so takes on a belief about the latter’s performance in the funded venture to determine the offer. This study suggests that there exists a critical point in the VC’s belief—and correspondingly in the VC’s ownership share—that maximizes the total return to the two parties. It also uncovers optimal revision strategies for the VC to adopt if the offer is rejected where it is shown that the VC should develop a strong advisory capacity and minimize time constraints to facilitate investment.

Chapter 3 simulates venture capital deals as per the theoretical model and confirms the existence of critical points in the VC’s belief and ownership share that maximize the returns to the two parties and their total return. Particularly, the VC’s return (in excess of his or her return from an alternate investment) peaks for a moderate ownership share for the VC. Since private information with the entrepreneur would preclude the VC from knowing these critical points *a priori*, the VC should demand a moderate ownership share to stay close to such a peak. Using data from simulations, we also generate predictions about the properties of the venture capital deal space—notably: (a) Teamwork is crucial to financing; and (b) If the VC is highly confident about the entrepreneur’s performance, it would work to the latter’s advantage. Chapter 4 reports the results from our survey of eight seasoned VCs affiliated with seven firms operating in Canada, USA, and UK, where our findings received a high degree of support.

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Working for a PhD degree as part of a mid-career change is not smooth sailing as many would agree. Family responsibilities constantly pose a challenge to allocating long hours to researching and writing, though many would be fortunate—as I have been—to have their spouse assume an increased share of those responsibilities. In any case, as I soon discovered at Waterloo, this arduous journey often concludes successfully with some great help.

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Every horse must find its own path as I learnt from a beautifully framed phrase in the office of Jayaraman Vaidhiyanathan, my esteemed boss in my prior engineering career. Moving to Canada and embarking on doctoral studies for a mid-career change have truly been in the spirit of that phrase for me. Surely this thesis marks a milestone on the way.

Dedication

To my mom

Kanthimathi

and

to the memory of my dad

S. M. Narayanan,

for their love.

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Chapter 1

Introduction

Chapters 2, 3, and 4 in this thesis concern the venture capital deal process and the properties of the deal space under private information—specifically, about the entrepreneur’s disutility of effort. Venture capitalists (VCs) most often use the “VC method” of valuation while considering investing in a venture. In that method, the VC has to judge the probability of successful exit—namely, the probability that the venture would attain certain valuation in a given time-frame. With that probability, the VC can compute the ownership share he/she should demand from the entrepreneur in exchange for investing in the venture the amount the entrepreneur demands. After investing the required amount, the entrepreneur puts in effort and the VC advises and monitors the entrepreneur in order to make the venture a success. Given that the primary factors in the control of the two parties that would influence that probability are the anticipated levels of the entrepreneur’s future performance (effort level) and the VC’s advisory support to that entrepreneur and that the entrepreneur seeking financing may be a first-time entrepreneur who lacks a verifiable track-record (e.g., a graduate student with a technological idea), the valuation exercise—specifically, judging the entrepreneur’s effort level and thereby the above probability—may often be challenging to the VC who may consequently demand too high or too low of an ownership share. If that share is too high, the entrepreneur may lose some of his/her motivation and not perform to the best. If too low, the VC may receive a lower return than otherwise possible. In other words, the VC needs to carefully judge the entrepreneur’s effort level and thereby the above probability, and demand an appropriate ownership share.

Though seminal, the models in the venture capital contracting literature—focusing on security design and the protective clauses part of VC contracts—do not study the VC’s ownership share in line with the “VC method.” Neither is the VC’s first offer always accepted by the entrepreneur in practice as predicted by those models. Because those models assume that the bargaining power rests with the entrepreneur, private information about entrepreneurial characteristics does not matter and the VC (who is only permitted by the entrepreneur to break-even) merely has to accept the offer the entrepreneur determines. Though those models have successfully explained VCs’ preference for special securities (such as convertible preferred) instead of common equity, their significant disconnection from the “VC method” limits the extent to which they can inform practitioners.

We strive in this thesis to fill the gap in the literature by departing from those models in a major way. We assume that the deal process is iterative where the incompletely informed VC holds the bargaining power and determines the offer by taking on a belief about the

entrepreneur's effort level (equivalently, the probability of successful exit in the "VC method"). Because of the information mismatch, the offer may be unattractive and hence rejected by the entrepreneur. However, the VC's belief may be hazy and belong to an interval; so he/she may improve that belief and consequently may be able to put forth a more favorable offer to the entrepreneur if the original offer is rejected. While in the rest of this chapter we present a detailed overview of the entire thesis, we model the above iterative process in Chapter 2 using a double-sided moral hazard framework where we also consider private information with one party—namely the entrepreneur, to study how the deal process may unfold and also to derive the conditions under which the VC may revise a rejected offer. Chapter 3 reports the simulation study of that model that we carried out to study the properties of the venture capital deal space under private information. In that study, (1) we scrutinized the impact on deal outcomes of changes in the VC's belief and (2) we simulated deals to generate synthetic data which we then used on regression analyses to make predictions about how different model parameters influence various deal outcomes (predictions could not be derived algebraically for some deal outcomes, hence this approach). In Chapter 4, we report on the survey of a small set of seasoned VCs we administered to assess the empirical validity of those predictions. Finally, having presented a detailed overview of the thesis in the introductory chapter, we give a brief summary of the thesis in Chapter 5 and also identify in that chapter possible directions for future research. A detailed overview of Chapters 2, 3, and 4 follows.

Chapter 2 titled *Venture Capital Investment: Initiating and Revising the Deal* presents a theoretical model of the venture capital deal process. Specifically, the model assumes private information available with the entrepreneur on his/her disutility of effort and bargaining power with the VC (a situation especially applicable to first-time entrepreneurs in early stages of their venture). Disutility of effort depends on multiple factors—economic and behavioral—such as human capital related competence, commitment, and preference for work that are all necessary for the entrepreneur to turn a technological idea into a successful venture. To elaborate, an entrepreneur who has the capacity to turn his/her idea into a successful venture, is committed to that goal, and is willing to suffer stressful effort in realizing that goal would have a low disutility of effort. However, when a VC carries out a due diligence on the proposal of an entrepreneur who does not have a verifiable track-record, it may not always be possible for the VC to assess those entrepreneurial characteristics—and consequently, that disutility—correctly. Since the entrepreneur's performance (effort level) will depend on that privately known disutility, the VC in practice uses "gut feelings" to judge that effort level (and thereby the probability of successful exit from the investment, in the "VC method") for determining the ownership share he/she should demand. If that is the case, what are the consequences of a misjudgment? How may the deal process unfold and what are

the strategies available to the VC if the entrepreneur rejects the offer? Since the optimal contract models in the literature assume complete information, we cannot use those models to answer these questions; hence the need for a new model.

We use a double-sided moral hazard framework that also incorporates one-sided private information where the VC chooses the offer terms that maximize the value of his/her portfolio of investments such that the investment in question is at least as attractive as an alternate investment opportunity. While doing so, the VC takes on a belief about the entrepreneur's effort level. Using the private information on his/her disutility of effort, the entrepreneur evaluates the offer at the optimal effort level that maximizes his/her return to decide on that offer. If he/she rejects the offer and if there is room for the VC to improve his/her belief, the VC may be able to revise the offer; specifically, we derive the conditions under which the VC would be able to revise the offer and depict the strategies available to the VC in a two-dimensional space defined by ownership share and the sensitivity of the VC's service (advising and monitoring) with respect to his/her belief.

Our illustrative example suggests that there may be critical values for the VC's belief (and corresponding ownership shares) that maximize the returns to the two parties. We also analyze the impacts of changes in the base salary paid to the entrepreneur (an aspect of VC financing largely ignored in the literature) and find that a higher base salary is not necessarily good for the entrepreneur or bad for the VC. The findings imply that making entrepreneurial characteristics transparent to the VC can benefit the entrepreneur (because with better information the VC may not underestimate the entrepreneurial effort and consequently demand a large ownership share) and that the VC's ownership share should neither be too high nor too low (because the illustrative example suggests that the VC's excess profit—namely, the VC's return in excess of his/her return from an alternate investment—is an inverted-U shape with respect to that ownership share). Since the resulting deals would often be sub-optimal (from the viewpoint of maximizing either the deal welfare—the sum of the two parties' returns—or the VC's excess profit), future research may inquire whether and how that inefficiency can be eliminated or minimized under private information.

Chapter 3 titled *Properties of the Venture Capital Deal Space* is a simulation study of the above theoretical model to shed light on the properties of the venture capital deal space under private information. There are twelve parameters in our theoretical model, so the deal space is a 12-dimensional hypercube (those parameters being: the VC's cost of capital, investment amount, the VC's unit cost of service—i.e., the unit cost for the VC's time, the VC's marginal return to service—a measure of the VC's time constraints, base salary paid to the entrepreneur, the relative importance of the entrepreneur's solo-work and that of teamwork, the entrepreneur's effectiveness in solo-work and that in teamwork, the VC's effectiveness (in teamwork), the entrepreneur's unit cost of effort—i.e., disutility of effort,

and the VC's belief on the entrepreneur's effort level). While the first eleven of the parameters define a deal scenario, the twelfth is the belief that the VC facing the scenario takes on in order to determine the offer. Recall that our illustrative example in Chapter 2 suggests that there may be critical values of the VC's belief and corresponding ownership shares that maximize the returns to the two parties. However, that observation was only made using one scenario. Though for that scenario the values for some of the parameters had been chosen from the literature, we decided to confirm that finding with a simulation (Simulation I). We also decided to simulate deals (in Simulation II) and use the resulting synthetic data for regressions to uncover insights about the parameter sensitivities of various deal outcomes.

In Simulation I, we simulated 5,200 scenarios using samples drawn quasi-randomly from wide parameter domains and then computed various deal outcomes for 200 values of the VC's belief drawn uniformly across its domain for each of those scenarios (thus we had 1.04 million deal computations). That simulation confirmed that indeed there exist critical values for the VC's belief and corresponding ownership shares that maximize the returns to the two parties and the deal welfare for each scenario. It further showed that, for scenarios with a possibility of deal closure, the critical value of the VC's belief (corresponding ownership share) that maximizes the deal welfare is bounded on the lower (upper) side by the belief (ownership share) that maximizes the VC's excess profit and on the upper (lower) side by the belief (ownership share) that maximizes the entrepreneur's return. This property, which we formally conjecture, implies that the VC needs to carefully judge the entrepreneur's effort level (equivalently, the probability of successful exit in the "VC method") and correspondingly the ownership share to demand if he/she wishes to maximize the excess profit. Future research could use regression analysis to show how the eleven parameters of a scenario influence the critical values of the VC's belief and ownership share. We, however, note that one of those eleven parameters—namely, the entrepreneur's unit cost of effort—is unknown to the VC, so the VC can only hope to estimate the critical ownership shares in terms of that unknown unit cost (for the scenario in which he/she is placed) using the coefficients of parameters estimated in such a regression.

Using the data from the simulation, we also graphed the distributions of the various critical values and found that the critical ownership share that maximizes deal welfare is less than 0.2 in about two-thirds of the scenarios, that maximizing the VC's excess profit varies widely but is between 0.2 and 0.5 in about 45% of the scenarios, and that maximizing the entrepreneur's return is less than 0.1 in about 80% of the scenarios. These observations suggest that in practice it is unlikely that maximum welfare would be realized or that entrepreneurs would obtain their best return as far as VCs hold the bargaining power and entrepreneurial characteristics are not completely known. Those observations further suggest that VCs would be better off not targeting certain ownership percentages to demand (e.g.,

33%, less than 50%, etc.); instead, they should demand an ownership share that is appropriate to that particular deal and that ownership share can be considerably low or high in a sizable number of cases.

In Simulation II, we quasi-randomly chose 10,400 deals (i.e., full sets of parameters) and computed various deal outcomes. We then conducted regression analyses using the resulting synthetic data to predict the sensitivities of various deal outcomes (i.e., probability of VC making an offer, the VC's ownership share and service level, the entrepreneur's effort level, probability of entrepreneur exerting best effort, probability of entrepreneur accepting an offer, returns to the two parties, and deal welfare) with respect to the twelve parameters. From that exercise, several interesting predictions emerged; some of them are: (1) Teamwork is crucial to venture capital financing (i.e., deal outcomes are highly sensitive to the entrepreneur's effectiveness in teamwork and the relative importance of teamwork); (2) If the VC is highly confident about the entrepreneur's performance, it would work to the advantage of the entrepreneur; (3) Though the entrepreneur's unit cost of effort does not directly influence the VC's offer (because that information is not known to the VC), that unit cost is the factor that affects various deal outcomes the most negatively; and (4) Base salary only plays a minor role in influencing deal outcomes. We also conducted a simulation in a small hypercube (one that had narrow domains for the parameters and that surrounded the parameter values taken from the literature for our illustrative example of Chapter 2) and found qualitatively similar results when we repeated the regressions using the data from that small hypercube. Thus properties appear to be homogenous across the deal space.

Chapter 4 titled *Survey of Venture Capitalists* concerns the survey of VCs that we administered for empirical validation of the key assumptions of our theoretical model, and the predictions from our propositions, conjecture, and regressions. Since, for empirical validation, it would be more practical to seek agreement on our findings from VCs who are experts in deal negotiation than collect data on the model parameters and the deal outcomes for a large number of actively considered proposals, we administered an online survey, using an online survey portal SurveyMonkey, to eight seasoned VCs located in Toronto, Waterloo, and Montreal and affiliated with firms operating in three countries—Canada, the USA, and the UK. We sought their level of agreement with thirty nine items that related to our assumptions and predictions. While thirty three of those items were supported, one was disagreed with, and for the remaining five we identified plausible reasons for the apparent lack of support and discovered new insights while doing so.

Our sample of VCs supported our key assumptions that the VC uses judgment in determining the offer terms (unlike in the optimal VC contracting literature) and that a rejected offer may be revised (an action irrelevant to optimal contracts where one party puts forth an offer that is immediately acceptable to the other party). In line with our conjecture,

the survey respondents also agreed that the entrepreneur usually likes to own a larger part of the venture than what the VC offers. Those respondents however disagreed that the VC's time constraints can affect whether the VC will revise a rejected offer (as we propounded in one of our propositions). Indeed as per the proposition those time constraints can cease to affect the VC's decision regarding revising when the VC has minimized or eliminated those constraints (say by engaging a team of junior analysts for assistance). The respondents agreed that the size of the base salary offered can affect whether the deal will close; hence it is conceivable that the VC may revise a rejected offer by increasing the base salary while maintaining the ownership share as in the original offer. Finally, the responses supported most of the predictions of our regressions. Particularly, the responses confirmed the importance of teamwork in enabling VC financing and the importance of the VC's belief on the entrepreneur's effort level (equivalently, the VC's ownership share) in influencing how the returns are divided between the two parties.

Though our sample of VCs is small and non-random, the sample is of experts. The VCs have negotiated numerous deals, many of them with first-time entrepreneurs. They all sit on boards and actively advise entrepreneurs. Many of them were entrepreneurs themselves earlier in their career. Their firms have numerous portfolio firms under management in various sectors - Information and Communication Technologies (ICT), biotechnology, and green technology among others. Thus the evidence is credible, but future research could strive to survey a larger number of practicing VCs.

Chapters 2, 3, and 4 together present a coherent picture of venture capital investment under private information about the entrepreneur's disutility of effort. The VC has the bargaining power in the deal most often and he/she uses judgment in determining the entrepreneur's future performance (effort level) and the offer terms. The entrepreneur rejects the offer sometimes and the VC may revise such a rejected offer. Thus indeed the deal process is an iterative process in practice (though many times the first offer may be accepted).

Furthermore, the VC's excess profit is an inverted-U shape with respect to ownership share (though the curve is not always smooth; it can have kinks), so the VC must demand an ownership share that is appropriate for that particular deal to maximize his/her return from the investment rather than target a desired share. If the VC has the bargaining power, welfare is unlikely to be maximized; neither is the entrepreneur likely to obtain his/her best return (in a vast majority of cases, the latter would need 80% ownership share for best return). The VC should strive to minimize his/her time-constraints and maximize advisory capacity (so he/she would not exhaust that capacity even at high level of service) to be better able to finance ventures.

Moreover, the entrepreneur should only ask for a minimum necessary base salary in consideration of his/her overall return from the venture. Though a larger base salary to the entrepreneur poses the risk of a bigger loss to the VC (in case the venture fails), the latter should actively consider paying a large salary in order not to lose an otherwise attractive deal, if that salary is essential to the entrepreneur and not unreasonably large relative to the expected returns from the venture. Base salary would not play a major role in any other respects. The entrepreneur must strive to be effective in teamwork especially if teamwork is crucial to the venture (such as when the VC's business skills are particularly necessary). But since that effectiveness depends not only on the entrepreneur's ability to cooperate with the VC but also on his/her competence and since the entrepreneur's effectiveness in solo-work (that depends only on his competence) also plays a considerably large role, the entrepreneur's competence is perhaps the most important factor on which he/she should focus on in order to be financed.

This thesis, intended as a contribution to the VC contracting literature, departed from the existing optimal contract models in a major way. Chapter 2 modeled the VC deal as an iterative process employing a new approach that is in sync with the "VC method"—namely, by formally modeling the VC's belief and studying offer revisions in the context of changes in that belief. While doing so, it also considered base salary—an aspect of venture capital financing that has only received scant attention in the literature. Chapter 3 used a simulation model to scrutinize the deal process under private information in microscopic details—namely, how twelve parameters affect a variety of deal outcomes. Specifically, we are not aware of any past research that makes any predictions on how the returns to the two parties and the deal welfare would vary with the VC's estimation of the probability of successful exit (in the "VC method"). Neither are we aware of past research that has studied the impacts on VC deals of cost for the VC's time or his/her time-constraints. Finally, Chapter 4, by surveying a small but expert set of VCs, contributes to the literature by offering empirical evidence for our findings. We hope that this thesis will inspire thinking on VC contracting and steer that literature in this new direction, and thus offer a contribution to that literature in an intellectually demanding but practically valuable way.

Chapter 2

Venture Capital Investment: Initiating and Revising the Deal

2.1 INTRODUCTION

The need to better understand investment offers—and the actions/reactions of the involved parties—results from significant and consistent discrepancies between investors and entrepreneurs regarding firm valuation and expected performance (Mason and Harrison, 1996).¹ Firm valuation per share (or pricing) as well as the terms and conditions of the investment deal are also crucial to entrepreneurs (Valliere and Peterson, 2007). Too high a valuation from the entrepreneur may lead to a rejection by the venture capitalist (VC), while too low a valuation by the VC can discourage the entrepreneur, thereby affecting the performance of the funded venture (Amit, Brander and Zott, 1998).²

This chapter attempts to provide a clearer understanding of VC investment offers by considering the level of effort to be allocated in the venture by the fund-seeking entrepreneur or, in other words, by considering *entrepreneurial characteristics*. It also attempts to identify the conditions under which a VC should choose to revise an offer when rejected. Since VCs exist because of their ability to reduce the cost of information asymmetry between entrepreneur and investor, and since both parties are prone to moral hazard (Amit et al., 1998), we approach this investment deal phenomenon with a principal-agent model. In this model, an entrepreneur possessing private information on his/her characteristics—specifically, disutility of effort—seeks investment and a VC decides whether or not to make an offer.

The VC considers the entrepreneur's private information by forming a belief on the entrepreneur's level of effort to be allocated to the new venture. Both parties maximize their respective expected return based on their effort allocated to the venture and their ownership share, as well as other factors such as investment amount and cost of capital. Although the return to the entrepreneur only comes from his/her proposed business venture, the return to the VC comes from a portfolio of ventures. In addition to offering a description of how the investment deal might unfold when the entrepreneur possesses private information, our formal approach also allows us to study the impacts on the return to both parties of changes

¹ Thanks to Rod McNaughton, this chapter had its origin in a research question on venture capital for green technology but metamorphosed into one concerning deals soon after I started a preliminary review of VC literature to first understand the investment process. I thank Moren Levesque for checking for mathematical accuracy and intensely helping me in the general development of the chapter. I thank Brian Cozzarin for his advice at various times in the course of this chapter. Any errors that may remain are mine.

² We interchangeably use “VC” to denote both venture capital and venture capitalist, depending on the context.

in the VC's belief on the entrepreneur's effort and of including a base salary for the entrepreneur as part of the investment deal. Considering a base salary is only one of many possible contract provisions that try to incent the entrepreneur, but one left rather unexplored.

Extant literature suggests that entrepreneurial characteristics—the outcome of which being the entrepreneur's level of effort—represent the primary factors that affect the valuation of a firm (e.g., Fried and Hisrich, 1994), but also that VCs extensively use their “gut feeling” to account for these characteristics (Messica, 2008; Levie and Gimmon, 2008). The subjectivity of this measure (i.e., “gut feeling”), and resulting challenges associated with valuing a firm, have led to numerous studies.³ Yet, these studies neglect the private information that is possessed by the entrepreneur on these characteristics (i.e., his/her disutility of effort). Even optimal contracting studies (e.g., Casamatta, 2003) do so by assigning the bargaining power and the offer decision to the entrepreneur, not the VC; hence, when evaluating an offer the key role played by the VC's “gut feeling” in considering the entrepreneur's characteristics is likely to disappear.

We address this gap in the literature by allowing the VC to form a belief on the entrepreneur's level of effort, and investigate the sensitivity of the investment offer as the VC alters this belief. In the proposed model, the VC maximizes his/her expected return from a portfolio of ventures believing that the entrepreneur in question will at least allocate a certain minimum level of effort to the corresponding venture member (i.e., the entrepreneur is believed to at least “perform” at a certain minimum level). We use this minimum level to more formally capture the VC's “gut feeling” regarding the entrepreneur's behavior. This minimum level is not necessarily a “low” level; in fact, it can be an overestimate of the entrepreneur's effort level.

Contributions from this model are multifold. First, we characterize and numerically illustrate the investment deal process to uncover relationships between some of the key decision variables in initiating the deal. Among other things, this exercise suggests that a rejected offer can allow the VC to incrementally revise that offer in order to increase his or her excess profit as well as the investment-deal welfare (i.e., sum of net returns to both parties). Second, we derive the conditions necessary for the VC to make a revised offer if rejected, and show that they depend on the manner in which the offer is revised (e.g., offering a higher base salary to the entrepreneur), on the VC's ownership share, and on the change in the VC's service level as entrepreneurial effort is expected to increase. For instance, we show that when the VC believes that the entrepreneur's effort can significantly enhance his or her marginal productivity, that VC is increasingly encouraged to close a deal and revise the offer.

³ For instance, Zacharakis and Meyer (2000) focus on the VC process; Amit et al. (1998) and Admati and Pfleiderer (1994) on the *raison d'être* of VCs; Shepherd, Armstrong and Lévesque (2005) on VCs' limited attention and optimal proportion of venture proposals to fund; and Casamatta (2003) on optimal contracting.

We further portray three revision strategies we put forward (1. do not revise the offer; 2. revise the offer by reducing the VC ownership share; 3. revise the offer by increasing the entrepreneur's base salary) on a two-dimensional space divided by three threshold lines to unearth the importance of not only the magnitude of a VC's ownership share, but also the magnitude of the change in that VC's service level as his or her belief improves regarding the entrepreneur's behavior.

In §2.2 we describe two important bodies of literature that relate to our research questions (*how should the investment deal unfold and when should the VC choose to revise an offer when rejected*). §2.3 offers a description of the deal process, which leads to a formal principal-agent model and an illustrative example of that process. §2.4 presents necessary and sufficient conditions under which a rejected investment offer should be revised, whereas §2.5 discusses the impacts of paying a base salary to the entrepreneur as part of the offer. §2.6 concludes by articulating practical insights, and identifying limitations as extensions of this work.

2.2 FIRM VALUATION AND MODELING MORAL HAZARD

Although the commercial potential of a venture (e.g., based on technology and/or marketability of the new offering) is important, VCs consider an entrepreneur's characteristics, which can be represented by economic (e.g., human capital related competence) or behavioral dimensions (e.g., preference for work), to be *the* most important factors that affect firm valuation (Fried and Hisrich, 1994; Pintado, de Lema and Van Auken, 2007). Consequently, background checks on the entrepreneur are crucial because top management capabilities may become primary indicators of the venture's potential (Zutshi, Tan, Allampalli and Gibbons, 1999). Gorman and Sahlman (1989) claim that wrong doing of senior managers can drive venture failures. Failure rates are high for newly funded ventures (e.g., Dimov and De Clercq, 2006), which forces VCs to carefully scrutinize entrepreneurial characteristics. Other key factors affecting firm valuation include the service to be rendered by the VC (i.e., the level of effort invested in the newly funded venture; Amit et al., 1998; Hsu, 2004) and the bargaining power of the VC (Inderst and Mueller, 2004). Although many other factors may be considered when a firm is valued, we focus in this article on analyzing the most important one, entrepreneurial characteristics, everything else being equal, and thus pay special attention to the level of effort allocated by the two parties involved in the investment deal.

The most popular valuation method among VCs is the so-called "VC method." As per Metrick (2007), a firm's *total valuation* is the *exit valuation* multiplied by the *expected retention percentage* and divided by the *value multiple*. Exit valuation is the valuation of the firm at the end of the investment contract, the expected retention percentage is the proportion

of current number of shares to number of shares at the time of exit, and the value multiple is the reciprocal of the product of *discount factor* and *probability of successful exit*. If the present worth of returns to the VC or, in other words, the *partial valuation*, which is equal to the VC's ownership share times the total valuation, is at least equal to the investment, then the VC invests. The relationships among the VC method's components are formally presented in Appendix A.

This formal representation has enabled us to demonstrate (in Appendix A) that the crucial component for our focus is the *probability of successful exit* because that probability is directly proportional to the new venture's expected revenue (used to compute expected returns to both parties). That probability is an assessment made by the VC following due diligence and it depends on "gut feeling" (Messica, 2008; Levie and Gimmon, 2008) that accounts for the level of effort to be allocated in the venture by the fund-seeking entrepreneur. Entrepreneurial effort affects the probability of successful exit, especially for first-time entrepreneurs lacking a track-record and possessing private information on their disutility of effort (likely unidentifiable through due diligence). The VC must thus use his/her "gut feeling" to form a belief on the entrepreneur's effort level, with a lower bound that can either be an underestimate or be an overestimate of the true effort level.⁴ Information asymmetry thus emerges and moral hazard arises.

Moral hazard in the VC-entrepreneur relationship can be double-sided (e.g., Amit et al., 1998; de Bettignies and Brander, 2007). On the one hand, moral hazard from the entrepreneur arises because, as articulated above, the entrepreneur's disutility of effort may render his/her actual level of effort allocated to the venture less than the level hoped for by the VC. On the other hand, moral hazard from the VC arises too because the VC possesses a portfolio of investments and hence offers a level of service that maximizes expected return from that portfolio rather than from any single venture (Dimov and De Clercq, 2006; Shepherd et al., 2005; Kanninen and Keuschnigg, 2003; Jääskeläinen, Maula and Seppa, 2006). Therefore, the literature suggests that, under time constraints, the level of service rendered by the VC may end up below the level that maximizes the VC's return from the focal venture. This implies that the VC's level of service in the venture is a second important construct that affects (albeit more indirectly) the probability of successful exit. In fact, the VC's service level is itself influenced by the entrepreneur's effort level, thereby suggesting a primary effect on the probability of successful exit from entrepreneurial effort and a secondary effect from the VC's service. With that probability and the new venture's expected

⁴ Zacharakis and Shepherd (2001) found that 96% of the VCs they surveyed were inaccurate in their investment decisions (VCs either overestimated or underestimated entrepreneurs) but those VCs were, nevertheless, overconfident about those decisions. The VC's belief on the entrepreneur's minimum effort level may significantly misrepresent the entrepreneur's true effort, providing additional support for the need to also consider revising this belief.

revenue being proportional (Appendix A), this discussion allows us to model the expected revenue as a function of both parties' effort (i.e., the entrepreneur's effort level and the VC's service level).

We propose a principal-agent model of the investment deal process that has been inspired by the work of Amit et al. (1998), who has demonstrated the economic necessity of VCs as an intermediary in a market for private equity, and by Metrick (2007), who has illuminated the VC method. Our model incorporates double-sided moral hazard with private information on entrepreneurial characteristics (i.e., disutility of effort). A growing body of literature has considered double-sided moral hazard in the VC-entrepreneur relationship, focusing on choice of security type (Repullo and Suarez, 2004), cash-flow rights (Schmidt, 2003), or contracts when a business angel investor is involved in addition to the VC (Elitzur and Gaviols, 2003). Fairchild (2004) considers the bid of two VCs, focusing on the combined effects on bargaining agreements of value-added services, reputation-seeking, and bargaining power. Fairchild (in press) analyzes the entrepreneur's decision for selecting a VC versus an angel. In Hellmann (1998) the VC chooses the optimal rate at which to replace the entrepreneur, while Hellmann (2002) studies corporations that invest in ventures to acquire them for economies of scale or to eliminate their competition. Inderst and Mueller (2004) look at capital market characteristics to develop a model of contracting, bargaining, and search. Kannianen and Keuschnigg (2003) focus on the optimal portfolio size.

Nevertheless, these studies do not consider the private information of the entrepreneur on his/her disutility of effort. Studies that add the consideration of private information to the double-sided moral hazard in the VC-entrepreneur relationship are, to the best of our knowledge, only a few. Houben (2002) models private information for both entrepreneur and VC, focusing on the endogenous determination of security type, to explain why redeemable and convertible preferred stocks are often used in VC finance. We also note that, in Amit et al. (1998), the entrepreneur's private information is on the venture's quality (and information asymmetry is resolved before an offer is made). In other words, the focus of these important works differs substantially from ours.

Further, the literature on factors that affect firm valuation identifies entrepreneurial characteristics as the primary determinant, but our principal-agent formulation allows us to identify *tradeoffs* in the deal process that are generated by those characteristics. Also, while the valuation method literature uses the VC's "gut feeling" to estimate the probability of successful exit, we instead formally represent the "gut feeling" with a VC's belief on the minimum level of effort to be allocated by the entrepreneur in the new venture. Doing so enables us to capture the entrepreneur's private information and go one step further from Amit et al. (1998) (and others) to uncover how the deal process might unfold when the entrepreneur possesses private information.

Moreover, in our proposed model the bargaining power lies with the VC. This setting, while fundamentally different from the optimal contract literature where entrepreneurs typically hold the bargaining power under complete information (e.g. Casamatta, 2003; Biais and Casamatta, 1999), better captures early-stage venturing. Kaplan and Stromberg (2003) argue that, in early-stage ventures, information asymmetry is present, especially when the entrepreneur is inexperienced. Also, many scholars (Metrick, 2007; Koskinen, Rebello and Wang, 2009; Parker and van Praag, 2006; Desai, Gompers and Lerner, 2003) support that the VC determines the offer in early-stage ventures, not the entrepreneur. Even models of technology transfer (e.g., Aghion and Tirole, 1994; Jensen and Thursby, 2001; Jensen, Thursby and Thursby, 2003), where an inventor-entrepreneur sells an invention and his/her efforts are still needed after the sale to commercialize it, do not have predictions transferable to our setting because the bargaining power lies with the inventor-entrepreneur, which also eliminates the need to consider private information on the entrepreneur's disutility of effort.

Our modeling approach further enables us to investigate the deal iteratively by letting the VC revise the investment offer rather than characterizing contract terms that are acceptable to all parties at once, a feature more representative of the optimal contract literature. Milestone-based cash-flow and control rights are integral parts of VC contracts and have been studied by a vast body of literature (e.g., Aghion and Bolton, 1992; Dewatripont and Tirole, 1994), because these rights are necessary to mitigate agency costs and increase the chance that expected results would be achieved. Yet in the real world, the first step in VC contracting is valuing the venture in terms of simple equity (Metrick, 2007), which is the core of the so-called "VC method." VCs then determine the security type and these rights exogenously of valuation (Kaplan and Stromberg, 2003; Metrick, 2007) depending primarily on the agency costs in the investment but also on tax rules, the VC's sophistication or experience, and market conditions (Cumming, 2005a, 2005b; Cumming & Johan, 2008). They may finally refine the valuation based on the security type and rights chosen (Metrick, 2007). Our aim is to provide a theoretical explanation for valuation as used in the VC method, and as such scrutinize this first step thoroughly rather than look at the complete contract.

2.3 A MODEL FOR DESCRIBING THE INVESTMENT PROCESS

Consider an entrepreneur who seeks VC investment I for a new business venture. The VC requires an ownership share $\alpha \in (0,1)$ of the expected revenue R and may elect to pay a base salary b to the entrepreneur based on exogenous considerations (e.g., to enable the entrepreneur to meet his/her living expenses).⁵ The VC may also elect to offer advisory

⁵ Payments like base salaries are also modeled in Keuschnigg and Nielsen (2002), and in Repullo and Suarez (2004), where surplus is transferred to the entrepreneur if VCs compete to obtain the deal. On the other hand, an

service s post investment, noting that this variable cannot be explicitly included in the contract since it cannot easily be observed by the entrepreneur (thus making the contract incomplete). Per unit cost of service w represents the cost for the VC's time (akin to an hourly consulting fee).⁶

The entrepreneur expects to allocate effort e to the funded venture (a variable that also cannot be explicitly included in the contract since it cannot easily be observed by the VC) and encounters a privately known disutility—and hence per unit cost ω —from allocating effort. This cost, termed *unit cost of effort*, depends on multiple factors. Zider (1998) describes the profile of an ideal entrepreneur from a VC's perspective, much of which pertains to entrepreneurial effort that depends on factors like commitment and competence. Hence, ω depends on the entrepreneur's commitment, competence and, accordingly, preference for work. Lack of commitment arises when the entrepreneur benefits from private actions not aligned with the VC's interest (Hart and Moore, 1999), or when the entrepreneur has not yet completely given up prior wage work and is thus involved in “hybrid entrepreneurship” (Folta, Delmar and Wennberg, 2010). Lack of competence arises when the entrepreneur does not know where to direct his/her effort without the VC's guidance. The more the entrepreneur lacks commitment and competence, and the less he/she likes to work, the higher is ω .

Expected revenues are positively associated with the entrepreneur's effort level and the VC's service level (both with diminishing returns; Amit et al., 1998); that is, $R = R(e,s)$. Denoting partial first-order derivatives with a single suffix and partial second-order derivatives with a double suffix, the marginal productivities of the entrepreneur (R_e) and the VC (R_s) are thus positive, whereas the effect of effort level on R_e (i.e., R_{ee}) and that of service level on R_s (i.e., R_{ss}) are negative. Valliere and Peterson (2007) also observed that, as an entrepreneur gains experience, he/she increasingly values teamwork (i.e., compatibility) with the VC. The two parties are unlikely to enter into a contract if they do not expect to work well together.⁷ Therefore, the expected interactions between entrepreneurial effort and VC service (R_{es} and R_{se}) are positive, and since entrepreneurial effort is essential to an early-stage venture (e.g., Hellmann, 2007), no revenue is expected in its absence. Formally,

entrepreneur's decision to accept a base salary could consider the tradeoffs between personal-income and capital-gains taxes, and the realization of current income versus greater equity (Keuschnigg and Nielsen, 2002).

⁶ The VC can also outsource service to a paid “entrepreneur-in-residence or EIR” (Schwarzkopf, Lévesque and Maxwell, 2010, offer an exploratory study on the roles of EIRs) or a business service provider. The level of service meant here is the VC's time spent for each of the portfolio ventures by way of direct involvement or supervision of the provider. Through outsourcing, the VC can boost time effectiveness, thus increasing w , but total service cost sw might decrease.

⁷ We note that the findings of Hart and Moore (2008), where parties enter into a contract not anticipating *ex post* incompatibility, are not transferable to our study, because uncertainty is resolved at the time of signing the final contract (in our study the uncertainty is never fully resolved).

$$R_e > 0, R_s > 0, R_{ee} < 0, R_{ss} < 0, R_{es} > 0, R_{se} > 0, \text{ and } R(0,s) = 0. \quad (1)$$

The revenue function R is known to both parties since the VC has conducted due diligence over the proposed venture and the entrepreneur, and since the entrepreneur has proposed the venture and presumably acquired background information on the VC (Zider, 1998). Thus, both parties know the information in Eq. (1) prior to the first offer.

2.3.1 The VC's Problem

The VC's problem is to determine the ownership share α^* to claim and the service level s^* to expect to allocate. This is resolved in three steps: Step 1, the VC derives an equation in e , s , and α from his/her objective function in which the VC maximizes total return PV from his/her portfolio of ventures; Step 2, the VC derives another equation in e , s , and α from his/her participation constraint in which the VC requires an adequate return from the proposed (focal) venture; Step 3, the VC takes on a belief about e and solves the above two equations for the remaining two unknowns, s and α . We next expand on how these three steps formally proceed.

In Step 1, consider $PV = V + v$, where V is the VC's expected return from the focal venture and v is that from the remainder of the portfolio. Since the VC can only alter service levels across ventures in order to maximize PV , and denoting the total amount of service at the VC's disposal as S , we obtain $PV(s) = V(s) + v(S-s)$. The first-order condition for optimality is $PV_s = V_s - v_{S-s} = 0$, which leads to the solution $V_s = v_{S-s} = c$, where marginal return to service $c (\geq 0)$ is equal across all ventures in the portfolio. Since V (if the deal closes) is the excess of the VC's share of revenues over the base salary paid to the entrepreneur, investment amount, and cost of service, it can be expressed as

$$V = \alpha R(e, s) - b - I - s w. \quad (2)$$

It follows from Eq. (2) and the above solution that

$$V_s = \alpha R_s(e, s) - w = c \quad \text{or, equivalently,} \quad R_s(e, s) = \frac{c+w}{\alpha}, \quad (3)$$

and from Eq. (1) and Eq. (3) that $V_{ss} = \alpha R_{ss} < 0$. That is, expected return is concave in service for the focal venture (and also for the non-focal ventures since the return function of any venture is analogous to Eq. 2). Hence, $PV_{ss} = V_{ss} + v_{S-s-s} < 0$ and the second-order condition for optimality is satisfied. Step 1 therefore yields Eq. (3) in e , s and α (given c and w), where s is unique because R is concave in s per Eq. (1) and the feasible set of solutions ($0 \leq s \leq S$) is compact. Petty and Gruber (in press) also argue that VCs are time-constrained

(i.e., $c > 0$) and that the composition of a VC portfolio and the time allocated by the VC to manage the portfolio are key decision-making criteria.

In Step 2, let r be the VC's cost of capital over the contract's life. The VC's participation constraint, which holds if the VC receives an adequate return on investment (considering the base salary paid to the entrepreneur as well as the cost of service), is expressed as

$$\alpha R(e, s) \geq (1 + r)(I + b) + s w. \quad (4)$$

The excess of the left-hand side of Eq. (4) over the right-hand side represents the excess profit P from investing in the venture. That is,

$$P = \alpha R(e, s) - (1 + r)(I + b) - s w \geq 0. \quad (5)$$

The VC obtains a second equation in e , s and α using Eq. (5) with $P = 0$ (given r , I , b , and w). The constraint in Eq. (5) is binding, for if the entrepreneur believes that $P > 0$, then there is still room for the entrepreneur to reject the offer claiming that it is unattractive. The VC cannot know for sure whether or not the offer is unattractive to the entrepreneur because the latter possesses private information about his/her disutility of effort. Yet, all else equal, the VC knows that an increase in P will lead to an increase in his/her ownership share α in Eq. (5) and a decrease in the entrepreneur's return (in Eq. 6 introduced below). Consequently, the constraint in Eq. (5) is binding with $P = 0$.

In Step 3, the VC forms a belief that the entrepreneur will at least allocate a certain minimum level of effort e_{min} to the new venture (a level that is not necessarily "low"), which enables the VC to consider the entrepreneur's private information regarding the disutility of entrepreneurial effort. The VC's belief refers to the effective effort level where results are achieved, not nominal effort that only accounts for the number of hours spent on the job. An entrepreneur may not achieve adequate results despite working long hours due to, for instance, a lack of business competence required to transform a technical idea into a commercial product. Since the VC is only likely to invest if he/she can compute an adequate expected return, a first consequence of this assumption of a minimum effort level e_{min} is that the VC may demand an ownership share above what the entrepreneur may like to concede (this may happen when the VC underestimates that level). Another is that some worthy entrepreneurs will not be funded (negotiations can fail under information asymmetry; Muthoo, 1999) or will be offered deals found inefficient *ex-post* (i.e., the terms of agreements fail to realize the potential gains, making the negotiation costly). Nevertheless, letting the VC form such a belief can *ex-ante* be an efficient approach to establishing a common informational basis for an agreement (Kennen and Wilson, 1993). With $e = e_{min}$, the VC solves Eq. (3) and Eq. (5) for the remaining two unknowns and obtains s^* and α^* (given r , I , w , c and b). The VC then makes the offer (α^*, b) to the entrepreneur, expecting to allocate

service s^* for e_{min} , as will be numerically illustrated below after describing the entrepreneur's problem.

2.3.2 The Entrepreneur's Problem

The entrepreneur must decide whether to accept the offer or not, which he/she also does in three steps: Step 1, the entrepreneur forms rational expectations about s^* and e_{min} using the offer terms and background information on the VC; Step 2, the entrepreneur computes the effort level e^* to be allocated (given s^*) from his/her objective function in which the entrepreneur maximizes his/her return E from the focal venture; Step 3, the entrepreneur decides to accept the offer or not from his/her two participation constraints in which $e^* \geq e_{min}$ and $E \geq 0$. We now expand on how these three steps formally proceed.

In Step 1, because the service level selected by the VC and his/her belief on the entrepreneur's effort are not explicitly included in the contract, the entrepreneur must form rational expectations about s^* and e_{min} based on solving Eq. (5) (with $P = 0$) and Eq. (3), given α^* , b , r , I , w and c . We note that sharing information with the entrepreneur on the VC's cost of capital r , cost of time w , and marginal return to service c is in the interest of the VC because an uninformed entrepreneur might reject an offer that is attractive to both parties, or accept an unattractive offer that might lead to friction post-deal.

In Step 2, the entrepreneur expects a return E from the venture, which is the sum of the base salary and the excess of his/her share of revenues over the cost of effort, that is

$$E = b + (1 - \alpha)R(e, s) - e \omega. \quad (6)$$

The first-order condition for optimality of Eq. (6) yields the entrepreneur's incentive compatibility constraint:

$$E_e = (1 - \alpha^*)R_e - \omega = 0 \quad \text{or, equivalently,} \quad R_e(e^*, s^*) = \frac{\omega}{1 - \alpha^*}. \quad (7)$$

From Eq. (1) and Eq. (6), $E_{ee} = (1 - \alpha^*)R_{ee} < 0$ and the second-order condition for optimality is satisfied. Eq. (7) yields an optimal effort level e^* (given s^* , ω , and α^*), which is unique because E is concave in e (i.e., $E_{ee} < 0$) and the feasible set of solutions is compact (i.e., $0 \leq e \leq e_{UB}$, where e_{UB} is the entrepreneur's best effort).

In Step 3, the entrepreneur decides on whether or not to accept the investment offer. The entrepreneur must decline that offer if $e^* < e_{min}$ (though E may be positive) because the VC's excess profit P would be negative in Eq. (5), again potentially leading to friction post-deal; we note that clauses to be enforced in the contract to protect the interests of the VC should also encourage the entrepreneur to reject the offer. If $e^* \geq e_{min}$, the entrepreneur must compute E in Eq. (6) (given b , α^* , e^* , s^* , and ω) and accept the offer whenever $E \geq 0$.

When the entrepreneur rejects the offer, the VC may alter the terms with a revised ownership share by updating his/her belief on e_{min} . But since this belief is uncertain, it belongs to a particular interval. The VC can thus make the initial offer with a belief that corresponds to the lower bound of the interval, and iteratively revise that offer until the upper bound of the interval has been reached. An update of this belief can even be justified since a rejection signals that the VC might have been too conservative. We note, however, that the VC's belief is an assessment that is crucial to protect an investment with uncertain return. There might not be much room for a revision (i.e., a small interval), but if rejected again, this iterative process could repeat itself until a mutually agreeable deal is reached. Also, when the entrepreneur accepts the offer and his/her optimal effort level e^* exceeds the VC's belief on e_{min} , the venture's revenue will exceed what had been anticipated by the VC.

2.3.3 An Illustrative Example

We illustrate how the investment deal unfolds by first setting the VC's belief on e_{min} at 1,000 hours/year and study the deal outcomes for a range of the entrepreneur's privately known unit cost of effort, ω . Then, we fix ω at \$3,000/hour and study the deal outcomes for a range of values for e_{min} .

We use $R(e, s) = k_1 e^{\varepsilon_1} + k_2 e^{\varepsilon_2} s^\sigma$, where $k_i > 0$ for $i \in \{1, 2\}$, $0 \leq \varepsilon_j < 1$ for $j \in \{1, 2\}$, $0 \leq \sigma < 1$ and $\varepsilon_2 + \sigma < 1$, which satisfies the assumptions of our model. This functional form is adapted from Fairchild (in press) to permit revenue generation even in the absence of VC service. More specifically, $k_1 = 10,000$, $k_2 = 10,000$, $\varepsilon_1 = 0.85$, $\varepsilon_2 = 0.80$, $\sigma = 0.15$, $r = 15\%$, $I = \$2$ million, $b = \$50,000$, $w = \$1,500$ per hour of service, $c = \$500$ per hour of service, and $e_{UB} = 4,000$ hours/year (around 80 hours/week) for the entrepreneur's best effort.⁸ An investment of \$2 million and a contract life of 1 year are considered, although these figures can be altered without affecting our results qualitatively. The other values for the VC-related parameters r , I , w and c are determined from relevant literature. Indeed, Metrick (2007) estimates the cost of venture capital as 15%. The selected cost for the VC's time w corresponds to an annual income of \$3 million (at 2000 hours/year) to be brought back by the VC to his/her VC firm, again in line with Metrick (2007). The positive marginal return to service c accounts for the possibility of a time-constrained VC. The investment-related parameters b , k_1 , k_2 , ε_1 , ε_2 and σ are assigned values consistent with a \$2 million investment.

⁸ We use number of hours (a nominal effort level) as the unit of measure for both the entrepreneur's (effective) effort level and the VC's service level for ease of exposition.

For a range of the entrepreneur's unit cost of effort ω , Table 2.1 illustrates the deal initiation process with e_{min} set at 1,000 hours/year.⁹ The VC's offer is the same irrespective of the entrepreneur's private information because it only depends on the VC's belief on e_{min} . The VC asks for an ownership share of 30% and expects to offer 112 hours/year of service (Gorman and Sahlman, 1989, found that VCs typically spend about 110 hours per portfolio firm per year). In scenarios 1 to 4, ω is low and the deal should close for two reasons: the entrepreneur's optimal effort level e^* is more than e_{min} ; and the entrepreneur is expected to experience a large return. In fact, the entrepreneur's disutility of effort is so low that e^* far exceeds the best effort (i.e., 4,000 hours/year). In scenarios 7 to 9, on the other hand, the unit cost of effort is high and the deal should not close because e^* is exceeded by e_{min} . Further, the VC would experience a loss if the offer had been accepted.

TABLE 2.1
Illustrative Example of the Investment Deal Process ($e_{min} = 1,000$ hrs/yr)[†]

Scenario	Entrepreneur's unit cost of effort in \$/hr, ω	Entrepreneur's optimal effort level for the given offer in hr (which cannot exceed 4,000), e^*	Entrepreneur's return in \$ at e^* , E^* ($\times 000$)	Entrepreneur's decision	VC's excess profit in \$ at e^* , P^* ($\times 000$)
1	1	4,000	19,144	Accept	5,355
2	1,000	4,000	15,144	Accept	5,355
3	2,000	4,000	11,144	Accept	5,355
4	3,000	4,000	7,144	Accept	5,355
5	4,000	3,575	3,161	Accept	4,660
6	5,000	1,023	1,169	Accept	48
7	6,000	370	537	Reject	-1,408
8	7,000	157	292	Reject	-1,972
9	8,000	75	182	Reject	-2,223

[†] The VC's offer remains constant (30% in ownership share and 112 hours/year of service) because it only depends on his/her belief on the entrepreneur's minimum effort level e_{min} .

For a range of the VC's belief on e_{min} , Table 2.2 illustrates the deal initiation process with the entrepreneur's unit cost of effort ω set at \$3,000/hour. As e_{min} varies, the VC's offer

⁹ Numerical values in Tables 1 and 2 for the endogenous parameters are those anticipated respectively by the VC and the entrepreneur at the time of signing the deal, not necessarily actual figures observed in the funded venture.

varies. When the VC is not confident about the entrepreneur's performance (that is, e_{min} is extremely low), the VC should not make an offer.¹⁰ In this example, as the VC's belief improves, he/she should be willing to demand a lower ownership share and allocate a lower service level. As a result, the entrepreneur's optimal effort level and expected return should increase, with the former being subject to the 4,000 hours/year upper bound. But the entrepreneur should reject the offer, unless the optimal effort level exceeds e_{min} and his/her expected return is positive.

¹⁰ The deal might still go through even when the entrepreneur only puts in roughly 4 hours for every hour of the VC effort due to positive returns to both parties (e.g., the venture is highly profitable).

TABLE 2.2
Illustrative Example of the Investment Deal Process: ω is set at \$3,000/hour

VC's belief on the entrepreneur's minimum effort level in hr, e_{min}	VC's service level in hr, s	VC's ownership share, α	Entrepreneur's optimal effort level in hr (which cannot exceed 4,000) e^*	Entrepreneur's return in \$ at e^* , E^* ($\times 000$)	Entrepreneur's decision	VC's excess profit in \$ at e^* , P^* ($\times 000$)	Welfare, W^* ($=E^*+P^*$)
1	129.073	> 1 (infeasible)	NA [†]	NA	No offer made	NA	NA
200	115.831	> 1 (infeasible)	NA	NA	No offer made	NA	NA
250	115.253	0.9099	0	50	Reject	-2,523	-2,473
300	114.780	0.7837	24	66	Reject	-2,206	-2,140
350	114.379	0.6907	177	167	Reject	-1,086	-919
400	114.032	0.6191	562	420	Accept	815	1,235
450	113.725	0.5621	1,224	853	Accept	3,217	4,069
500	113.450	0.5156	2,152	1,458	Accept	5,845	7,303
550	113.201	0.4769	3,311	2,213	Accept	8,501	10,714
575	113.085	0.4598	3,964	2,637	Accept	9,798	12,435
576	113.080	0.4592	3,991	2,654	Accept	9,849	12,504
577	113.076	0.4585	4,000	2,672	Accept	9,855	12,527
580	113.062	0.4566	4,000	2,724	Accept	9,802	12,526
585	113.040	0.4534	4,000	2,810	Accept	9,715	12,526
600	112.973	0.4441	4,000	3,061	Accept	9,464	12,525
650	112.764	0.4159	4,000	3,820	Accept	8,701	12,521
700	112.570	0.3914	4,000	4,479	Accept	8,038	12,517
1000	111.634	0.2921	4,000	7,144	Accept	5,355	12,499
2000	109.808	0.1654	4,000	10,529	Accept	1,934	12,464

[†] Not applicable

The richness of such a table is to look for patterns as we illustrate the investment deal process. The upper bound on the entrepreneur's effort level yields interesting observations. If the VC's belief on e_{min} keeps improving beyond a certain point, the entrepreneur reaches the upper bound (i.e., best effort level). At that upper bound, although the VC may be ready to concede a larger ownership share to the entrepreneur, such a generous offer cannot increase the entrepreneur's level of effort further. Consequently, the VC's expected return starts to decrease, although the entrepreneur's expected return keeps increasing due to an increase in his/her ownership share. This phenomenon is illustrated in Table 2.2, where the VC's excess profit peaks for a "critical" e_{min} .¹¹ This phenomenon is also captured in that table for the sum of VC's excess profit P and entrepreneur's expected return E , namely the investment-deal welfare W .

Tables 2.1 and 2.2 further show that the entrepreneur may accept the first offer without renegotiation. The VC may therefore fall prey to overpayment by taking a lower ownership share than necessary to get the offer accepted, because deals that are inefficient *ex-post* can take place under information asymmetry (Kennen and Wilson, 1993; Muthoo, 1999). The VC may reduce the probability of such overpayment by setting e_{min} low and then revising it as necessary. However, overpayments are not necessarily undesirable for the VC. For instance, referring to Table 2.2, the VC's excess profit P increases up to a critical point where e_{min} equals 577 as the VC increasingly overpays and the entrepreneur increasingly gains. This counterintuitive situation arises because the entrepreneur's effort level increases when he/she is given a higher ownership share leading to an increase in the revenue and, as a result, the VC's gain is higher from the enlarged pie, in spite of a diminished share of the pie. Thus, any VC wishing to enhance post-deal excess profit should be willing to overpay.

However, the entrepreneur's private information prevents the VC from knowing *a priori* the critical e_{min} (where his/her post-deal excess profit is maximized). Consequently, systematically overpaying in the hope that he/she can gain more effort from the entrepreneur and increase the size of the pie is not viable. A good strategy for the VC might thus be to demand a moderate ownership share to enhance the chance that he/she overpays (i.e., the offer is accepted) and stays close to the peak excess profit.

In the next section we go a step further by investigating the conditions under which a rejected offer should be revised. We put forward three revision strategies (1. do not revise the offer; 2. revise the offer by reducing the VC ownership share α ; 3. revise the offer by increasing the entrepreneur's base salary b) and illustrate on a two-dimensional space when each strategy is optimal to use. This additional analysis allows us to unearth the importance

¹¹ The excess profit is set to zero while determining the offer, but actual (i.e., post-deal) excess profit will typically be positive (because $e^* > e_{min}$).

of not only the magnitude of a VC's ownership share on investment offers, which has been well recognized in the extant literature in entrepreneurial finance (e.g., Metrick, 2007; Kaplan and Stromberg, 2003; Amit et al., 1998; Bernile et al., 2007; Casamatta, 2003), but also the importance of the magnitude of the change in the VC's service level as his/her beliefs improve regarding the entrepreneur's effort level.

2.4 REVISING THE INVESTMENT DEAL

When the entrepreneur rejects the VC's investment offer and there is an opportunity for revising the deal, the VC can decrease his or her ownership share α , and keep the same base salary b , or increase b and keep α unchanged.¹² However, since these decisions depend on the entrepreneur's minimum effort level e_{min} , that level becomes the main determinant of the offer terms. The VC can revise the offer as long as there is room for upwardly adjusting the minimum effort level. In other words, α can go down, or b can go up, but e_{min} needs to increase because it balances back the loss to the VC. We first look at necessary and sufficient conditions for revising the offer when b is kept fixed. In this case, a change in e_{min} alters both the VC's service level s and ownership share α , and we must thus consider this dual impact to obtain Proposition 1.¹³

Proposition 1:

Case (i). *The marginal change ds/de_{min} in the VC's service level, as the VC upwardly revises his/her belief on e_{min} , is negative.* Then a rejected offer should be revised if and only if this change exceeds a lower bound. The lower bound depends on the value of the ownership share claimed by the VC in the rejected offer.

Case (ii). *The marginal change ds/de_{min} in the VC's service level, as the VC upwardly revises his/her belief on e_{min} , is positive.* Then a rejected offer should be revised if and only if this change is below an upper bound. The upper bound does not depend on the value of the ownership share claimed by the VC in the rejected offer.

When the change ds/de_{min} in the VC's service level per additional unit of the VC's belief on e_{min} is very negative and below a (negative) threshold, the decrease in expected revenue from a reduced service level (due to a higher e_{min}) and the reduced return from a lower ownership share outweigh the saving in service cost. As a result, revising the offer is

¹² It is not clear if VCs revise offers by increasing base salary (since a higher base salary would pose a risk of a larger loss to the VC in the event of venture failure). In fact, one of our VC contacts informed us that they do not. Nevertheless, our survey of VCs (reported in Chapter 4) revealed that the size of the base salary offered can influence whether the deal will close. Since it is not inconceivable that offers may be revised by increasing base salary, we include this analysis. However, that inclusion does not imply that we recommend this kind of revision.

¹³ Proofs of all propositions appear in the appendix.

unattractive to the VC. The lower threshold on the change in service level also translates into a lower threshold for the VC's ownership share, and hence revising the deal is unattractive to the VC unless the ownership share granted remains substantial. Similarly, when the change in service level (from an increase in e_{min}) is positive and exceeds an upper threshold, the cost of service increases considerably. At the same time, a reduced ownership share further diminishes the VC's return, making the revision unattractive.

The specifics of the thresholds on the change in service level ds/de_{min} depend on the sign of that change (as specified in Appendix B). Worth noting are the numerous other factors (i.e., other than the VC's ownership share as per the rejected offer) that affect these thresholds, including: the marginal return to VC service; the marginal productivity of the entrepreneur (as per the VC's belief); the effect of entrepreneurial effort on the marginal productivity of the VC (as per the VC's belief); and the effect of service level on the marginal productivity of the VC. For instance, if the marginal productivity of the entrepreneur (as per the VC's belief) increases, everything else being equal, the threshold on the (negative) service level change is relaxed and revising the offer likely becomes more attractive to the VC. However, if the effect of service level on the marginal productivity of the VC increases (i.e., it becomes more negative), everything else being equal, the threshold on the (positive) service level change becomes tighter and revising the offer likely becomes less attractive. Overall, a larger VC's ownership share as per the rejected offer, a smaller marginal return to VC service, a larger marginal productivity of the entrepreneur (as per the VC's belief), a larger effect of entrepreneurial effort on the marginal productivity of the VC (as per the VC's belief), and/or a smaller (negative) effect of service level on the marginal productivity of the VC should encourage the VC to revise the offer by reducing his or her ownership share.

We also derive a necessary and sufficient condition under which the change in service level ds/de_{min} is positive. Specifically, that change is positive when the VC's productivity per additional unit of e_{min} is above a critical threshold (formally, $\frac{ds}{de_{min}} > 0$ if and only if $R_{se_{min}} > \frac{R_s \cdot R_{e_{min}}}{R}$, as shown in Appendix B). The rationale is that, when the VC's productivity is large enough, the increase in revenue due to increased service offsets the increase in the cost of service, encouraging a positive change in service level.

Proposition 2, instead, highlights a necessary and sufficient condition under which revising a rejected offer should take place when the VC's ownership share α is kept fixed but the base salary b is increased. Contrary to Proposition 1, we note in this case that, although the VC's belief on e_{min} is still a key determinant of the offer terms, whether or not the offer should be revised is unaffected by the adjustment made on that minimum effort level. We do

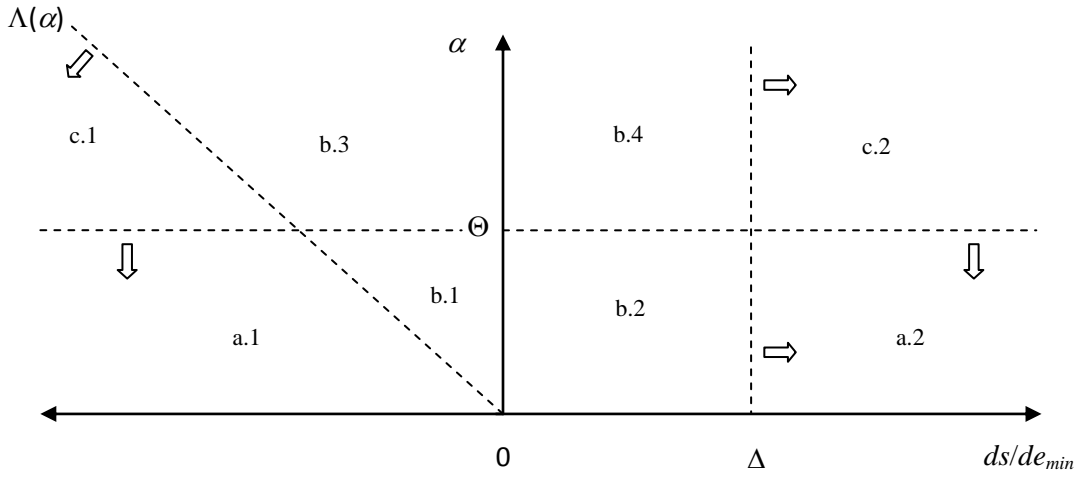
verify, nevertheless, that the VC's service level should increase with an upward adjustment in e_{min} (i.e., $\frac{ds}{de_{min}}$ is always positive).

Proposition 2: Revising the deal by increasing the entrepreneur's base salary should take place if and only if the VC's ownership share exceeds a critical threshold.

Since the initial investment offer was made based on no excess profit, an increase in the base salary is desirable only if the VC's share of revenues increases over and above the additional cost of service arising from an upward adjustment in the VC's belief on e_{min} . As a result, the VC's ownership share must exceed a certain threshold. That threshold depends on the following: the unit cost of service, the VC's marginal productivity and the effect of service level on that productivity, the entrepreneur's marginal productivity (as per the VC's belief), and the effect of the entrepreneur's effort on the marginal productivity of the VC (as per the VC's belief). Specifically, a lower cost for the VC's time, a higher productivity for the VC, a smaller (negative) effect of service level on that productivity, a larger effect of the entrepreneur's effort on the marginal productivity of the VC (as per the VC's belief), and/or a higher entrepreneurial productivity should encourage a revision by increasing the base salary.

Figure 2.1 summarizes when and how the decision to revise the offer should take place based on Propositions 1 and 2, while Table 2.3 summarizes our sensitivity analysis on whether or not the decision to revise is more likely to happen based on how a change in a key model parameter affects the various critical thresholds. Figure 2.1 also shows the directions in which those thresholds should move to increase the likelihood of revising. These revision strategies complement existing literature (Fried and Hisrich, 1994; Pintado et al., 2007; Zutshi, 1999) by emphasizing the role played by not only the characteristics of the entrepreneur but also those of the VC (service level) in firm valuation and expected returns. Also, we note that Propositions 1 and 2 result from the moral hazard arising from the VC, because the conditions for whether or not to revise an offer are born from the constraints he or she faces. But the need to revise arises from the constraints of the entrepreneur as he or she is the one who decides to accept or reject the initial offer.

FIGURE 2.1
Summary of Revision Strategies



Legend:

- α Ownership share claimed by the VC in the rejected offer
 - ds/de_{min} Marginal change in the VC's service level as the VC upwardly revises his/ her belief on e_{min}
 - Δ Threshold on the change in the VC's service level when that change is positive
 - $\Lambda(\alpha)$ Threshold on the change in the VC's service level when that change is negative
 - Θ Threshold on the VC's ownership share when that share is fixed
 - b The entrepreneur's base salary
 - a.1 & a.2 Regions where the strategy "Do not revise the offer" applies
 - b.1 & b.2 Regions where the strategy "Revise the offer by reducing α " applies
 - b.3 & b.4 Regions where the strategy "Revise the offer by reducing α or increasing b " applies
 - c.1 & c.2 Regions where the strategy "Revise the offer by increasing b " applies
- Mathematical expressions for the thresholds are detailed in Appendix B. The block arrows show the direction in which those thresholds should move to increase the likelihood of revising.

TABLE 2.3
Sensitivity of the Decision to Revise the Investment Offer

Increase in the parameter	The probability of selecting		
	Revision Strategy 1: Do not revise the offer (a.1 + a.2)	Revision Strategy 2: Revise the offer by reducing the VC's ownership share α (b.1 + b.2 + b.3 + b.4)	Revision Strategy 3: Revise the offer by increasing the entrepreneur's base salary b (c.1 + c.2 + b.3 + b.4)
R_{semin} : effect of the entrepreneur's effort on the marginal productivity of the VC (as per the VC's belief) a measure of teamwork	Decreases	Increases	Increases
$ R_{ss} $: effect of service level on the marginal productivity of the VC	Increases	Decreases	Decreases
R_{emin} : marginal productivity of the entrepreneur (as per the VC's belief)	Decreases	Increases	Increases
R_s : marginal productivity of the VC	Decreases	No change	Increases
α : VC's ownership share in the rejected offer	Decreases	Increases	No change
c : marginal return to service a measure of the VC's time constraint	Increases	Decreases	No change
w : unit cost of service	Increases	No change	Decreases

2.5 IMPACTS OF THE BASE SALARY

We bring our analysis of the VC investment deal process to an end by fixing the VC's belief on the entrepreneur's minimum effort level e_{min} . We do this to study the influence of the base salary b (paid to the entrepreneur) on the VC's ownership share α and on the VC's service level s , as well as the influence of b on the entrepreneur's effort level e and return E , the VC's excess profit P , and on the investment-deal welfare $W (= P + E)$. In the absence of a steady income, a base salary may be necessary for the entrepreneur. But whether an increase in its magnitude causes both parties' returns to be better or worse is unclear. Proposition 3 articulates our findings.

Proposition 3: Everything else being equal, if the VC increases the entrepreneur's base salary, then that VC's ownership share and service level should increase. The resulting increase in the VC's ownership share does not necessarily decrease the entrepreneur's optimal effort level, nor does the increase in the base salary necessarily increase the entrepreneur's return, decrease the VC's excess profit, or decrease the investment-deal welfare.

When the VC increases the entrepreneur's base salary (yet keeping e_{min} fixed), the VC must increase his or her ownership share to keep the excess profit non-negative. Since the VC must also satisfy the portfolio value-maximizing constraint (incentive compatibility constraint) in Eq. (3), the VC's marginal productivity decreases due to the increase in ownership share. The service level s must then increase due to the decreasing nature of the VC's productivity as s increases.

Although the literature supports that an increase in the VC's ownership share should decrease the entrepreneur's incentive to allocate more effort (e.g., Amit et al., 1998), prior work has ignored the positive impact of the VC's service level on the entrepreneur's productivity, which can encourage the entrepreneur to allocate more effort. Furthermore, the entrepreneur's return may decrease in spite of an increase in the base salary because the entrepreneur's ownership share decreases. We also note that, even though the entrepreneur's base salary is a direct loss to the VC and paying a base salary above the ongoing market wage may attract the wrong kind of entrepreneurs, the VC can still benefit from increasing it because the VC's increase in ownership share may result in a larger excess profit.

These observations add to the entrepreneurial finance literature, which has been limited regarding the importance of entrepreneurial salaries. Keuschnigg and Nielsen (2001, 2002) and Repullo and Suarez (2003) have modeled upfront payments, although they rationalize them based on the surplus transferred to the entrepreneur when VCs compete to obtain an investment deal. This surplus is, however, only available if a VC has made an offer while facing a positive excess profit. Then, for a given ownership share, the VC can offer a

base salary as high as that excess profit. But, as per our findings, such excess can instead be transferred by increasing the entrepreneur's ownership share. We already noted that the VC's ownership share increases when a base salary is paid at zero excess profit. Thus, a base salary costs the entrepreneur some of his or her ownership share whether the offer is made at a surplus or at no excess profit.

2.6 CONCLUSION

Entrepreneurship scholars (Fried and Hisrich, 1994; Messica, 2008; Levie and Gimmon, 2008) suggest that entrepreneurial characteristics (the outcome of which is the level of effort allocated by the investment-seeking entrepreneur) are crucial to firm valuation and, in turn, the VC's expected return and desire to invest. We therefore studied the VC investment deal process based on those characteristics, the conditions that encourage a rejected offer to be revised, and when and whether the entrepreneur and/or the VC can benefit from including a base salary for the entrepreneur as part of the deal. We now address strategy implications based on our findings, and conclude with a discussion of some limitations of our study and opportunities for future work.

Making entrepreneurial characteristics more transparent can benefit entrepreneurs. Our illustrative example (Table 2.2) suggested the existence of a critical value for the VC's belief on the entrepreneur's level of effort e_{min} , where the VC's excess profit and the investment-deal welfare (total of net returns to both parties) reach an optimal value. The VC would not want to be in the region above this critical value since in that region the entrepreneur would—to the detriment of the VC—take an increasingly larger share of the value created by the venture. Nevertheless, since Table 2.2 suggests that the entrepreneur's ownership share and return might increase with an increase in e_{min} , the entrepreneur may find that informing the VC about his or her entrepreneurial characteristics (thereby diminishing the amount of private information and increasing the VC's confidence) is in that entrepreneur's best interest.

Service rendered and teamwork may be crucial to VC investment. Our propositions 1 and 2 also propose that the VC be encouraged to revise the offer when he/she can maintain a high level of productivity even at high levels of service (sensitivity in Table 2.3 on R_{ss}). This implication from our model is consistent with Hsu's (2004) work, where entrepreneurs are found to accept lower valuation for a highly reputed VC, suggesting that the 'quality' of the VC is important. VCs of higher 'quality' possess greater expertise that enables them to maintain higher levels of productivity, even at high levels of service. Further, if service allocated by the VC enhances the entrepreneur's marginal productivity (and vice versa)—i.e., they work well together (sensitivity in Table 2.3 on R_{semin})—then the VC would be encouraged to revise the offer. These observations complement the findings of Valliere and

Peterson (2007), where teamwork between the VC and the entrepreneur has also been found crucial in VC financing. Our analysis therefore further complements this literature by characterizing conditions that should encourage an investment offer to be revised, if rejected, based on both the importance of service level exercised by the VC and the teamwork of the parties involved.

VCS' time constraints may discourage them from revising their offers. Proposition 1 further shows that the threshold on the ownership share is expected to augment with an increase in the marginal return to service (sensitivity in Table 2.3 on *c*), making a revision less likely. Existing literature has not yet uncovered this insight on the impact of the marginal return to service on deal closing. Although the need for VCs to claim an ownership share is well-documented (Amit et al., 1998), what characterizes the actual level (and the threshold to exceed) is still under scrutiny.

Industry specialization may encourage VCs to close more deals. The preference of the entrepreneur for high productivity on the part of the VC at high levels of service necessitates a high 'quality' VC, as noted in the previous implication. The VC can alleviate this pressure on himself/herself by specializing in a few industries and, as a result, be more productive to the invested ventures, even at high levels of service. Specialization would then encourage VCs to revise their offers more often and potentially invest in more ventures. This implication is consistent with existing literature, including Norton and Tenenbaum (1993), where VCs have been observed to specialize rather than diversify.

Entrepreneurs may lose, yet VCs gain from the payment of a base salary. Proposition 3 proposes that the entrepreneur may be worse off (in terms of expected return), yet the VC better off (in terms of excess profit), when the entrepreneur receives a base salary. Scholars, including Keuschnigg and Nielsen (2001, 2002) and Repullo and Suarez (2003) have claimed that, when VCs compete for a deal, a base salary should be offered to transfer surplus to the entrepreneur to the detriment of the VC. However, our analysis suggests that, independently of whether or not competition is present, the payment of a base salary can favor the VC due to its influence on the VC's ownership share and on both VC's service level and entrepreneur's effort level.

But if you pay them well, be ready to put more effort. Proposition 3 also suggests that, everything else being equal, if the VC pays a base salary to the entrepreneur, then the VC's service level should increase; in other words, they are not substitutes. Although this appears counter-intuitive, we first note that the VC claims a higher ownership share when paying a base salary. Consequently, the VC has to supply more service to maximize his or her portfolio value. For the entrepreneur, his or her ownership share decreases with the acceptance of a base salary, yet the entrepreneur's optimal effort level may not decrease

because the VC supplies more service, which in turn tends to increase the entrepreneur's effort level (due to teamwork between both parties). The literature has dealt with base salary payment (e.g., Keuschnigg and Nielsen, 2001), but the impacts of such payments on the effort levels of the VC and of the entrepreneur have not been as deeply scrutinized.

While our analysis is theoretical and based on mathematical reasoning, the underlying tradeoffs we have used and those we have uncovered are familiar in the entrepreneurship literature. Nevertheless, our principal-agent model has allowed us to effectively capture the double-sided moral hazard present in the investment deal, and consider the private information held by the entrepreneur, while investigating the sensitivity of the investment offer as the VC alters his/her belief on the entrepreneur's effort level. More specifically, we have unearthed the importance of not only the magnitude of a VC's ownership share, but also of the marginal change in that VC's service level as he/she alters that belief (Figure 2.1 and Table 2.3). We have also added some rigor by offering a formalized iterative process of the deal, which is in sync with the so-called VC method and has predictions consistent with empirical outcomes. Particularly, we show that a VC uncertain about the entrepreneur's effort does not need to offer a share just above zero, because his/her excess profit (post-deal) does not need to monotonically increase as the entrepreneur's share decreases. For instance, Metrick (2007) argues that VCs may estimate a probability of successful exit well above zero, while Kaplan and Stromberg (2003) suggest that VCs typically only require a moderate ownership share.

Our arguments, however, have limitations because they are based on some modeling assumptions. For instance, a lack of teamwork (i.e., $R_{es} < 0$ and/or $R_{se} < 0$) may arise. Relaxing the teamwork assumption would add flexibility to our insights, even though the vast majority of deals involve fairly thorough assessments to ensure teamwork. Also, inspired by our framework and simulation that reveal the presence of a deal-welfare-maximizing ownership share, future research could focus on how to design contracts (maybe with milestone payments) that can maximize investment-deal welfare in the presence of private information on the entrepreneur's disutility of effort. As our simulation demonstrated, while determining the investment offer the use of "gut feeling" instead of milestone payments can result in a suboptimal ownership share (from the view point of maximizing either the VC's excess profit or the investment-deal welfare). Further research on the investment-deal phenomenon would certainly uncover more insights on the VC-entrepreneur relationship and on what encourages a deal to close.

Chapter 3

Properties of the Venture Capital Deal Space

3.1 INTRODUCTION

In this chapter, we report the simulation study based on our theoretical model of Chapter 2.¹⁴ We used wide domains for the model parameters so that the simulation study covers all practically relevant regions of the VC investment deal space. Using quasi-randomly generated parameters, we computed deal outcomes. We used the resulting synthetic data to verify our suggestion in Chapter 2 that there may exist a “critical” point in the VC’s belief about the entrepreneur’s minimum effort level e_{min} that maximizes the VC’s excess profit as well as the investment deal welfare; we also used the data for regression analyses to uncover insights that the theoretical model does not readily reveal (sensitivity analysis through algebraic derivations is not possible for some deal outcomes). Finally, we synthesized the findings to answer some practically relevant questions.

In §3.2, we describe the Monte-Carlo method that we used for the simulations. While in §3.3 we provide a description of our simulation study, we report our regression analyses in §3.4. We answer some practically interesting questions and identify implications for practice in §3.5 and conclude in §3.6. The pseudo-code and the computer codes used for the simulations are furnished in Appendices C and D.

3.2 MONTE CARLO METHODS

Monte Carlo simulation

Monte Carlo (MC) simulation is a class of computational algorithms that rely on repeated random sampling to compute results. Metropolis and Ulam (1949), among the earliest pioneers of the method, described the method as summarized here: (a) Define a domain of possible inputs; (b) Generate inputs randomly from the domain using a specific probability distribution; (c) Perform a deterministic computation using the inputs; and (d) Aggregate the results of the individual computations into the final result. Two key properties of MC simulation are: the computation's reliance on good random numbers, and its slow convergence to a better approximation as more data points are sampled.

¹⁴ This simulation study was inspired by Rod McNaughton’s suggestion to me to simulate the theoretical model in conjunction with a case study or a VC survey. Mary Thompson guided me into the right track by advising me to consider Quasi-Monte Carlo simulation. Christiane Lemieux, Hooria Munawar, and Pal Subbiah lent helpful advice. I thank Brian Cozzarin for his advice on econometric modeling. Any errors that may remain are mine.

Quasi-Monte Carlo Simulation

Quasi-Monte Carlo (QMC) simulation, which performs better than MC simulation with respect to convergence (e.g., Morokoff and Caflisch, 1995; Sloan and Wozniakowski, 1998; Niederreiter, 1978), varies from MC simulation in two key respects: one, inputs are generated quasi-randomly in a space-filling manner, within the domains specified, using low-discrepancy sequences such as Sobol or Korobov; second, results pertaining to different points in the multi-dimensional hypercube (problem space) can be studied, but may not be aggregated to arrive at an overall result since inputs are not chosen using probability distributions of those inputs.

Applications of Monte Carlo Methods

Monte Carlo methods have been used in a wide range of applications in natural sciences (Caflisch, 1998), even extremely critical applications such as nuclear weapon projects. Physicists at Los Alamos Scientific Laboratory were investigating radiation shielding and the distance that neutrons would likely travel through various materials. Despite having most of the necessary data, the problem could not be solved with theoretical calculations. John von Neumann and Stanislaw Ulam suggested that the problem be solved by modeling the experiment on a computer using chance. Being a secret, their work required a code name. Von Neumann chose the name "Monte Carlo" (Metropolis, 1987; Lemieux, 2009).

Simulation has been widely used in social sciences—for example, to test models with synthetic data (e.g. Cozzarin and Westgren, 2000). In finance—of greater relevance to us—Monte Carlo methods are often used because most finance models do not have analytical solutions (Joy, Boyle, and Tan, 1996), an issue that we share because decision rules and restricted domains for some parameters make algebraic derivations of closed-form solutions considerably difficult for us. Some of those finance applications include calculating the value of companies, evaluating investments in projects at the business unit or corporate level, and evaluating financial derivatives, by simulating various sources of uncertainty that affect their value.¹⁵

In fact, simulation is such a powerful tool of analysis that a variety of applications can make use of this. For example, governments may use it to predict how tax revenues will change and different sections of population be affected if a complicated piece of tax legislation is implemented. Central banks may use it to predict the risks of catastrophic events in the economy as contributing parameters in the economy change. Though the mathematics of simulation is well-advanced, challenges in modeling the phenomenon being

¹⁵ Phelim Boyle pioneered, in 1977, the use of simulation in derivative valuation (Lemieux and L'Ecuyer, 2001; Boyle, 1977).

studied limit the use of simulation. The problem is more acute in social sciences than in natural sciences.

3.3 DESCRIPTION OF THE SIMULATION STUDY

3. 3.1 Rationale for the simulation study

Monte Carlo methods are appropriate for our purpose because these methods are helpful when it is infeasible or impossible to compute an exact result with a deterministic algorithm (Hubbard, 2007). In our case, a deterministic model using empirical data is infeasible because it is impractical to find a large number of empirical observations that cover the entire deal space - for example the cost of venture capital r (which is empirically around 15% as per Metrick, 2006) and base salary b (a wide domain of which we would like to study but may be difficult to empirically observe). In other words, though empirical, available data points may not be large enough rendering this kind of deterministic modeling to be of limited use for our purpose.

Secondly, some parameters of our model are difficult to extract from real data. For example, entrepreneurs will probably under-state their disutility of effort (captured by unit cost of effort ω). Even if they do not, it would be difficult for them to quantify it. Similarly, while VCs can be expected to truthfully reveal their beliefs about entrepreneur's minimum effort level e_{min} , it would still be difficult for them to quantify it. Another parameter that may be difficult to quantify is VCs' marginal return to service c across their portfolio ventures that is a measure of their time constraints. On the other hand, if we use MC simulation, we can randomly generate values for such parameters of our model provided we are able to make reasonable distributional assumptions for those parameters. If we use the quasi-Monte Carlo (QMC) simulation and quasi-randomly generate values in a space-filling manner, we will not even need to make those distributional assumptions.

Thirdly, entrepreneurs and VCs may resort to intuition to quantify such parameters in view of the above difficulty. It has been found that the Monte Carlo methods are useful for modeling phenomena with significant uncertainty in inputs and that actual observation is routinely better predicted by simulations than by human intuition (Hubbard, 2009).

Fourthly, a simulation study based on Monte Carlo methods can generate large amounts of synthetic data, on which regression analyses can be carried out to uncover new insights about the sensitivity of deal outcomes with respect to various model parameters. An alternate approach for sensitivity analysis is to find the simple derivative of deal outcome Y with respect to a model parameter X_i (i.e., $\partial Y / \partial X_i$), but that approach is not always feasible. For example, we would be interested in studying the sensitivity of the deal outcome "Probability of VC Making an Offer"; but it is difficult to derive an expression for that deal outcome from our mathematical model of the investment process in §2.3. On the other hand,

we can study the sensitivity of that deal outcome by employing Probit model on synthetic data generated using our mathematical model. Such a procedure is known as “sampling-based sensitivity analysis” where—once the sample is generated—several strategies (including simple input-output scatter plots) can be used to derive sensitivity measures (e.g., Helton, Johnson, Salaberry, & Storlie, 2006; Pannell, 1997). Applications in Finance are abundant since analytical solutions are often absent (e.g., Joy, Boyle, & Tan, 1996; Lemieux & L’Ecuyer, 2001; Boyle, 1977).

Lastly but more importantly a simulation study *per se* may reveal some unforeseen phenomena of the deal process. In Chapter 2, the illustrative example had revealed the possible existence of a “critical” point in the VC’s belief (and, correspondingly, in his or her ownership share) that maximizes the VC’s excess profit as well as the investment deal welfare. In fact, because of great practical significance of such a finding, one of the necessities of a simulation study was to reconfirm whether such a critical point indeed exists everywhere in the hypercube (that is, under a variety of scenarios).

Still another—albeit minor—use of the simulation study is that we can verify our propositions. Though we have proofs for those propositions, verification through simulation will help us make sure that no inadvertent errors have taken place in the proofs and the resulting conclusions.

3.3.2 Rationale for choosing QMC simulation

We chose Quasi-Monte Carlo simulation since the use of MC simulation is not always appropriate. Since MC simulation uses inputs drawn using probability distributions, the results provide probabilities of different outcomes occurring (as in reality). On the other hand, QMC simulation is essentially deterministic modeling (L’Ecuyer and Lemieux, 2002). The problem with this method is that inputs assigned to a parameter to represent different scenarios are all accorded the same weight, which may not be realistic (because some scenarios may be more likely in reality than other scenarios). It has been noted that (probabilistic) MC simulation has a narrower range—that is, more accurate results—than (deterministic) QMC simulation because the latter assigns equal weight to all scenarios (Vose, 2000).

However, QMC simulation is better suited when probability distributions of parameters are not known with reasonable confidence and hence aggregate results cannot be determined anyways (PucRio, 2009). Recall that our theoretical model, in conjunction with our choice of the Cobb-Douglas production function (used by Fairchild, in press) for the revenue function in our illustrative example, has allowed us to characterize the VC investment deal process as a 12-dimensional hypercube where the twelve dimensions or

exogenously determined parameters are $r, I, w, c, b, k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma, \omega$, and e_{min} .¹⁶ Information on the probability distributions of these parameters is scant in the literature. While we may be able to make reasonable distributional assumption for some parameters (such as log-normal for investment I), it is clear that aggregated results will be debatable. For this reason, QMC is better suited for our purpose. It may be noted that MC simulation using uniform probability distributions may serve this purpose, but generating inputs using quasi-random sequences (as QMC does) is more efficient (PucRio, 2009).

Secondly, MC simulation is time-consuming in terms of computation. So in general, it is to be preferred to deterministic algorithms only when there are several sources of uncertainty, in which case the latter method would be even more time-consuming (PucRio, 2009). If there are d sources of uncertainty (dimensions) and we wish to consider n sample points in each of those dimensions, the deterministic algorithms will perform n^d computations (that is, they have exponential time-increase), whereas MC simulation will only randomly pick N sample points in the d -dimensional hypercube (where N is a polynomial function of d) and perform N computations (that is, they have polynomial time-increase and, typically, $N(d) \ll n^d$). In our case, the number of exogenously-determined parameters is twelve, which is not small (Bratley, Fox, and Niederreiter, 1992) especially considering that we would like to have a large sample size.

However, QMC simulation makes use of low-discrepancy sequences (also known as quasi-random sequences) to generate inputs, which permits it to achieve a given accuracy with a number of computations that is much less than n^d thereby decreasing the run-time considerably. In fact, QMC's performance can even be better than MC's (Wang and Fang, 2003). It has been found that QMC performs much better than MC for high dimensions in the best case though it performs much worse in the worst case. However, it has also been found that the worst-case bound is not very reliable for practical purposes. Moreover, N would be much larger (for MC) than the number of points necessary for QMC, for a given level of accuracy. Hence QMC is to be preferred to MC in cases similar to ours (PucRio, 2009). This is a secondary reason why we employ QMC simulation.

3.3.3 Developing Parameters

We chose samples for the twelve model parameters quasi-randomly from wide domains, which are necessary to capture most of the conceivable venture capital deal space. However, too large a hypercube will be practically irrelevant (for example, specifying a maximum limit of \$100 million for investment amount I for a start-up is unwarranted), in fact undesirable because it will dramatically increase the total number of sample points in order to have adequate number of points in the practically relevant regions of the hypercube. A very large

¹⁶ The revenue function used is $R(e, s) = k_1 e^{\varepsilon_1} + k_2 e^{\varepsilon_2} s^\sigma$.

simulation run will take a very large run time thereby discouraging us from freely experimenting different runs. Table 3.1 below summarizes the domains specified in the simulation study vis-à-vis the specific values used in the illustrative example in Chapter 2.

Recall that, in our illustrative example in the previous chapter, we chose specific values for the various parameters supported by the literature, and then varied ω and e_{min} to study deal outcomes. Table 3.1 shows that the domains used in simulations for the various parameters are wide enough in comparison to the values used in the illustrative example. We have very likely captured in our hypercube the empirically relevant regions of the VC deal space.

TABLE 3.1
Parameter Domain Specifications

Parameter	Description	Minimum	Maximum	Specific value used in the illustrative example	Remarks
r	Cost of venture capital	0%	100%	15%	
I	Investment amount	\$500,000	\$10,000,000	\$2,000,000	
w	Unit cost of service	\$500 / h	\$10,000 / h	\$1,500 / h	
c	Marginal return to service (a measure of the VC's time-constraints)	0	\$10,000 / h, but $c \leq w$	\$500 / h	Since more profitable activities would be exhausted first, we set $c \leq w$
b	Base salary	0	\$500,000	\$50,000	
k_1	Relative importance of the entrepreneur's solo-work	1	100,000	10,000	
k_2	Relative importance of team work	1	100,000	10,000	
ε_1	Entrepreneur's effectiveness in solo-work	0	0.99	0.85	This upper limit ensures concavity
ε_2	Entrepreneur's effectiveness in teamwork	0	0.99	0.8	
σ	VC's effectiveness (in teamwork)	0	0.99, but $\varepsilon_2 + \sigma \leq 0.99$	0.15	We set $\varepsilon_2 + \sigma \leq 0.99$ to ensure concavity of teamwork
ω	Unit cost of effort	\$1 / h	\$80,000 / h	(\$1 / h, \$8,000 / h)	
e_{min}	VC's belief on the entrepreneur's minimum effort level	1 h	4,000 h	(1, 2000)	The 4,000 upper limit operationalizes best effort

We used Sobol sequence (a well known low-discrepancy sequence) to quasi-randomly choose sample for the above parameters. This is a space-filling sequence that covers the space efficiently—that is, a low number of Sobol points are sufficient to cover the space for a given accuracy of results (e.g. Lemieux, 2009; PucRio, 2009). Table 3.2 gives a summary of the samples generated for the twelve parameters in a run that involved 10,400 12-dimensional quasi-random points. An inspection of the means, standard deviations, minimum, and the maximum assures that Sobol sequence has indeed returned a space-filling sample of points.

TABLE 3.2
Summary of Quasi-Random Samples

Parameter	Number of quasi-random samples	Mean	Std. Dev.	Min	Max
r	10,400	0.4998996	0.2886794	0.0001221	0.999878
I	10,400	5,248,470	2,742,521	500,580	10,000,000
w	10,400	5,249.499	2,742.482	501.16	9,999.42
c	10,400	3,495.556	2,306.63	0.610352	9,943.85
b	10,400	249,987.9	144,327.3	61.0352	499,939
k_1	10,400	49,496.88	28,576.25	7.04248	98,988.9
k_2	10,400	49,497.5	28,576.08	13.085	98,988.9
ε_1	10,400	0.4950638	0.2857662	0.0001209	0.98994
ε_2	10,400	0.4950202	0.2857885	0.0001209	0.98994
σ	10,400	0.3305472	0.2337187	0.0000604	0.976042
ω	10,400	40,005.38	23,091.55	10.7655	79,995.1
e_{min}	10,400	2,000.525	1,154.364	1.24408	3,999.51

3.3.4 Additional assumptions for simulation

We used in the simulation study the same specific functional form for revenue that we used in the illustrative example in Chapter 2. Moreover, we employed several assumptions in the simulation study in order to abstract the reality as richly as possible and harness the power of simulation to uncover as many new insights as possible about the venture capital deal process. Those assumptions are: (a) the entrepreneur can create value in solo-work (that is, even if the VC only invests and does not provide service; $k_1 > 0$) whereas the VC cannot do so in the startup without the entrepreneur,¹⁷ (b) Teamwork is more important to the venture than the entrepreneur’s solo-work ($k_2 > k_1$) or vice-versa ($k_1 > k_2$), (c) the VC may be more effective than the entrepreneur in their teamwork ($\sigma > \varepsilon_2$) or vice-versa ($\varepsilon_2 > \sigma$), (d) there is a

¹⁷ The entrepreneur’s effort is essential in the early-stages of the venture (Hellmann, 2007). As the venture grows, the VC would increasingly be able to dispose the entrepreneur if necessary (e.g. Gorman and Sahlman, 1989).

maximum limit to the VC's service level to any firm in his/her portfolio (we set $s \leq 1000$ hours / year),¹⁸ and (e) there is a maximum limit to entrepreneur's performance – that is, there is a best effort (we set $e^* \leq 4,000$ hours/year and $e_{min} \leq 4,000$ hours/year).¹⁹

3.3.5 Simulation runs, Pseudo-code, and Implementation

We carried out two simulations. First, we quasi-randomly chose all the parameters except e_{min} and then computed the deal outcomes for the entire range of e_{min} for each of the resulting 11-dimensional points that constitute a deal scenario; we then investigated if there exists a “critical” value of e_{min} that maximizes the VC's excess profit as well as the investment deal welfare. Second, we quasi-randomly chose all the twelve model parameters and used the resulting synthetic data to carry out regressions to generate predictions on deals; we also extended this simulation to cover offer revisions and investigated if all the propositions hold always.

It is useful to elaborate on the important difference between the two simulations. To understand the difference, we need to recall that a combination of *eleven* parameters of the model (excluding e_{min}) characterize a deal *scenario* that the VC may face. The question of a *deal* only arises when the VC—facing a scenario—takes on a particular level of belief on e_{min} to determine an offer. That is, a combination of all *twelve* parameters characterizes a deal (which may close or not). In Simulation I, we simulate scenarios to find out if each scenario has a “critical” value of e_{min} . On the other hand, in Simulation II, we simulate individual deals to ultimately generate predictions on deals.

Before programming in any simulation software or a general programming language, it is useful to write a pseudo-code from the problem since that would help to organize the problem before starting coding (e.g., Olsen, 2005; Linn and Clancy, 1992; Lee, Bard, Pinedo, and Wilhelm, 1993). Hence initially we wrote pseudo-code that is in Appendix C.²⁰ Pseudo-code is a kind of structured English for describing algorithms. It allows the designer to focus on the logic of the algorithm without being distracted by the details of the language syntax of the software program in which the simulation is implemented. At the same time, the pseudo-code needs to be complete. It should describe the entire logic of the algorithm so that implementation becomes a rote mechanical task of translating line by line into source code.

¹⁸ Recall that Gorman and Sahlman (1989) found that VCs' total available time and average service hours to any one firm for a one year period are, respectively, 2,000 hours and 110 hours. Since VCs use about half of their time in activities (other than service) such as screening and due diligence of potential investments (e.g. Fried and Hisrich, 1994), the maximum service a firm can hope to receive is 1,000 hours if that firm is the only firm in its VC's portfolio.

¹⁹ The plausibility of a cap on the entrepreneur's effort level (i.e., the existence of best effort) is recognized in some studies such as Innes, R. D. (1990).

²⁰ As the simulation project progressed, we tried various simulations and did not feel the necessity to write pseudo-code any more. Hence the pseudo-code furnished only covers a part of our simulations.

In general the vocabulary used in the pseudo-code should be the vocabulary of the problem domain, not of the implementation domain. The pseudo-code is a narrative for someone who knows the requirements (problem domain) and is trying to learn how the solution is organized. However, the logic must be decomposed to the level of a single loop or decision (Pseudo-code, 2003). Depending on the writer, pseudo-code may vary widely in style, from a near-exact imitation of a real programming language at one extreme, to a description approaching formatted prose at the other (Pseudo-code, 2009). Our pseudo-code used the vocabulary of our problem domain, but could readily be used for coding.

The simulations were programmed in C++ and implemented in Microsoft Visual Studio 2008 SP1, an integrated development environment from Microsoft. The simulation code is furnished in Appendix D.²¹ There are many mathematical computing programs such as MATLAB, Octave, Maple, and Mathematica and we had originally planned to use MATLAB for its versatility and popularity. However, we later chose C++ because it is fast. Run-time was the most important consideration for us since we planned to run large simulations involving a million computational cycles.

3.3.6 Simulation I for Studying the Properties of the Deal Space

In Simulation I, which we carried out to check if there indeed exists a critical point in the VC's belief (about the entrepreneur's minimum effort level e_{min}) as suggested by our illustrative example of Chapter 2, we chose 5,200 scenarios (defined by eleven of the model parameters—namely, $r, I, w, c, b, k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma,$ and ω) quasi-randomly and then, for each of those scenarios, we varied the parameter e_{min} from 0 to 4,000 hours in steps of 20 hours. Thus we generated a total of $5,200 \times 200 = 1.04$ million 12-dimensional points (deals) and computed various deal outcomes for each of those 1.04 million points (e.g., the VC's optimal ownership share and service level, whether the offer is feasible or not, the entrepreneur's optimal effort level subject to its cap and his/her return, whether the offer is accepted or not, the VC's actual excess profit, and the deal welfare). In other words, we froze all the parameters except e_{min} and studied how the deal outcomes vary as we vary e_{min} . We then checked if there is an e_{min} (and a corresponding critical α) that maximizes the VC's excess profit and the investment deal welfare. Once we finished with a particular scenario, we did the same for another scenario. We repeated the above cycle for all the 5,200 scenarios. Since run time was expected to be several hours, the run was split into four separate runs (each run being a continuation of the previous Sobol sequence) and four spreadsheets each containing 260,000 records were created.

We then inspected the results to find out if there exists—for each scenario—a unique critical value of e_{min} . Our illustrative example in the previous chapter had also suggested a

²¹ We tried various simulations in the simulation study but furnish here only the most essential codes.

critical value for the VC's ownership share α as depicted in Table 2.2 (we recall that unique solution for α^* for a given e_{min} in §2.3.1 implies a unique correspondence between e_{min} and α). Consequently, we expected and looked for the existence of a critical value of α (corresponding to the critical value of e_{min}) too. The findings follow.

Simulation I confirms that, for every scenario where a deal can close (i.e. the maximum value of the VC's excess profit P was positive at least for part of the domain of e_{min} , so there is a chance that the VC will put forth an offer that may be acceptable to the entrepreneur), there indeed exists a unique critical value of e_{min} (which we denote e_{minP}) and a corresponding unique critical value of α (denoted α_P) that maximize the VC's excess profit P . The simulation results also show that there exist critical values of e_{min} and α (denoted e_{minW} and α_W) that maximize the investment deal welfare W , but that those values are not necessarily the same as those that maximize the VC's excess profit P . In fact, the simulation results also revealed the existence of a critical value of e_{min} denoted e_{minE} (and a corresponding critical value of α denoted α_E) that maximizes the entrepreneur's return E . All these critical values only exist for scenarios that have a possibility of deal closure.²²

Of the 5,200 scenarios of Simulation I, only 1,035 have a possibility of deal closure. In other words, the entrepreneur's optimal effort level e^* is greater than or equal to e_{min} (and the VC's post-deal excess profit is nonnegative) at least for part of the domain of e_{min} . We found that all these 1,035 scenarios have unique values for e_{minE} , e_{minP} , and e_{minW} . Moreover, we found that there is unique global maximum for E , P , and W for these 1,035 scenarios. Same results were observed for α_E , α_P , and α_W . Another observation was that once the investment deal welfare is maximized it only decreases marginally with a further increase in e_{min} (or a decrease in α) for a vast majority of scenarios. Only a few scenarios had steep declines.

Figures 3.1 to 3.3 depict, respectively, how E , P , and W (all in the Y-axis) vary with the VC's belief on e_{min} (in the X-axis) for the first five scenarios of the 1,035 scenarios that have a possibility of deal closure. Figure 3.4 depicts in a single graph how E , P , and W vary for one of those five scenarios. In all these figures, peak values are also marked for easy reference.

²² These critical values also exist for scenarios where no deal can close (i.e., where the VC's excess profit P is negative for any value of e_{min}). We however note that the question of maximizing P , W , or E is irrelevant where there is no chance for a deal to close.

FIGURE 3.1
Sensitivity of Entrepreneur's Return E with respect to e_{min}
(For five sample scenarios)

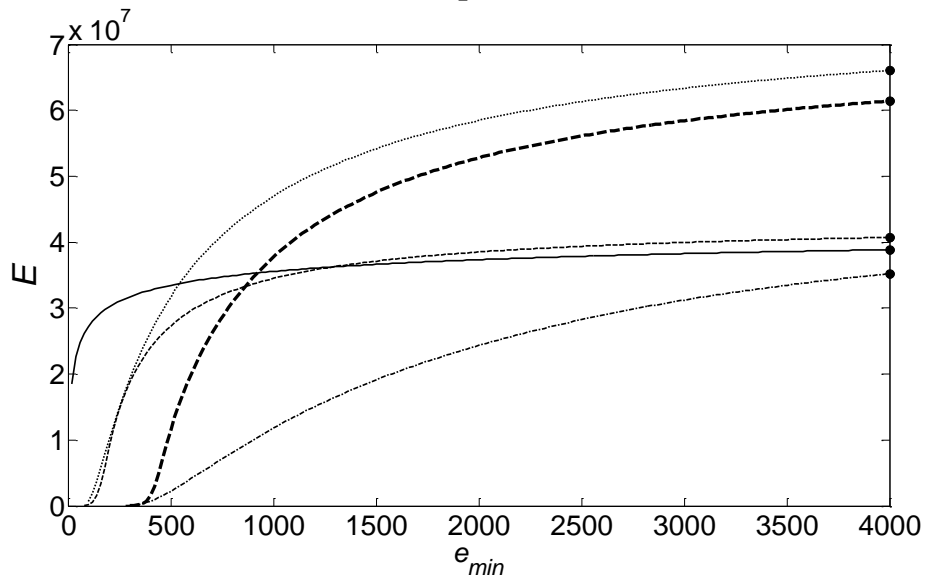


FIGURE 3.2
Sensitivity of the VC's Excess Profit P with respect to e_{min}
(For five sample scenarios)

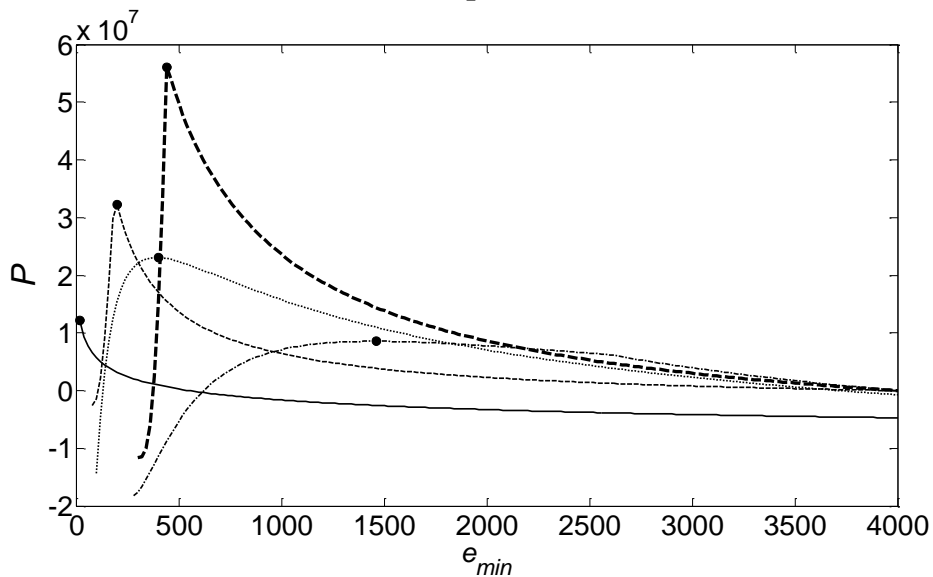


FIGURE 3.3
Sensitivity of Deal Welfare W with respect to e_{min}
(For five sample scenarios)

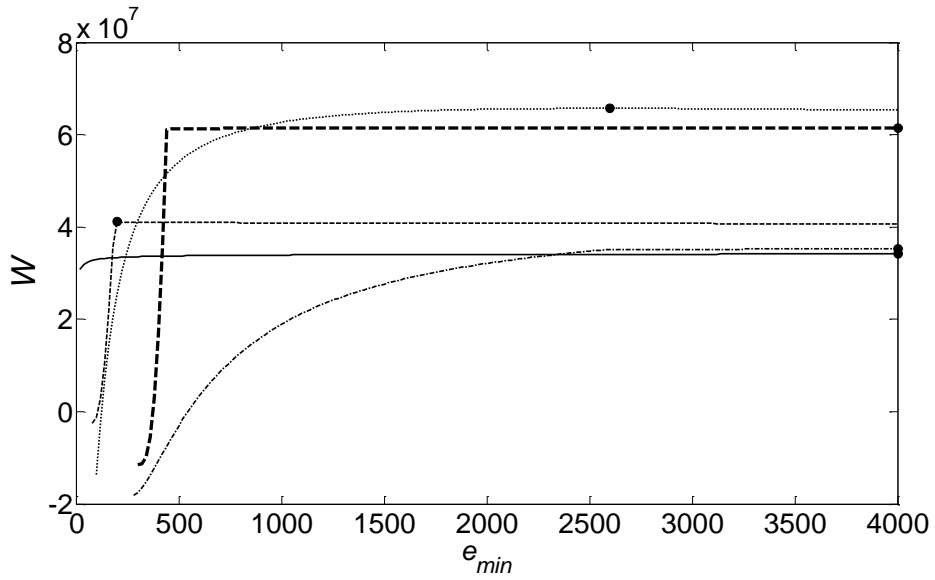


FIGURE 3.4
Sensitivities of E , P , and W with respect to e_{min}
(For one sample scenario)

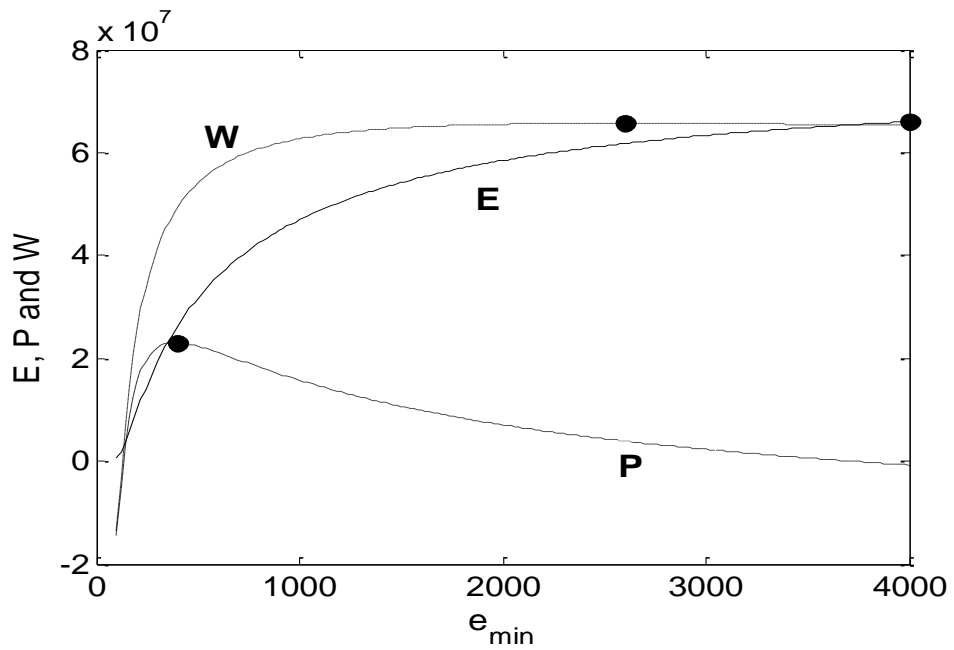


Figure 3.1 shows that the critical value of e_{min} that maximizes E , namely e_{minE} , is 4,000 hours (which represents the best effort of the entrepreneur) in all these five scenarios, but the simulation results show that e_{minE} can be less. Consequently, we use Figures 3.5 and 3.6 to show the distribution of e_{minE} among the 1,035 scenarios that have a possibility of deal closure (with frequency in the Y-axis). Nevertheless, a vast majority (859 scenarios) have $e_{minE} = 4,000$ hours.

FIGURE 3.5
Distribution of e_{minE}

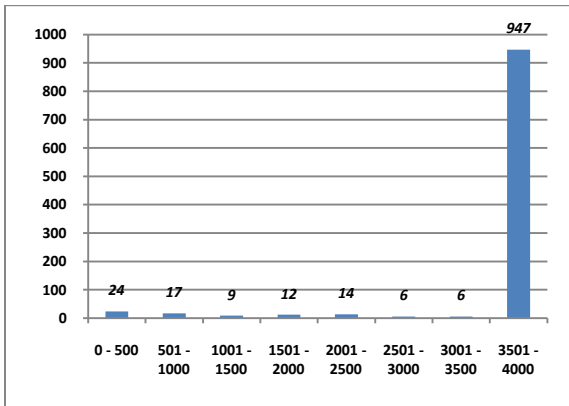


FIGURE 3.6
Distribution of e_{minE} in sub-range

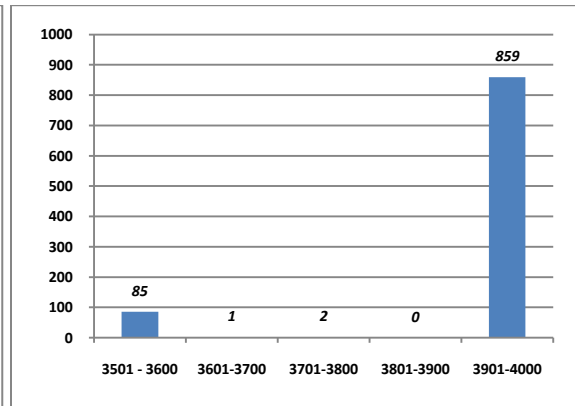


Figure 3.2 suggests that the critical value of e_{min} that maximizes P , namely e_{minP} , is very low (with e_{minP} close to 0 for one, around 1,500 for one, and between these two values for the rest in that figure). Consequently, we use Figures 3.7 and 3.8 to show the distribution of e_{minP} among the 1,035 scenarios that have a possibility of deal closure. A vast majority (803 scenarios) have $e_{minP} \leq 500$ hours.

FIGURE 3.7
Distribution of e_{minP}

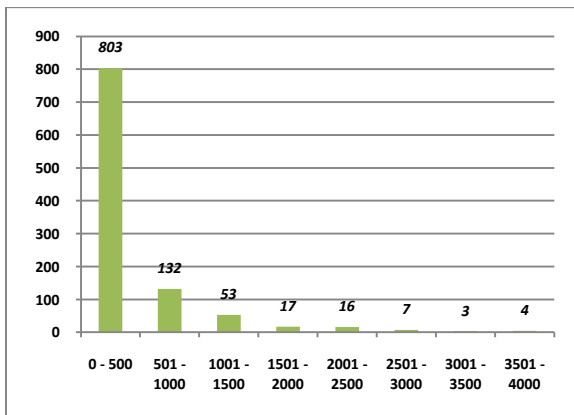


FIGURE 3.8
Distribution of e_{minP} in sub-range

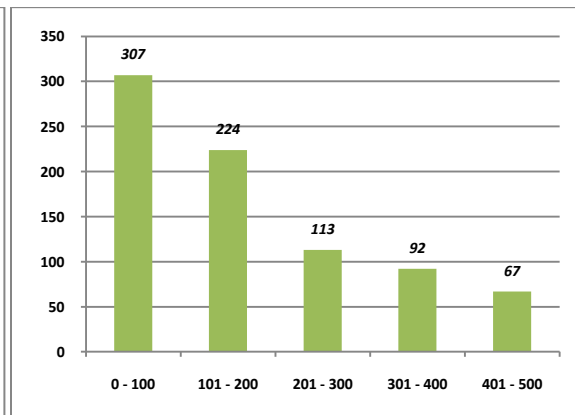


Figure 3.3 suggests that the critical value of e_{min} that maximizes W , namely e_{minW} , can lie anywhere in the range of e_{min} . Consequently, we use Figures 3.9 and 3.10 to show the distribution of e_{minW} among the 1,035 scenarios that have a possibility of deal closure. 607 scenarios have e_{minW} at 4,000 hours (the best effort of the entrepreneur) and 280 have $e_{minW} \leq 500$ hours, showing clustering at the two extremes but also the domination of the former. An important observation about e_{minW} is that, for scenarios that have a possibility of deal closure, it is always bounded by e_{minP} at its lower limit and by e_{minE} at its upper limit (we computed $[e_{minE} - e_{minW}]$ and $[e_{minW} - e_{minP}]$ and found them always nonnegative).

FIGURE 3.9
Distribution of e_{minW}

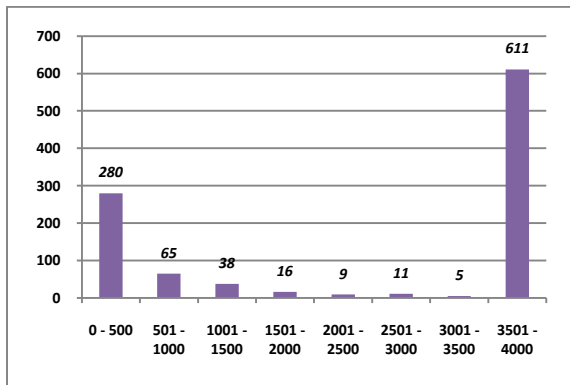
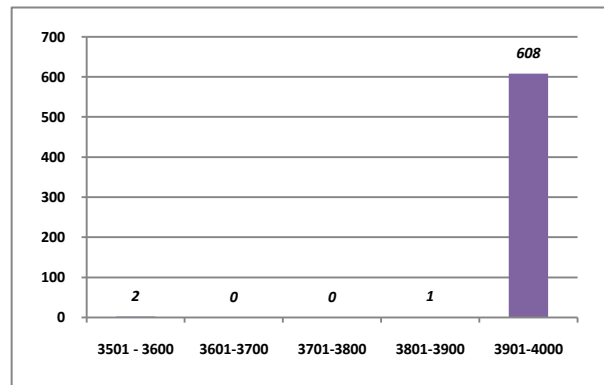


FIGURE 3.10
Distribution of e_{minW} in sub-range



Figures 3.11 to 3.13 depict, respectively, how E , P , and W (all in the Y-axis) vary with the VC's ownership share α (in the X-axis) for the first five scenarios of the 1,035 scenarios that have a possibility of deal closure. Figure 3.14 depicts in a single graph how E , P , and W vary for one of those five scenarios. In all these figures, peak values are also marked for easy reference.

FIGURE 3.11
Sensitivity of Entrepreneur's Return E with respect to α
(For five sample scenarios)

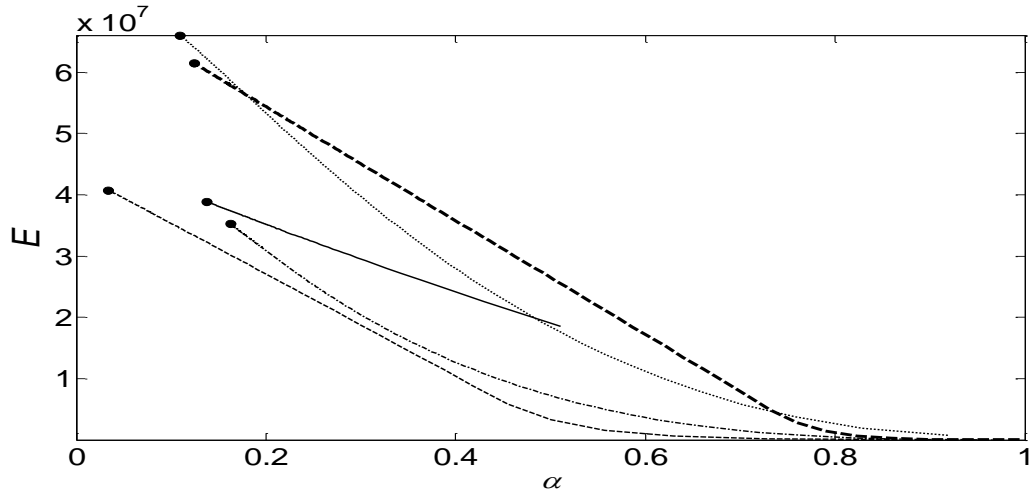


FIGURE 3.12
Sensitivity of VC's Excess Profit P with respect to α
(For five sample scenarios)

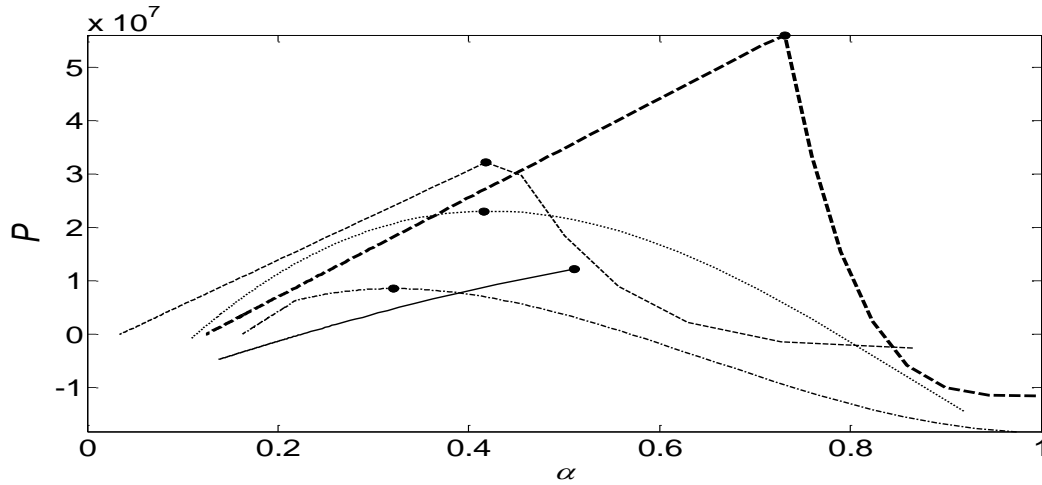


FIGURE 3.13
Sensitivity of Deal Welfare W with respect to α
(For five sample scenarios)

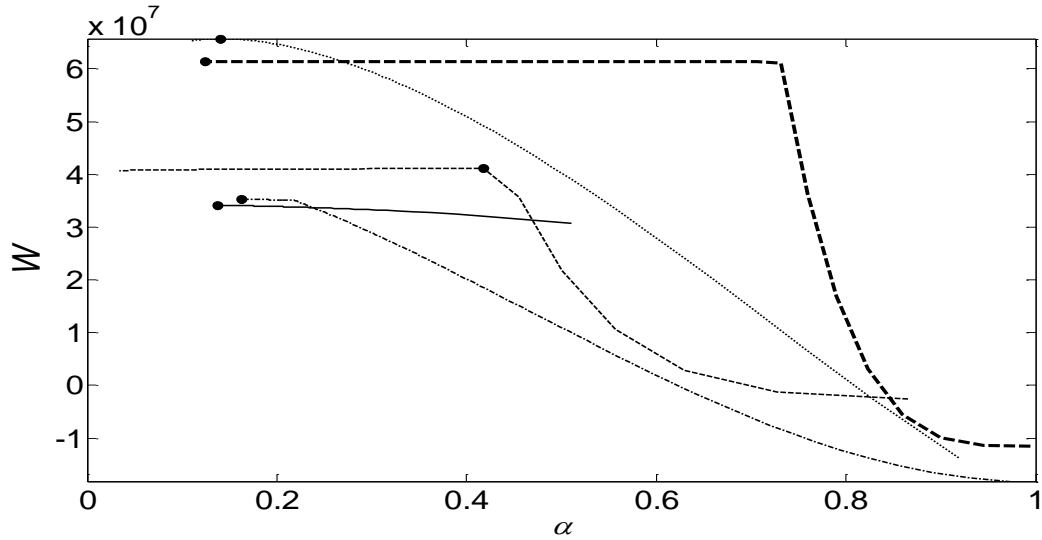


FIGURE 3.14
Sensitivities of E , P , and W with respect to α
(For one sample scenario)

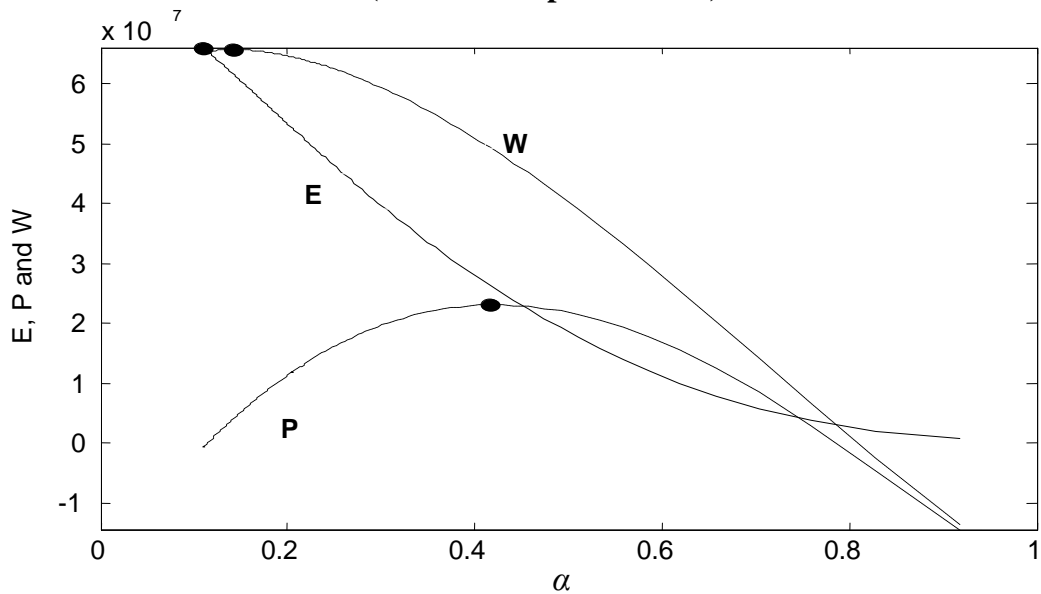


Figure 12 shows that the critical value of α that maximizes E , namely α_E , is low and varies from about 0.05 to about 0.2 in all those five scenarios, whereas α_P varies from about 0.3 to about 0.75 (Figure 13) and α_W from about 0.1 to about 0.75 (Figure 14). Moreover, as we already noted, we found that α_W (that equals 0.14 in Figure 15 for a particular sample

scenario) is bounded by $\alpha_E (= 0.10)$ and $\alpha_P (= 0.42)$ for all scenarios that have a possibility of deal closure.

Figures 3.15, 3.16, and 3.17 show the distributions of α_E , α_P , and α_W , respectively, among the 1,035 scenarios that have a possibility of deal closure. It is found that α_E is very low (< 0.1) in a vast majority of scenarios, whereas α_P is distributed widely (though dominant in the sub-range 0.2 – 0.3) and α_W is concentrated on the lower end (though a significant number of scenarios have moderate to high α_W). An important observation is that α_W is bounded by α_E at its lower limit and α_P at its higher limit for all those 1,035 scenarios (we computed $[\alpha_P - \alpha_W]$ and $[\alpha_W - \alpha_E]$ and found them always nonnegative).

FIGURE 3.15
Distribution of α_E

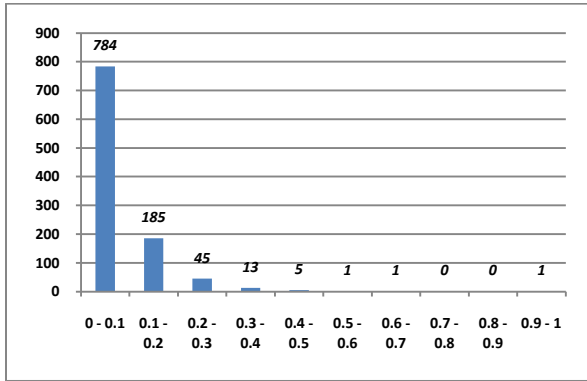


FIGURE 3.16
Distribution of α_P

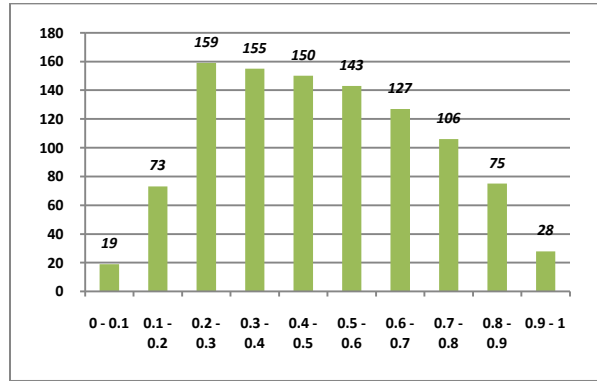
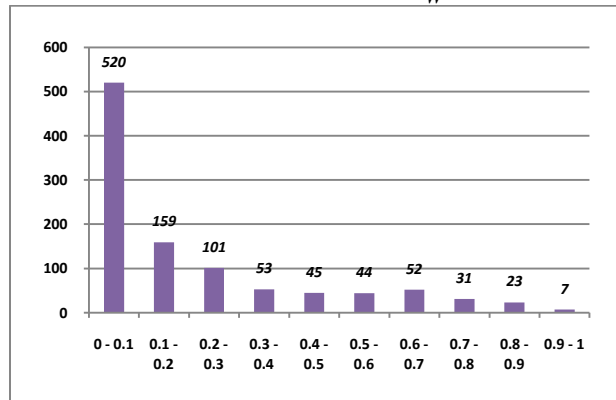


FIGURE 3.17
Distribution of α_W



We find from the above simulation that: (i) unique critical values of e_{min} and α exist that maximize the entrepreneur’s value E , the VC’s excess profit P , and the investment deal welfare W ; and that (ii) e_{minW} and α_W are bounded by e_{minE} and e_{minP} , and α_E and α_P ,

respectively, for any scenario that has a possibility of deal closure. Recall that we have chosen a large number of scenarios (5,200), in a space-filling manner, from a hypercube defined with wide domains for the parameters (hence very likely capturing the empirically relevant VC investment deal space within it). That simulation design allows us to conjecture that:

Conjecture:

- (a) Unique e_{minP} , e_{minE} and e_{minW} for the VC's belief regarding the entrepreneur's minimum effort level exist that respectively maximize the VC's excess profit P , the entrepreneur's expected return E , and the investment deal welfare W . Also, in scenarios where a deal can close (i.e., $e^* \geq e_{min}$),

$$e_{minP} \leq e_{minW} \leq e_{minE}.$$

- (b) Unique α_P , α_E and α_W for the VC's ownership share exist that respectively maximize the VC's excess profit P , the entrepreneur's expected return E , and the investment deal welfare W . Also, in scenarios where a deal can close (i.e., $e^* \geq e_{min}$),

$$\alpha_E \leq \alpha_W \leq \alpha_P.$$

The reason for the existence of critical values of the VC's belief on e_{min} and ownership share is as follows. Recall that the VC is forced to take on a belief on the entrepreneur's effort level because of the private information possessed by the latter on his or her disutility of effort. If the VC is overly pessimistic (that is, e_{min} is very low), he or she may demand a high ownership share α (as in Table 2.2) thereby decreasing the entrepreneur's incentive to take effort (e.g., Amit et al. 1998; de Bettignies and Brander, 2007; Gompers, 1997; Hellmann, 2006; Cassamatta, 2003). Even if the VC's service level increases, the firm's revenue, the entrepreneur's return, and the VC's excess profit (in spite of a high α) may all decrease with a high α . On the other hand, as the VC's belief improves regarding the entrepreneur's effort level, the former may demand a lesser ownership share α , which may lead to an increase in the returns to the two parties. However, if the VC's belief improves beyond a point, the effect of reduced α (if any) may dominate that of an increase in the firm's revenue arising from increased entrepreneurial effort, causing the VC's excess profit to start declining. Moreover, the entrepreneur may reach his or her best effort level and cannot be motivated further (which causes kinks in the curves in Figures 3.2, 3.3, 3.12, and 3.13).

Our approach of employing e_{min} (namely, letting the VC take on a belief while facing private information), not found in the extant literature, has allowed us to uncover the above insight in the conjecture, which has practical significance. For example, the conjecture implies that VCs should claim a moderate ownership share in order to maximize their own return. Moreover, with the above insight novice entrepreneurs may appreciate why VCs' may

not normally demand a low ownership share. Bernile et al. (2007) found in their proprietary international dataset that VC ownership share had a mean, min, and maximum of 29.74%, 2.5%, and 100%; our observation that the critical ownership share that maximizes the VC' excess profit may vary widely across its range (Figure 3.16) is perfectly in line with that empirical evidence. Furthermore, our finding in that figure that in bulk of the cases that critical ownership share is between 20% to 60% is consistent with the mean ownership share found in that study as well as Kaplan and Stromberg (2003) who reported typical VC share of 50% in the US. The US VCs' ownership share had a mean of 32.36% in the dataset of Bernile et al. (2007).

If the VC's belief regarding e_{min} improves (and consequently α decreases) further beyond another critical point, the entrepreneur's incentive to take more effort will saturate (due to cost overriding benefit) leading to no further increase in the entrepreneur's return. Thus there is a critical point in the VC's belief regarding e_{min} that would maximize the entrepreneur's return. Simulations reveal that this point e_{minE} (and corresponding α_E) is the best effort level of the entrepreneur in a vast majority of cases though it can be less in some cases. That is, in a vast majority of cases, the entrepreneur gets to maximize his or her return if the VC is confident that the entrepreneur will put in best performance (and consequently demands a low ownership share). The VC contracting literature has not uncovered this insight about how the entrepreneur's maximal return may be related to the VC's assessment of the entrepreneur since that literature has not considered private information about the entrepreneur's disutility of effort (e.g., de Bettignies and Brander, 2007; Amit et al. 1998; Fairchild, 2007; Bernile, Cumming, and Lyandres, 2007) though it is known that VCs assess novice and experienced entrepreneurs differently (Wright, 1997).

The investment deal welfare W , which is the sum of the returns to the two parties, can start to decrease at e_{minP} (and corresponding α_P) if the decrease in the VC's excess profit P exceeds the increase in the entrepreneur's return E . If not, W will keep increasing till it starts to decrease at e_{minE} (and corresponding α_E) or earlier. Thus this critical point e_{minW} (and corresponding α_W) that maximizes welfare is bounded such that $e_{minP} \leq e_{minW} \leq e_{minE}$ and $\alpha_E \leq \alpha_W \leq \alpha_P$. This observation from our simulation study is consistent with but more robust than that of Bernile et al. (2007)—who in their study of optimal VC portfolio size that ignores the entrepreneur's private information about his or her characteristics—provide closed-form expressions for α_W and α_P and show that, for any number of firms in the VC portfolio, α_W is less than α_P . Analytical studies usually ignore bounds on parameters, and obtain analytical solutions using continuous and differentiable functions. However, in reality, the VC's excess profit (which is essentially an inverted-U shape) may not be a smooth function in many cases (as revealed in Figures 3.2 and 3.12); consequently, deal welfare may also not be smooth (Figures 3.3 and 3.13). We incorporated realistic bounds on parameters

and chose a simulation study in preference to analytical proofs and obtained new insights in the process.²³

A vast majority of scenarios had e_{minE} at 4,000 hours (Figures 3.5 and 3.6), which denotes the best effort of the entrepreneur. Since the VC presumes that the entrepreneur will only allocate a minimum effort level in order to account for the private information of the latter, e_{min} is highly unlikely to be 4,000; and correspondingly, the VC's ownership share is highly unlikely to be very low. In fact, VCs normally take up much larger ownership shares (Bernile et al, 2007; Kaplan and Stromberg, 2003; DevelopmentCorporate, 2010; A VC, 2009; PwC, 2010), so these observations suggest that the entrepreneur does not get to maximize his/her value in most of the deal space consistent with the empirical observation in the literature (e.g., Zider, 1998) that entrepreneurs are put at a steep disadvantage.

A vast majority of scenarios (803 out of 1,035) have $e_{minP} \leq 500$ hours (Figures 3.7 and 3.8). This suggests that, under information asymmetry about the entrepreneur's characteristics, it is a rewarding strategy for the VC to believe that the entrepreneur will only allocate a moderate level of effort. Correspondingly, Figure 3.16 offers a possible explanation for why the VC is unlikely to demand a low ownership share, by showing that the VC's excess profit is usually maximized at moderate to high VC ownership shares. Literature—as noted above—records empirical prevalence of moderate VC ownership shares, but explanation for why it might be so is lacking. Some authors analytically characterize optimal ownership share (e.g., de Bettignies and Brander, 2007; Bernile et al, 2007), but all with the assumption of complete knowledge of entrepreneurial characteristics and none appears to explain the above empirical prevalence.

Recall that the investment deal welfare-maximizing minimum effort level of the entrepreneur as believed by the VC, namely e_{minW} , is polarized in the two extremes—the best effort level of the entrepreneur at 4,000 and the one close to zero (Figure 3.9)—with the former being the dominant (Figure 3.10). Under our key assumption that the VC takes on a belief about the entrepreneur's effort level, the above observation implies that, in most of the deal space, accepted offers will not be welfare-maximizing. In fact, correspondingly, roughly a half of the scenarios have welfare-maximizing VC ownership share α_W less than 0.1 (Figure 3.17), a share that is unlikely to happen for two reasons: (1) the VC's excess profit-maximizing ownership share α_P is moderate to high, not low (Figure 3.16); and (2) the VC is likely to be on the upside of the power equation between the two parties since entrepreneurs are usually credit-constrained (e.g., Aghion, Bacchetta, and Banerjee, 2001; Åstbro and Bernhardt, 2003; Holtz-Eakin, Joulfaian, and Rosen, 1994; Murray, 1999), so the agreed

²³ The conjectured relationships on e_{min} and α do not always hold true for scenarios where no deal can close. Again we note that the question of maximizing P , W , or E is anyways irrelevant for such scenarios.

upon VC ownership share is likely to be closer to α_P rather than α_W . We however note that—as Figures 3.3 and 3.13 show—the investment deal welfare is close to its peak for a wide range of e_{min} and α , so not maximizing welfare may not be a serious issue. The literature is inadequate (except for some studies such as Bernile et al, 2007) with respect to its scrutiny of the VC’s ownership share that is desirable from the view point of welfare. Since entrepreneurship—especially, innovative startup activity—is an important driver of growth (Acs and Szerb, 2006; Pamela Mueller, 2007; Murphy, Shleifer, and Vishny, 1991), our findings on VC ownership share vis-à-vis welfare is of interest.

3.3.7 Simulation II for Generating Synthetic Data

We primarily carried out Simulation II to generate synthetic data for regression analyses that can generate predictions on the parameter sensitivities of various deal outcomes. We also used that simulation to verify if all our propositions hold true in all deals (to assure there are no inadvertent errors in the proofs). We generated 10,400 12-dimensional quasi-random sample points consisting of all the model parameters—namely, $r, I, w, c, b, k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma, \omega$, and e_{min} (each such point representing a deal) and computed the deal outcomes for each deal (the same deal outcomes as in Simulation I). Then, if an offer was rejected, we revised that offer by increasing e_{min} of the previous offer by 100 (letting the VC’s ownership share α to vary while keeping the entrepreneur’s base salary b fixed) and determined the revised deal outcomes. While doing so, we verified whether (i) the condition for ds/de_{min} (the marginal change in VC service with respect to e_{min}) to be positive holds true and (ii) Proposition 1 holds true. If the revised offer was also rejected, we revised the offer again by increasing e_{min} by a further 100 and repeated the above cycles till we had revised the original offer thrice or till the offer was accepted - whichever happened earlier. Then, we revised all the rejected original offers by increasing e_{min} by 100 (letting the entrepreneur’s base salary b vary while keeping the VC’s ownership share α fixed) and determined the revised deal outcomes. While doing so we verified if Proposition 2 holds true. We repeated this cycle till we had revised the original offer thrice or till the offer was accepted - whichever occurred earlier. Finally, for each of the 10,400 scenarios, we increased the base salary b by \$25,000 while keeping e_{min} the same at the original quasi-randomly chosen value and recomputed the deal outcomes. While doing so, we verified if Proposition 3 holds true. We repeated this cycle till we had increased the base salary thrice. We found that all the three propositions held true for all the deals. We now report out regression study in the next section.

3.4 REGRESSION ANALYSES ON SYNTHETIC DATA

We used the synthetic data generated in Simulation II for regression analyses to uncover what factors influence the following deal aspects of interest and how: (i) probability of VC making an offer; (ii) the VC’s ownership share and service level; (iii) the entrepreneur’s

effort level; (iv) probability of entrepreneur exerting best effort; (v) probability of entrepreneur accepting an offer; and (vi) the entrepreneur's return, the VC's excess profit, and the investment deal welfare. We present the estimation results of the above regression analyses in Tables 3.4-3.10. Discussions on the findings immediately follow the respective tables.

3.4.1 Issues with the Regression Analyses

A potential issue with the regression analyses is that we do not use any kind of sampling weights on the synthetic data generated from space-filling sample points of the hypercube. The effect of the space-filling sample points would be akin to sample points drawn from uniform distribution. Recall that information about the distribution (plausible or empirically observed) is scant in the literature wherever parameter values have been noted. Recall also that we have used a large hypercube to characterize the VC deal space and that the boundary of the region within that hypercube that applies in practice is not clearly known. Moreover, the whole manifold (space) is not smooth due to kinks noted in, for example, Figure 3.2. Consequently, lack of weighting may bias the estimates since sample points may vary in practical importance or influence. To deal with this problem, we generated 100,000 space-filling sample points from a small hypercube that is (roughly) centered on the specific values of the model parameters that we used in our illustrative example with justification; we then repeated the regressions with the synthetic data from the small hypercube. If the estimates of the two hypercubes are sufficiently close, the estimates may not be biased. While Table 3.3 presents the parameter domains for the small hypercube, the regression results of that hypercube are presented in Tables 3.4 to 3.10 alongside those of the large hypercube.

We note that pair-wise correlation was nearly zero for all the pairs of parameters except (w, c) and (ε_2, σ) . For the former, it was +0.5647 and +0.4105, respectively for the large and the small hypercubes. For the latter, it was respectively -0.6122 and -0.6125. As Tables 3.1 and 3.3 show, the above two pairs are inter-dependent. The marginal return to service c —which denotes the value the VC could have created if he or she had had one extra hour—and the unit cost of service w are (positively) correlated because that lost value could be large for a VC with a large unit cost. We recall that we set $c \leq w$ because more profitable opportunities would be exhausted first (a standard assumption in economic theory). The exponents ε_2 and σ are (negatively) correlated because we set $\varepsilon_2 + \sigma \leq 0.99$ to ensure concavity of teamwork. In spite of high correlation, we retain these parameters in the regressions since they are conceptually different. We also note that we have let revenue-related parameters k_1 and k_2 to be drawn independent of investment I since it is well-known that revenues in early-stage entrepreneurial ventures are inherently uncertain (e.g., Mason and Harrison, 2002, who report that, in their sample of angel investments, 34% exited at a

total loss but 23% showed a return of 50% or more; Baum and Silverman, 2004; Brouwer and Hendrix; 1998).

TABLE 3.3
Parameter Domain Specifications – Small Hypercube

Parameter	Minimum	Maximum	Specific value used in the illustrative example
r	10%	20%	15%
I	\$500,000	\$3,500,000	\$2,000,000
w	\$500 / h	\$2,500 / h	\$1,500 / h
c	0	\$2,500 / h, but $c \leq w$ always	\$500 / h
b	0	\$200,000	\$50,000
k_1	1	40,000	10,000
k_2	1	40,000	10,000
ε_1	0	0.99	0.85
ε_2	0	0.99	0.8
σ	0	0.99, but $\varepsilon_2 + \sigma \leq 0.99$ always	0.15
ω	\$1 / h	\$30,000 / h	(\$1 / h, \$8,000 / h)
e_{min}	1 h	4,000 h	(1, 2000)

3.4. 2 Further Properties of the Deal Space and Discussion

Probability of VC Making an Offer

We estimated from the twelve model parameters the probability that an offer will be made by the VC, by employing a Probit model on the 10,400 observations of the large as well as the 100,000 observations of the small hypercubes. The estimation results are presented in Table 3.4.²⁴

The probability of VC making an offer is positively affected by the parameters w , c , k_1 , k_2 , ε_1 , ε_2 , σ , and e_{min} ; and negatively by r , I , and b ; but is not affected by ω . Recall that the VC's ownership share α encourages the VC to make an offer (as per the VC's participation constraint in Equation 4 in Chapter 2), but also that α will be high when, everything equal, the VC time is worth high and/or he or she is busy (high w and/or c) so that the VC's incentive compatibility constraint in Equation 3 is satisfied. An increase in any of the parameters k_1 , k_2 , ε_1 , ε_2 , σ increases revenue $R (= k_1 e^{\varepsilon_1} + k_2 e^{\varepsilon_2} s^\sigma)$, encouraging the VC to make an offer. Moreover, if the VC is more confident about the entrepreneur's performance (that is, e_{min} is high), he or she is encouraged to make an offer. The cost of VC capital r (a

²⁴ Elasticity values we report are at means.

hurdle rate), and the investment amount I and the base salary b paid to the entrepreneur (both potential losses) all discourage the VC from making an offer. The entrepreneur's unit cost of effort ω does not affect the probability of VC making an offer because ω is the entrepreneur's private information that cannot be part of the VC's consideration.

TABLE 3.4
Probit Model of Probability of VC Making an Offer

	Dependent Variable (DV): Probability of VC Making an Offer			
	Coefficients		Elasticity at means ²⁵	
	Large Hypercube	Small Hypercube	Large Hypercube	Small Hypercube
r	-0.722*** (.057)	-1.093*** (.187)	-0.184*** (.015)	-0.063*** (.011)
I	-2.29e-07*** (6.66e-09)	-6.15e-07*** (6.80e-09)	-0.613*** (.019)	-0.474*** (.005)
w	6.53e-05*** (7.23e-06)	1.755e-04*** (1.02e-05)	0.175*** (.019)	0.101*** (.006)
c	8.57e-05*** (8.78e-06)	3.99e-04*** (1.07e-05)	0.153*** (.016)	0.151*** (.004)
b	-2.32e-07*** (1.13e-07)	-7.20e-07*** (9.34e-08)	-0.030*** (.014)	-0.028*** (.004)
k_1	8.81e-06*** (5.80e-07)	2.11e-05*** (4.87e-07)	0.222*** (.015)	0.158*** (.004)
k_2	1.27e-05*** (5.89e-07)	3.16e-05*** (4.94e-07)	0.320*** (.015)	0.237*** (.004)
ε_1	2.341*** (.065)	2.476*** (.022)	0.591*** (.017)	0.472*** (.004)
ε_2	3.979*** (.086)	4.175*** (.029)	1.004*** (.025)	0.796*** (.006)
σ	1.249*** (.087)	1.165*** (.027)	0.211*** (.015)	0.148*** (.004)
ω	-3.29e-07*** (7.17e-07)	-5.01e-07*** (6.27e-07)	-0.007 (.015)	-0.003 (.004)
e_{min}	3.40e-04*** (1.47e-05)	3.58e-04*** (4.89e-06)	0.347*** (.015)	0.276*** (.004)
Constant	-3.794*** (.118)	-3.843*** (.048)		
Probability predicted at means			.691	.776
N	10,400	100,000		
LR Chi ²	6,287	58,151		
Prob > Chi ²	0.000	0.000		
Pseudo R ²	0.452	0.454		

Significance level: $p < 0.01$ is denoted by ***, $p < 0.05$ by **, and $p < 0.10$ by *. Standard errors are noted in parentheses.

Table 3.4 reveals some interesting observations and implications. First, the results are qualitatively the same for both the large and the small hypercubes. Second, the probability of

²⁵ Elasticity is $\frac{\partial \ln y}{\partial \ln x} = \frac{\partial y}{\partial x} \cdot \frac{x}{y} = \frac{\% \Delta y}{\% \Delta x}$, thus it is a measure of sensitivity. Specifically, it measures estimated percentage change in the dependent variable for a one percent increase in the concerned explanatory variable.

VC making an offer is highly sensitive to the parameters ε_1 , ε_2 , and I (most sensitive to ε_2 at 1; that is, the probability of VC making an offer increases by 1% when ε_2 increases by 1%). The entrepreneur's effectiveness in solo-work ε_1 and in teamwork ε_2 are major factors motivating the VC to make an offer, ε_2 being the most important. The investment amount is a major factor discouraging the VC. Consequently, the entrepreneur should strive to convince the VC of his or her effectiveness in teamwork (consistent with Valliere and Peterson, 2007, that compatibility is important; and with Bruno, Mcquarrie, and Torgrimson, 1992, that problems with VC relationships is a factor of failure) and to lower the investment amount (consistent with PwC, 2010, that VCs try to invest less) in order to enhance the prospects of obtaining an offer. While the literature recognizes the importance of compatibility and low investment to secure a deal, our insights about the sensitivities are deeper (we uncover the importance of other parameters too).

VC's Ownership Share and Service Level

We estimated from the twelve model parameters the log values of the VC's ownership share α and service level s , by employing an Ordinary Least Squares (OLS) regression on the whole samples of the large as well as the small hypercubes.²⁶ Table 3.5 presents the elasticity estimates of α and s .

The VC's ownership share α is positively affected by the parameters r , I , w , c , and b ; and negatively by k_1 , k_2 , ε_1 , ε_2 , σ , and e_{min} ; but is not affected by ω . Recall that because r , I , and b are barriers to the VC, his or her ownership share α has to be high enough to induce the VC to invest. Recall also that, as per Equation 3 (in Chapter 2), α has to be high when w and c are high. Revenue R is high when k_1 , k_2 , ε_1 , ε_2 , σ , and e_{min} are high and a high R can enable the VC to demand a low ownership share α . Finally, the entrepreneur's effective wage rate ω (which is that party's private information) does not affect the ownership share α demanded by the VC.

Table 3.5 reveals some interesting observations and implications for practitioners. First, the results are again qualitatively the same for both the large and the small hypercubes. Second, the VC's ownership share is highly (negatively) sensitive to the parameters ε_2 , σ , and k_2 (most sensitive to ε_2 at -2.2; that is, α decreases by 2.2% when ε_2 increases by 1%). When these parameters are high, revenue generated from the entrepreneur-VC teamwork is high thereby permitting a low VC ownership share α . Though teamwork is the most important factor permitting a low α , the entrepreneur's effectiveness in solo-work (ε_1) and the VC's confidence in the entrepreneur (high e_{min}) are also important. The above observations are consistent with the literature (e.g., Kaplan and Stromberg, 2003, who find in their sample of VC funds that the entrepreneur's equity stake increases with firm performance). Investment

²⁶ These two parameters cannot be negative, so we choose to model them as log-normal.

amount I is an important factor necessitating a high α . If revenue increases in line with investment amount I , the VC's ownership share α may not have to be high. But, as we already noted a high investment may not result in high revenue in an uncertain investment. Finally, the VC's time-constraints c and the entrepreneur's base salary b only play a minor (though significant) role in influencing α . Findings in relation to the VC's unit cost of service or time-constraints are thin in the literature.

TABLE 3.5
OLS Model of VC's Ownership Share and Service Level

	DV: VC's Ownership Share α		DV: VC's Service Level s	
	Elasticity at means ²⁷		Elasticity at means	
	Large Hypercube	Small Hypercube	Large Hypercube	Small Hypercube
r	.269*** (.014)	.095*** (.013)	.450*** (.030)	.152*** (.027)
I	.902*** (.016)	.816*** (.006)	1.428*** (.033)	1.302*** (.012)
w	.268*** (.019)	.223*** (.007)	-.886*** (.040)	-.714*** (.015)
c	.051*** (.015)	.051*** (.005)	-.551*** (.032)	-.558*** (.01)
b	.058*** (.014)	.046*** (.004)	.082*** (.030)	.073*** (.009)
k_1	-.356*** (.014)	-.356*** (.004)	-.599*** (.030)	-.596*** (.009)
k_2	-1.001*** (.014)	-1.004*** (.005)	.872*** (.030)	.847*** (.009)
ε_1	-.941*** (.014)	-.942*** (.004)	-1.600*** (.030)	-1.573*** (.009)
ε_2	-2.205*** (.019)	-2.204*** (.006)	1.806*** (.039)	1.786*** (.012)
σ	-1.220*** (.015)	-1.214*** (.005)	2.273*** (.032)	2.312*** (.010)
ω	-.002 (.014)	1.592e-04 (.004)	.005 (.030)	-.001 (.009)
e_{min}	-.873*** (.014)	-.873*** (.004)	-.282*** (.030)	-.273*** (.009)
Ln (Y) predicted at means	-.915	-1.112	4.603	4.632
N	10,309 ²⁸	99,403	10,309	99,403
F	2,578	25,066	1,080	10,319
Prob > F	0.000	0.000	0.000	0.000
Adj. R ²	0.750	0.752	0.557	0.555

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses.

The VC steps up his/her involvement in the venture (high s) in order to influence its success when investment amount I and base salary b are high or when there is need to obtain high revenue because the VC's alternate investment fetches a high rate of return r . On the

²⁷ The elasticity for this table is estimated as $dy/d(\ln x)$ since the dependent variables have already been log-transformed.

²⁸ 91 of the 10,400 sample points (about 1%) could not be computed for α and s (they did not converge) since the algorithm had been optimized for run-time. Computing such records would have increased the run-time for every sample in the population, significantly increasing the overall run-time. Manual computations confirmed, as suspected, that these had values for α and s at both extremes. The same was the case with 597 of the 100,000 sample points (about 0.6%) of the small hypercube.

other hand, a VC with a high unit cost of service w or someone who is busy (high c) cannot offer a high level of service to the venture. Similarly, the VC would extend a high level of service when he or she can meaningfully contribute to the success of the venture (high σ) or when the teamwork is highly rewarding (high k_2 and ε_2). The VC would reduce the level of service when the entrepreneur is able to create value on his or her own (high k_1 and ε_1) or when he or she is confident of the entrepreneur's performance (high e_{min}) since in those cases there is reduced need for advising and monitoring. The estimates are in line with the above reasoning and also with observations in the literature. For example, Lerner (1995) reported that the VC's involvement increases when the need to monitor increases and that distance to the firm is a determinant of board membership—presumably because a VC with a high unit cost of service cannot offer a high level of service. Sapienza (1992) found that the more frequent the contact between the lead investor and the CEO, the more open the communication, and the less severe the conflict of perspective in the VC-CEO pair, the greater was the value of the involvement.

To sum up, the VC's service level is highly sensitive to his or her effectiveness in the venture σ (most sensitive at 2.3), the entrepreneur's effectiveness in teamwork ε_2 , and investment amount I (all positively); and the entrepreneur's effectiveness in solo-work ε_1 (negatively). While the entrepreneur's effective wage rate ω does not influence s , the entrepreneur's base salary b only plays a minor (though significant) role. Though literature discussing VC service is numerous, factors affecting service have not been comprehensively identified or their sensitivities adequately studied as in this research.²⁹ This knowledge would help entrepreneurs appreciate when they can expect a high level of VC service.

Entrepreneur's Effort Level

We estimated—first from the twelve model parameters and then from the VC's ownership share α and service level s —the entrepreneur's effort level and the probability that the entrepreneur will put in his or her best effort. The regressions employed a censored model and a Probit model on the observations of the large as well as small hypercubes, where an offer had been made. Effort level can only be positive, so we choose to model it as log-normal. Moreover, there is a limit to the effort level (the “best effort” of the entrepreneur, which we set at 4,000 hours). So effort level, denoted by *effortlimited* lies in $(0, 4000)$, with values equal to and above 4,000 capped and clustered at 4,000. A categorical variable *besteffort* was assigned 0 if effort level was below 4,000 and assigned 1 otherwise.

²⁹ Prior research has discussed VC service in various contexts such as financial contracting (e.g., Bergemann and Hege, 1998); the rationale for VC (e.g., Amit, Brander, and Zott, 1998); what VCs do (e.g., Gorman and Sahlman, 1989); how entrepreneurs value service (e.g., Hsu, 2004); impact of service (e.g., Jääskeläinen, Maula and Seppä, 2006; H. J. Sapienza, 1992); attention in the context of portfolio of investment (e.g., Dimov and De Clercq, 2006; Jääskeläinen, et al. 2006; Kannianen and Keuschnigg, 2003; Shepherd, Armstrong, and Levesque, 2005; Gifford, 1997); and VCs' time-constraint (e.g., Petty and Gruber, in press).

Consequently, we employ a censored regression on $\ln(\text{effortlimited})$, censored by besteffort . For the Probit model, we used besteffort as the dependent variable. Table 3.6 presents the elasticity estimates of effort level and probability of entrepreneur exerting best effort.

TABLE 3.6
Censored Regression Model of Entrepreneur’s Effort Level and Probit Model of Probability of Entrepreneur Exerting Best Effort

	Censored Regression Model DV: Effort Level		Probit Model DV: Probability of Entrepreneur Exerting Best Effort	
	Elasticity at means ³⁰		Elasticity at means	
	Large Hypercube	Small Hypercube	Large Hypercube	Small Hypercube
<i>r</i>	-.083 (.063)	-.013 (.061)	-.046 (.091)	-.002 (.079)
<i>I</i>	-.159** (.067)	-.040 (.026)	.053 (.095)	.191*** (.033)
<i>w</i>	-.468*** (.095)	-.444*** (.035)	-.182 (.135)	-.327*** (.045)
<i>c</i>	-.255*** (.073)	-.250*** (.024)	-.342*** (.106)	-.196*** (.031)
<i>b</i>	.104 (.066)	.022 (.020)	.056 (.095)	.041 (.026)
<i>k</i> ₁	1.552*** (.071)	1.511*** (.022)	1.243*** (.114)	1.136*** (.031)
<i>k</i> ₂	4.575*** (.076)	4.293*** (.023)	2.304*** (.140)	2.147*** (.038)
ε ₁	2.349*** (.080)	2.183*** (.024)	2.815*** (.167)	2.540*** (.043)
ε ₂	6.047*** (.133)	6.309*** (.040)	4.091*** (.260)	4.013*** (.070)
σ	2.616*** (.079)	2.799*** (.024)	.197 (.128)	.270*** (.034)
ω	-4.873*** (.069)	-4.632*** (.021)	-5.410*** (.248)	-4.762*** (.061)
<i>e</i> _{min}	.946*** (.075)	.812*** (.023)	.580*** (.111)	.396*** (.030)
Y predicted at means ³¹	4.027	4.359	.040	.059
N	6,328	66,156	6,330	66,182
Uncensored Obs.	4,936	50,907		
Right-censored Obs.	1,392	15,249		
LR Chi ²	6,630	66,695	3,556	37,331
Prob > Chi ²	0.000	0.000	0.000	0.000
Pseudo R ²	0.202	0.197	0.533	0.523
α	-3.045*** (.058)	-12.044*** (.066)	-1.069*** (.056)	-1.189*** (.019)
<i>s</i>	.841*** (.045)	.003*** (6.1e-05)	-.112*** (.026)	-.222*** (.009)

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses. The estimates of α and s are from separate models, for which we only report the estimates.

The entrepreneur’s effort level is affected positively by the parameters k_1 , k_2 , ε_1 , ε_2 , σ , and e_{min} ; and negatively by w , c , and ω ; but is not affected by r and b . The influence of I is

³⁰ Elasticity is estimated as $dy/d(\ln x)$ in this model since the dependent variable has already been log-transformed.

³¹ $\ln(Y)$ is predicted for the censored regression model.

ambiguous. The parameters k_1 , k_2 , ε_1 , ε_2 , and σ all affect revenue positively, so the entrepreneur may be motivated to put in large effort when these are high. When the VC is highly confident about the entrepreneur, the VC's ownership share α would be low, which would motivate the entrepreneur to put in greater effort. When the VC's unit cost of service is high (high w) and/or the VC is busy (high c), he or she may not advise/monitor the entrepreneur adequately, which may decrease the entrepreneur's effort level. Similarly, when the entrepreneur is not adequately committed, competent, and willing to work hard (high ω), he or she would put in a low level of effort. Finally, the parameters r , b , and I are either inconsequential or ambiguous for the following reason: as revealed in the previous Table 3.5, when the cost of capital r is high, the VC would claim a high ownership share α negatively affecting the entrepreneur's effort level; but the VC's service level s would also increase in turn positively affecting that effort level. The same is the case with the base salary b paid to the entrepreneur and investment amount I .

It is notable that the entrepreneur's effort is highly positively sensitive to his or her effectiveness in teamwork ε_2 , the relative importance of teamwork k_2 , and the VC's effectiveness σ (ε_2 being the most sensitive, at 6); it is highly negatively sensitive to the entrepreneur's unit cost of effort ω . Finally, though counter-intuitively, the VC cannot use high base salary b as a means to obtain better effort from the entrepreneur because the coefficient of b —though positive—is insignificant even at a 10% confidence level.

The influence of the various parameters on the probability of entrepreneur exerting best effort is the same as on effort level, except that the influences of the VC's unit cost of service w and effectiveness σ are ambiguous. Plausible explanations are that these parameters (that also affect the VC's service level) are influential only when effort level is moderate (and responsive to that service level) and that many sample points result in best effort anyway. We further note that the above probability is highly (negatively) sensitive to the entrepreneur's unit cost of effort ω and (positively) to his or her effectiveness in teamwork ε_2 (the former being the most sensitive, at -4.76). Again, it is noteworthy that base salary payment is not a means to make the entrepreneur put in best effort. Finally, in terms of deal outcomes, the entrepreneur's effort level is highly sensitive to the VC's ownership share α (-3 for the large hypercube and -12 for the small hypercube that may be empirically more relevant). The probability of entrepreneur exerting best effort is also considerably negatively affected by α . Though significant, the VC's service level s only plays a minor role.

The above results are interesting because the entrepreneur's performance is the primary factor affecting the success of the venture (e.g., Fried and Hisrich, 1994). Consequently, understanding its determinants would help VCs and entrepreneurs in enhancing the chance that their venture will succeed. While the literature has emphatically documented the impact of ownership share (a deal outcome) on entrepreneurial motivation

(e.g., Amit, et al. 1998; de Bettignies and Brander, 2007; Fee, 2002; and Nisar, 2005), prior research is scant on determinants of entrepreneurial effort in terms of fundamental parameters of the VC investment process.

Probability of Entrepreneur Accepting an Offer

We estimated from the twelve model parameters the probability that the entrepreneur will accept the offer, by employing a Probit model on the observations of the large as well as the small hypercubes where the VC had made an offer. The elasticity estimates are presented in Table 3.7.

TABLE 3.7
Probit Model of Probability of Entrepreneur Accepting an Offer

	DV: Probability of Entrepreneur Accepting an Offer	
	Elasticity at means	
	Large Hypercube	Small Hypercube
<i>r</i>	-.055 (.080)	-.010 (.069)
<i>I</i>	.1274 (.083)	.152*** (.029)
<i>w</i>	-.280** (.118)	-.341*** (.040)
<i>c</i>	-.316*** (.092)	-.211*** (.027)
<i>b</i>	.103 (.083)	.043* (.023)
<i>k</i> ₁	1.064*** (.098)	.990*** (.027)
<i>k</i> ₂	2.238*** (.123)	2.216*** (.034)
ε ₁	2.526*** (.141)	2.237*** (.036)
ε ₂	3.951*** (.227)	3.953*** (.063)
σ	.550*** (.111)	.657*** (.031)
ω	-4.699*** (.199)	-4.258*** (.051)
<i>e</i> _{min}	-.215** (.095)	-.387*** (.026)
Y predicted at means	.069	.092
N	6,330	66,182
LR Chi ²	3,902	40,826
Prob > Chi ²	0.000	0.000
Pseudo R ²	0.544	0.532
α	-.891*** (.045)	-.911*** (.014)
<i>s</i>	-.036* (.022)	-.106*** (.007)

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses. The estimates of α and *s* are from separate models, for which we only report the estimates.

The probability of entrepreneur accepting an offer is positively influenced by the revenue-related parameters *k*₁, *k*₂, ε ₁, ε ₂, and σ ; possibly positively by *I* and *b*; negatively by *w*, *c*, ω , and *e*_{min}; and not influenced by *r*. High expected revenue facilitates deal closure. High investment amount *I* by the VC and base salary *b* to the entrepreneur possibly encourage the latter to accept the offer because the entrepreneur needs them and they can

ultimately increase the entrepreneur's return. However, their influence is not certain since the revenue (and the entrepreneur's return) need not be high when the investment amount is high and base salary is only a small portion of the entrepreneur's overall (long-term) return (but a deal may not materialize if the entrepreneur is not paid a base salary that is essential to him/her in the short-term). If the VC is time-constrained (high c) or his or her unit cost of service w is high, he or she would demand a large ownership share α possibly making the offer unattractive to the entrepreneur. If the entrepreneur's unit cost of effort ω is high, the total cost of effort may be high which also may make the offer less attractive to the entrepreneur. Finally, if the VC is overly optimistic about the entrepreneur's performance (high e_{min}), he or she may claim a low ownership share α that may lead to high return to the entrepreneur but loss to the VC (i.e., the entrepreneur may find $e^* < e_{min}$). Though seemingly counter-intuitive, a high e_{min} decreases the chance that the entrepreneur will accept the offer because the protective clauses in the offer will discourage him or her from accepting a deal where the VC would incur a loss.

It is noteworthy that the probability of entrepreneur accepting an offer (and deal being closed) is most sensitive to the entrepreneur's unit cost of effort ω (at -4.7) followed by the entrepreneur's effectiveness in teamwork (at 3.95). It is logical that deals are unlikely to close for entrepreneurs who are less committed, competent, and willing to work hard. Moreover, deals may not close if the entrepreneur is not expected to work well with the VC. On the other hand, an excessive base salary does not appear to be an effective means to get the entrepreneur to accept the offer because the entrepreneur's ownership share and consequently his or her overall return will both decrease. In any case, base salary is among the factors least affecting the probability of entrepreneur accepting an offer. In terms of deal outcomes, a large VC ownership share decreases the chance that a deal will close, but the VC's service level appears to only play a minor (though significant) role.

The probability of entrepreneur accepting an offer (i.e., deal being closed) is important for obvious reasons. Specifically, these findings suggest that entrepreneurs should lower their unit cost of effort and be determined to work well with the VC in order to secure VC financing. They also suggest that deal closures may not be influenced by base salary payment (except when the entrepreneur is not offered a base salary that is essential to him or her), so VCs should strive to offer as high an ownership share as possible to the entrepreneur instead. The literature has scantily considered base salary payment so it does not have much to say about its impact on deal closures as we do.

Entrepreneur's Return

We estimated from the twelve model parameters the log of expected return to the entrepreneur E , by employing an OLS model on the observations of the large as well as the

small hypercubes where the entrepreneur accepted the offer. The elasticity estimates are presented in Table 3.8.

TABLE 3.8
OLS Model of Entrepreneur's Return

	DV: Entrepreneur's Return			
	Elasticity at means ³²			
	Large Hypercube		Small Hypercube	
<i>r</i>	.040	(.035)	.016	(.032)
<i>I</i>	.018	(.038)	.088***	(.014)
<i>w</i>	-.065	(.048)	-.098***	(.017)
<i>c</i>	-.098***	(.038)	-.076***	(.012)
<i>b</i>	-.022	(.036)	.018*	(.011)
<i>k</i> ₁	.461***	(.043)	.418***	(.012)
<i>k</i> ₂	1.009***	(.059)	1.070***	(.016)
ε_1	.657***	(.055)	.723***	(.015)
ε_2	1.367***	(.103)	1.228***	(.031)
σ	.147***	(.040)	.112***	(.012)
ω	-.412***	(.030)	-.454***	(.008)
<i>e</i> _{min}	.472***	(.039)	.439***	(.011)
Ln(Y) predicted at means	17.853		16.911	
N	1,606		17,658	
F	60		838	
Prob > F	0.000		0.000	
Adj. R ²	0.308		0.363	
α	-.543***	(.021)	-.574***	(.006)
<i>s</i>	.053***	(.017)	.043***	(.005)

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses. The estimates of α and *s* are from separate models, for which we only report the estimates.

The expected return to the entrepreneur is affected positively by the parameters k_1 , k_2 , ε_1 , ε_2 , σ , and e_{min} ; negatively by *c* and ω ; possibly positively by *I* and *b*; and possibly negatively by *w*; but is not affected by *r*. The parameters k_1 , k_2 , ε_1 , ε_2 , and σ are positively related to revenue, so they affect the expected return to the entrepreneur. As per Table 2.2, when the VC is more confident about the entrepreneur's performance (i.e., e_{min} is high), the latter may be allotted a large ownership share that may increase his or her return. A busy VC (with a high *c*) would seek a large ownership share α (as per Table 3.5) even while offering inadequate service to the venture (leading to lower revenue), both of which would decrease the entrepreneur's return. An entrepreneur who has a large unit cost of effort ω would have a low return. When the investment amount *I* is high, the revenue (and the entrepreneur's

³² Elasticity is estimated as $dy/d(\ln x)$ since the dependent variable has already been log-transformed.

return) may be high (though not necessarily). A high unit cost of service w that would necessitate the VC to seek a large ownership share α (Table 3.5) may consequently reduce the entrepreneur's return—but not necessarily, because decreased VC service resulting from a high w (Table 3.5) would also reduce the entrepreneur's effort level and total cost of effort (Table 3.6). The cost of capital r does not affect the entrepreneur's return since there is no direct relationship between the two as seen from the model equations in Chapter 2.

It is noteworthy that the entrepreneur's return is most sensitive to his or her effectiveness in teamwork ε_2 (at 1.3), followed by the relative importance of teamwork k_2 (at 1), implying that getting financed (and advised) by VCs is good for entrepreneurs. On the other hand, entrepreneurs in ventures where teamwork (i.e., VC service) is not crucial would have lower returns. Moreover, for reasons cited earlier, higher investment amount I may not always mean higher return to the entrepreneur. Furthermore, a high base salary may not mean high return; even if it does, its impact is minor. Finally, the VC's time-constraint (c) only appears to be a minor factor decreasing the entrepreneur's return. In terms of α and s , the entrepreneur's expected return decreases about 0.54% for a 1% increase in the VC's ownership share, while the VC's service s plays a minor role in directly increasing that return. These findings imply that entrepreneurs should focus on teamwork and consequently on the VC they select (because the VC's service has a multiplier effect on the entrepreneur's effort in generating revenue) and only seek a necessary base salary in order to increase their return. Evidence from the VC industry supports the above findings (e.g., Gerschick, 2006).

VC's Excess Profit

We estimated from the twelve model parameters the log of the VC's excess profit P , by employing an OLS model (Model 1) on the observations of the large as well as the small hypercubes where the entrepreneur accepted the offer. In order to shed more light on the influence of the VC's belief about the entrepreneur's minimum effort level e_{min} , we also estimated log of VC's excess profit on all the parameters excluding e_{min} (Model 2) and then only on e_{min} (Model 3). The elasticity estimates are presented in Table 3.9.

The VC's excess profit is positively affected by the parameters r , I , and b , and the revenue-related parameters k_1 , k_2 , ε_1 , and ε_2 ; and negatively by c , σ , ω , and e_{min} ; but is not affected by w . When the parameters r , I , and b are large, the VC's return from his or her alternate investment would be large too, as per Equation 4 (all else equal). If the venture is profitable enough to assure the VC such a large return, the VC's excess profit is also likely to be large. In general, the VC's excess profit would be large when the revenue is large as evident from the positive sensitivities to revenue-related parameters. All else equal, when the VC is time-constrained (high c), he or she would serve the venture inadequately, so revenue and the VC's excess profit would reduce. Again, everything equal, when the VC's

effectiveness σ is high in the venture, his or her service level would increase (as seen from Table 3.5), which may cause a larger increase in the cost of service than in the VC's share of revenue, resulting in decreased excess profit. When the entrepreneur's unit cost of effort ω is high, his or her effort and revenue would be low leading to low excess profit for the VC. Finally, when the VC is highly confident about the entrepreneur's performance (i.e., e_{min} is high), the former may claim a low ownership share leading to low excess profit.

TABLE 3.9
OLS Model of VC's Excess Profit

	DV: VC's Excess Profit					
	Elasticity at means ³³					
	Large Hypercube			Small Hypercube		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
r	.360*** (.033)	.317*** (.065)		.122*** (.033)	.141** (.060)	
I	1.120*** (.036)	.930*** (.070)		1.096*** (.014)	.890*** (.026)	
w	.061 (.046)	.052 (.089)		.012 (.018)	.013 (.033)	
c	-.085*** (.036)	-.077 (.070)		-.063*** (.012)	-.058*** (.023)	
b	.104*** (.034)	-.002 (.066)		.062*** (.011)	.060*** (.020)	
k_1	.061 (.041)	.127 (.079)		.105*** (.013)	.094*** (.024)	
k_2	.007 (.056)	.232** (.109)		.028* (.017)	.175** (.031)	
ε_1	.246*** (.053)	.191* (.103)		.324*** (.015)	.245*** (.028)	
ε_2	.129 (.098)	.406** (.191)		.138*** (.032)	.276*** (.059)	
σ	-.220*** (.038)	-.030 (.074)		-.309*** (.013)	-.110*** (.024)	
ω	-.145*** (.028)	-.061 (.055)		-.188*** (.008)	-.088*** (.015)	
e_{min}	-2.481*** (.037)		-2.349*** (.048)	-2.339*** (.011)		-2.219*** (.014)
Ln(Y) predicted at means	15.115	15.115	15.115	14.041	14.041	14.041
N	1,606	1,606	1,606	17,658	17,658	17,658
F	444	20	2,364	4,004	134	26,575
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
Adj. R ²	0.768	0.115	0.596	0.731	0.077	0.601
α	.818*** (.036)			.698*** (.011)		
s	-.083*** (.028)			-.114*** (.009)		

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses. The estimates of α and s are from separate models, for which we only report the estimates.

The most striking observation from Table 3.9 is that the VC's excess profit P is almost exclusively influenced by e_{min} . The explanatory power of the model that only includes e_{min} is about 60%, whereas that of the model that includes all of the rest of the parameters is merely

³³ Elasticity is estimated as $dy/d(\ln x)$ since the dependent variable has already been log-transformed.

12%. Because elasticities reported are estimated at means and because the VC's excess profit is non-linear and non-monotonic in e_{min} and α (as revealed in Table 2.2 and Figures 3.2 and 3.12), we do not discuss the estimates for e_{min} and α except to reiterate that the VC's belief on e_{min} (and consequently the ownership share he or she claims) is the most important determinant of the VC's excess profit. When the entrepreneur has private information about his or her characteristics, it is thus reasonable to expect the VC to underrate the entrepreneur with a low e_{min} . With that reasoning, the regression finding is consistent with our earlier finding from the simulation study that the value of e_{min} that maximizes the VC's excess profit P , namely e_{minP} , is often very low (see Figures 3.7 and 3.8).

Investment Deal Welfare

We estimated from the twelve model parameters the log of expected investment deal welfare (the sum of the expected return to the entrepreneur and the expected excess profit of the VC) by employing an OLS model on the observations of the large as well as the small hypercubes where the entrepreneur accepted the offer. The elasticity estimates are presented in Table 3.10.

The parameters that affect the entrepreneur's return E as well as the VC's excess profit P positively (I , b , k_1 , k_2 , ε_1 , and ε_2) influence the investment deal welfare W positively (since W is merely the sum of E and P). Those affecting E and P negatively (c and ω) affect W negatively. Parameters that positively affect one but do not affect the other (r) would affect W positively. Similarly, parameters that negatively affect one but do not affect the other (w) would affect W negatively. The parameters affecting one positively but affecting the other negatively (σ and e_{min}) can affect W either way.

There are two noteworthy observations about Table 3.10. One, investment deal welfare is most sensitive to the teamwork related parameters k_2 (the relative importance of teamwork) and ε_2 (the entrepreneur's effectiveness in teamwork). Particularly, a 1% increase in ε_2 would increase W by 1.1%, at means. This implies the desirability (from the welfare point of view) of VC financing where the VC and the entrepreneur work together. Two, it is the entrepreneur who plays the primary role in influencing welfare because the other entrepreneur-related parameters (namely, k_1 , ε_1 , and ω) also have high sensitivities while the rest of the parameters only have minor sensitivities. Together those two observations imply that VCs help entrepreneurs create value.

TABLE 3.10
OLS Model of Investment Deal Welfare

	DV: Investment Deal Welfare	
	Elasticity at means ³⁴	
	Large Hypercube	Small Hypercube
<i>r</i>	.061** (.031)	.034*** (.029)
<i>I</i>	.157*** (.034)	.198*** (.012)
<i>w</i>	-.054 (.043)	-.088*** (.016)
<i>c</i>	-.093*** (.034)	-.075*** (.011)
<i>b</i>	.005 (.032)	.017* (.010)
<i>k₁</i>	.428*** (.038)	.386*** (.011)
<i>k₂</i>	.885*** (.052)	.947*** (.015)
<i>ε₁</i>	.622*** (.049)	.686*** (.013)
<i>ε₂</i>	1.218*** (.091)	1.086*** (.028)
<i>σ</i>	.076** (.036)	.044*** (.011)
<i>ω</i>	-.399*** (.026)	-.430*** (.007)
<i>e_{min}</i>	.091*** (.035)	.135*** (.010)
Ln(Y) predicted at means	18.048	17.079
N	1,606	17,658
F	57	773
Prob > F	0.000	0.000
Adj. R ²	0.294	0.344
<i>α</i>	-.261*** (.021)	-.340*** (.006)
<i>s</i>	.010 (.017)	-.001 (.005)

Significance level: *** $p < 0.01$; ** $p < 0.05$; and * $p < 0.10$. Standard errors are noted in parentheses. The estimates of α and s are from separate models, for which we only report the estimates.

Table 3.11 summarizes our regression findings. We note that these findings are essentially our predictions (not empirical observations) about various parameter sensitivities of deal outcomes because these resulted from synthetic data (not empirical data). So these are prescriptive not descriptive.

³⁴ Elasticity is estimated as $dy/d(\ln x)$ since the dependent variable has already been log-transformed.

TABLE 3.11
Summary of Predictions on Parameter Sensitivities of Deal Outcomes

	Probability of VC making an offer	VC's Ownership Share	VC's Service Level	Entrepreneur's Effort Level	Probability of Entrepreneur Exerting Best Effort	Probability of Entrepreneur Accepting an Offer	Entrepreneur's Return	VC's Excess Profit	Deal Welfare
r	-	+	+	N.A.	N.A.	N.A.	N.A.	+	+
I	-	+	+	-?	+?	+?	+?	+	+
w	+	+	-	-	-?	-	-?	N.A.	-?
c	+	+	-	-	-	-	-	-	-
b	-	+	+	N.A.	N.A.	+?	+?	+	+?
k_1	+	-	-	+	+	+	+	+?	+
k_2	+	-	+	+	+	+	+	+?	+
ε_1	+	-	-	+	+	+	+	+	+
ε_2	+	-	+	+	+	+	+	+?	+
σ	+	-	+	+	+?	+	+	-	+
ω	N.A.	N.A.	N.A.	-	-	-	-	-	-
e_{min}	+	-	-	+	+	-	+	-	+
α	N.A.	N.A.	N.A.	-	-	-	-	+	-
s	N.A.	N.A.	N.A.	+	-	-	+	-	N.A.

Legend: "+" indicates positive influence; "-" negative; "?" possibly; and "N. A." Not affected.

3.5 SOME QUESTIONS OF PRACTICAL IMPORTANCE

Next we synthesize the results of the regression analyses to answer some questions of practical importance.

How do deal outcomes change when the VC is time-constrained?

A busy VC (with a high c) needs to claim a large ownership share α and allocate less service s in order to fulfill his or her incentive compatibility constraint in Equation 3. A large α and a low s together, probably make the investment more attractive to the VC, so the VC would be more likely to put forth an offer. However, the deal would be less attractive from the entrepreneur's view point, so his or her effort level and consequently the probability of accepting the offer both decrease. Even if accepted, the returns to the two parties and the deal welfare would all be less than what they would be when the VC is not time-constrained. The literature has scarcely dealt with the impact of VCs' time constraints on deal outcomes, so prior findings similar to ours are difficult to find.

How do deal outcomes change when the VC offers a high base salary to the entrepreneur?

Can base salary play an important role in VC deals?

A base salary is basically a hurdle to the VC in investing in the venture (because that money would be lost if the venture fails), so a high base salary decreases the chance that the VC will

put forth an offer; but it would increase the chance that the offer—if made—would be accepted by the entrepreneur. Though the VC would claim a larger ownership share, he or she would also allocate more service which in turn would increase revenue and possibly the entrepreneur's return as well. The entrepreneur's effort is however not affected by the size of his or her base salary. The increased ownership share and revenue (the latter resulting from the increased service level of the VC) exceed the increase cost of service resulting in increased excess profit for the VC. Thus it appears that high base salaries to entrepreneurs are desirable. However, as well observed by prior research, base salary payment is not incentive compatible so VCs would resist paying high base salaries to entrepreneurs (this might be a reason why fixed payments like base salary have not received much scrutiny in the literature).

As per our predictions, base salary is unlikely to play a major role in VC deals (after it is agreed upon by the two parties exogenously to our model). We recall our Proposition 3 (in Chapter 2) that suggests ambiguous effects of base salary on the returns to the two parties and deal welfare. In fact, the coefficient magnitudes and statistical significance of base salary are weak in our regressions for various deal outcomes presumably because the size and changes in base salary are small relative to the investment amount or the expected revenue of the venture. However, the VC may lose an otherwise profitable investment opportunity if the VC refuses to pay the base salary that is absolutely essential to the entrepreneur (while determining the base salary exogenously). So, base salary may play a role in deals.

What is the influence of teamwork vis-à-vis the entrepreneur's solo-work in VC investments?

The most noteworthy finding from regressions is that teamwork is the most influential factor in VC investment deals (i.e., for most of the deal outcomes studied). Recall that the probabilities of offer made, best effort, and offer accepted; and investment deal welfare are all most sensitive to the entrepreneur's effectiveness in teamwork (ε_2) and highly sensitive to the relative importance of teamwork (k_2). Entrepreneurs seeking venture capital must appreciate the importance of teamwork and convince the VC of their competence and willingness to cooperate with the latter. Ventures where VC advisory support is not crucial for success are less likely to be VC financed.

How do deal outcomes change with the entrepreneur's disutility of effort and the VC's belief about the entrepreneur's performance?

The entrepreneur's privately known unit cost of effort (ω) does not directly affect either whether the VC will put forth an offer or the offer terms (though the information asymmetry forces the VC to take on a belief about the entrepreneur's performance—i.e., effort level e_{min}). But a high ω decreases the chance of a deal closure as well as the returns to the two parties (ω is one of the factors to which deal outcomes are highly sensitive).

The VC's belief about the entrepreneur's performance (e_{min}) enables the VC to put forth an offer, but decreases the chance that the entrepreneur will accept the offer (because the entrepreneur may find that he or she cannot meet the expectations of the VC). The VC's excess profit peaks for a particular value of his or her belief about the entrepreneur's minimum effort level e_{min} (performance) and that value is most often low, though being too pessimistic would preclude the VC from investing in the first place. Consequently, making entrepreneurial characteristics more transparent can benefit the entrepreneur.

When would the VC demand a high ownership share? When would he/ she allocate more service to the venture?

As noted from Table 3.5, the VC would demand a high ownership share α when the investment amount I is high (to protect that large investment), expected revenue generation is low (i.e., especially, teamwork is expected to be weak), and when the information asymmetry is large.

Again as noted from the above table, the VC's service level s would be high when the investment amount I is high, the teamwork is expected to be strong, and when the VC is able to meaningfully contribute to the venture's success. These observations are well-known in the prior research.

How does a limit on the entrepreneur's effort level affect deal outcomes?

As noted in Simulation I, a limit on the entrepreneur's effort level is what gives rise to the existence of "critical" points in the VC's belief about the entrepreneur's performance (e_{min}) that maximize the VC's excess profit, the return to the entrepreneur, and the deal welfare, thereby forcing the VC to be careful with his or her belief (and consequently the ownership share he or she should demand). Analytical approach in the literature often ignores bounds on parameters, so our findings with respect to the above-mentioned critical points are an addition to the literature.

What is the effect on deal outcomes (all other things equal) of increasing the entrepreneur's base salary when correspondingly decreasing his/her ownership share?

As seen from Table 3.11, the VC's excess profit is positively sensitive to base salary as well as the VC's ownership share. So the VC stands to gain from the base salary payment (since his or her ownership share would increase). This is not to recommend that the VC should pay an exorbitant base salary since a high VC ownership share is not a guarantee for the VC to eventually break-even from the investment (fixed payments like base salary are not incentive compatible). But when not willing to pay the base salary that is essential to the entrepreneur (if that salary is not unreasonably high), the VC may lose an otherwise profitable deal.

Our predictions based on the regressions suggest that base salary would not influence the entrepreneur's motivation (as reflected in his or her effort level) but may increase his or her overall return (when controlled for ownership share). However, if his or her ownership share is correspondingly decreased, the entrepreneur's motivation and return will both decrease. So the overall influence of base salary on these deal outcomes is ambiguous, consistent with our Proposition 3.

3.6 CONCLUSION

Our illustrative example in Chapter 2 had suggested the existence of a "critical" point in the VC's belief about the entrepreneur's minimum effort level e_{min} (and a corresponding point in the VC's ownership share) that maximizes the VC's excess profit as well as the investment deal welfare. Because of the difficulty in obtaining analytical solutions (due to bounds on parameters and categorical decision rules in the sequential deal process), we carried out a simulation study to investigate if indeed such a critical point exists. Moreover, we used synthetic data from simulation on regressions to uncover insights not readily revealed by the mathematical model.

We carried out two simulations, one with 1.04 million sample points (arising from 5,200 11-dimensional quasi-random samples each checked against 200 values of e_{min} in its full range) and the other with 10,400 12-dimensional quasi-random sample points. The second simulation generated synthetic data which we used on regressions to estimate different deal outcomes such as VC ownership share, the probability of entrepreneur accepting an offer, and deal welfare. Since we did not use sample weights, we carried out a separate simulation using 100,000 sample points from a small hypercube that is roughly centered on the parameter values of our illustrative example that we had used with justification from the literature.

The simulation study revealed several insights. First, Simulation I confirmed our expectation of the above-mentioned critical point. In fact, simulation revealed different critical points in e_{min} that separately maximize the VC's excess profit, the entrepreneur's return, and the deal welfare. Based on these and further findings, we conjectured that critical e_{min} that maximizes the deal welfare is bounded (at the lower limit) by the point that maximizes the VC's excess profit and (at the upper limit) by the point that maximizes the entrepreneur's return. We conjectured similar bounds for critical VC ownership share. Second, the regression estimates using the synthetic data from the small hypercube (which may be empirically more relevant) are comparable to those from the large hypercube suggesting that properties are homogenous across the deal space. Major regression findings are that: (i) Teamwork (so VC advisory support) is crucial to VC financing (specifically, the entrepreneur's effectiveness in teamwork is the most important factor affecting deal

outcomes, followed by the relative importance of teamwork to the venture); (ii) The entrepreneur's disutility of effort is the most important factor that would negatively affect deal outcomes, once an offer has been made; (iii) The VC's high expectation about the entrepreneur's performance would lead to high share of the value created in the venture taken by the latter; and (iv) base salary payment normally would only play a minor role in deal outcomes.

Our simulation study has two notable limitations. First, we had to use a specific functional form for the revenue function unlike in our theoretical model that used generic function. However, though empirically different functional forms may be noticed, a Cobb-Douglas function meets all our model assumptions and is widely employed in economic theory. Second, our Simulation I only conjectures that there exist critical values of ownership share that maximize the returns to the two parties and the deal welfare. We do not have formal proof for the above conjecture, but our conjecture is of high practical significance.

Opportunities for further work may arise from the large amount of synthetic data that we already possess. We may, for example, carry out more regressions to check the robustness of the findings or to uncover new insights by segregating data with respect to, for example, whether solo-work is crucial ($k_1 > k_2$) or teamwork is crucial. Another opportunity is to try alternate functional forms for the revenue function. Moreover, we can identify the part of the large hypercube that is practically most relevant if we can collect empirical data on model parameters.

Chapter 4

Survey of Venture Capitalists

4.1. INTRODUCTION

If we were to use empirical data to test our predictions using, say, regression analysis, we would need data on the various deal parameters of our model pertaining to proposals that received active consideration by VC firms for investment.³⁵ That data would typically come from due diligence and a subsequent deal process while some would pertain to the VC and the entrepreneur. However, another (more practical) approach for empirical validation might be to seek the opinions of practicing VCs—who have negotiated a large number of investment deals especially with first-time entrepreneurs—in the form of their level of agreement/disagreement with our model assumptions and predictions. A substantial degree of support might then suggest that our model is empirically valid.

We take the second approach and report on a survey of eight seasoned VCs located in Toronto, Waterloo, and Montreal and affiliated with seven firms operating in three countries—Canada, USA, and UK. Specifically, we administered an online questionnaire using the survey portal SurveyMonkey which asked questions related to our assumptions, and predictions from our propositions, conjecture, and regressions (that used synthetic data from simulation). We found support for the vast majority of our important predictions.

This chapter is organized as follows: While we describe our survey planning, design, and administration in §4.2, we present the credentials of the eight VCs in §4.3. §4.4 compares the survey findings with our predictions, followed by §4.5 that concludes.

4.2 SURVEY PLANNING, DESIGN, AND ADMINISTRATION

Our first task in the survey project was to find how many VCs we could enlist to respond to our survey. One VC whom we knew (our VC contact) agreed to help us with enlisting VCs, so we met him for a face to face preliminary discussion. We briefed him of our theoretical research and the objective of the proposed survey. He advised us to contact him when we were ready with our survey instrument. The original survey instrument had 94 items of different kinds—many asked the respondent to choose from multiple choice (e.g., specifying level of agreement in a five-point scale and answering yes or no) while the rest required the respondent to provide quantitative data or a qualitative response. Those items covered our

³⁵ Tim Jackson's general advice and contacts were crucial to the survey project. I am grateful for Rod McNaughton's valuable advice on questionnaire development in the beginning and Mary Thompson's active help in polishing the questionnaire. Brian Cozzarin played a pivotal role in the entire project. Any deficiencies that may remain are mine.

assumptions, and predictions from our propositions, conjecture, and regressions (the last one relates to parameter sensitivities of deal outcomes).

Our VC contact advised us that the questionnaire needed be shortened drastically (so VCs do not give up before completing the survey). Specifically, he made it clear that the respondents should not have to spend more than fifteen minutes to complete the survey and advised us that there should only be fifteen to twenty items in the survey instrument.³⁶ He further advised us to administer the survey online (perhaps that mode is more convenient than mail mode to VCs, in the opinion of our VC contact).³⁷ He informed us that he could connect us with seven VCs. He also asked us to contact him again when the finalized survey instrument was ready so that he could send his emails to the VCs requesting them to complete our survey. We could then email the survey to those VCs. Furthermore, he advised us that we could contact over the phone any VC who had not completed the survey within three days after the first contact.

The need to limit the number of items in the survey instrument to a maximum of twenty posed severe restrictions in redesigning the survey. Since we had more than 90 items in the original survey instrument, limiting the number of items to twenty would be impractical if we were to seek VCs' responses to as many of our predictions as possible. So we decided to only include items for the most important assumptions and predictions. Consequently, we first removed the items that sought quantitative data and qualitative responses from VCs (those responses were only designed to give us some parameter values that apply in practice, which are not as important to us as VCs' responses to our assumptions and predictions). We then removed items related to proposition P2 since revising offers by increasing base salary does not seem to be an important problem in practice. As for the items pertaining to the predictions from our regressions, we prioritized them and removed the following items: (a) those relating to parameters that were predicted to not significantly affect many of the deal outcomes (e.g., the cost of venture capital r); (b) most of the items pertaining to ambiguous predictions (e.g., some predictions about investment amount I and unit cost of service w ; and some predictions concerning the probability of entrepreneur exerting best effort and the VC's excess profit); (c) items pertaining to predictions that are very likely to hold in practice anyway (e.g., those concerning the entrepreneur's unit cost of effort ω); and (d) the items pertaining to deal welfare (which is merely the sum of the entrepreneur's return and the VC's excess profit).

³⁶ In fact, our VC contact indicated that VCs routinely receive several such requests but do not easily give their time and asked us why they should do this (participate in the survey) at all.

³⁷ Furthermore, the survey length advised by our VC contact is in line with the literature (e.g., Garson, 2009), which notes that face-to-face interviews can sustain attention for as long as an hour while telephonic surveys may only do so for ten minutes, with self-administered surveys (mail or web) being in between.

Since we were still left with about fifty items, we decided to remove ten more items, split the seven VCs (other than our VC contact) to form two groups of five and four respondents each (with each group also including our VC contact), and administer separate surveys to the two groups with twenty items each. That would allow us to seek five responses for twenty items and four responses for the remaining twenty items, instead of eight responses each for only twenty items that was possible if we were to administer a single survey to all the respondents. Consequently we removed some more items pertaining to the predictions of our regressions and finally retained thirty-nine items for two surveys with one item included in both surveys. Since the assumption that rejected offers can be revised was the basis for a considerable part of our theoretical model, we decided to include an item pertaining to that assumption in both surveys in order to increase the likelihood that we know unambiguously whether rejected offers are indeed revised or not. All the retained items involved statements where the respondent was asked to choose his/her level of agreement with that statement in a seven-point Likert scale (strongly agree, agree, somewhat agree, neither agree nor disagree, somewhat disagree, disagree, and strongly disagree). Five-point or seven-point scales are normally used for level-of-agreement type items (e.g., Trochim, 2006) and these permit a neutral response.

Once the thirty-nine items to be included in two survey instruments were finalized, we divided them into two sets of twenty items each for the two instruments (repeating one item in both sets). While doing so, we tried to distribute the items relating to the predictions of our regressions into the two sets on the basis of deal outcomes and model parameters (i.e., if there were two items involving same parameter or same deal outcome, we included one in one instrument and the other in the other instrument). As for the items relating to assumptions, and predictions from the propositions and the conjecture, we evenly distributed the items into the two sets as far as possible.

When the two instruments were ready, we rephrased the items (statements) as necessary for easy reading and clarity (e.g., we replaced compound sentences with simple ones) since questions should be simple and unambiguous (Arsham, 2011). We also rephrased the items as necessary to ensure that positively-keyed items and negatively-keyed items were about equal in number in each set to avoid acquiescence bias—namely, the tendency of respondents to uniformly agree or disagree to the items in a survey (Frery, 1996).³⁸ For example, we rephrased an item from positively-keyed to negatively-keyed if necessary. The rephrasing exercise took place in several rounds of review and editing between the researcher and the members in the advisory committee until the two survey instruments (named Surveys

³⁸ A positively-keyed item is one for which a response of agreement is supportive of the model prediction associated with that item; a negatively-keyed items is one for which a response of disagreement is supportive.

A and B) were finalized.³⁹ The thirty nine unique items (statements) in those two surveys together are presented in Appendix F where each item is also assigned a questionnaire item number for reference purposes.⁴⁰

We created the online versions of surveys A and B in SurveyMonkey, a popular online survey portal. The surveys displayed the University of Waterloo logo.⁴¹ We allowed only one response per computer. Though the respondents could edit their responses before exiting or completing the survey, we did not allow them to do so afterwards. Neither did we display survey results to the respondents once they completed the survey. For anonymity, we set the surveys not to collect identifying information about the respondents (e.g., Internet Protocol (IP) address). When we were ready with our two online surveys, we informed our VC contact who in turn sent out his recruitment emails to the other seven VCs requesting them to participate in our survey. We then sent out our introduction email that also contained the online survey link to those VCs as well as our VC contact in two groups. We present the survey instrument A in its SurveyMonkey print version in Appendix E as a sample. Survey B contained items 2 and 21 to 39, but was otherwise identical with survey A.

Survey A had hundred percent response rate, while one VC did not participate in survey B.^{42,43} When we analyzed the survey responses, we found that responses to seven items appeared to be inconsistent with our predictions (out of the total thirty nine). Hence we decided to administer one more round of the survey with those seven items rephrased for greater clarity, for a reconfirmation of those apparently inconsistent responses. We prepared new survey instruments (named surveys A2 and B2) each of them containing eight rephrased items (one of those seven items had two rephrased versions).⁴⁴ Since we could include a maximum of twenty items in each instrument, we also included twenty four of the remaining thirty two items (twelve each in surveys A2 and B2) in order to maximize the overall number of responses from the survey project. To avoid administering the same item to a respondent

³⁹ At this stage, we obtained ethics clearance for the survey project from the Office of Research Ethics (ORE) of the University of Waterloo (ORE reference # 16864, Project Title: “Venture Capital Investment: Initiating and Revising the Deal”).

⁴⁰ The reference number of some of the items in that table have suffix where “a” indicates the original statement, and “b” and “c” indicate the rephrased versions of the corresponding original statement, discussion on which follows in this section. That table also shows the total number of responses received, the distribution of responses across different response choices, and the weighted average score for each item, discussion on which follows in §4.4.

⁴¹ Fox, Crask, and Kim (1988) found that university sponsorship improves response rate.

⁴² We decided not to follow up telephonically (from ethics point of view) because it was respondents’ decision to participate or not and also because only one did not participate.

⁴³ Non-response bias is not a problem here since all survey items apply uniformly to our respondents (Cui, 2003) who are all of similar professional stature.

⁴⁴ Though we could limit the item length to twenty five words or less recommended by the literature (e.g., Garson, 2009) for most of the original thirty nine items, the rephrased items often had to be longer; however, we split those items into two or three simple sentences where possible.

in the two rounds, items that appeared in survey A in the first round were now included in survey B2 and vice versa. The eight items (out of thirty two) that were excluded were those that had clear responses in the first round (i.e., they each had either a very high or a very low average score and usually had responses that were not widely dispersed).⁴⁵ The second-round of survey was then administered, but only one VC (out of four) responded to survey A2 and none responded to survey B2. We then compiled and analyzed the responses of both rounds, which we report in §4.4 after discussing the respondents in §4.3.

4.3 SURVEY RESPONDENTS

The online survey was administered to eight VCs of seven venture capital firms (with two of those VCs affiliated with one firm). In this section, we present anonymous details of the VCs and their firms. Since we knew from our VC contact the identity of those VCs and their firms, we could collect information about those VCs and their firms by accessing those firms' websites. All firms invest in high-growth technology companies at various growth stages including seed and early stages. Their investments typically range in size from C\$ 500,000 to C\$ 10 million. Some of these firms specifically state that they do not seek control in invested ventures, but all the firms actively commit their time and resources to ensure the success of ventures where their partners often take a seat in the board and use their expertise to play a key role for the success of the venture.

The VC from firm F1 has more than five years of investing experience and even longer operational leadership including board experience. This VC's investment experience includes that as the lead investor in at least five ventures some of which have also exited successfully, while the VC's operational experience includes CEO/COO positions in entrepreneurial ventures. Firm F1 has operations in the US and Canada and invests in information and communication technologies (ICT), has five partners (VCs), and has more than a hundred investments in its past and current portfolios.

The VC from firm F2 has more than ten years of investing and intellectual property legal experience focused on technology companies including board experience. The VC has negotiated and closed more than a hundred deals and was associated with more than ten successful exits. Firm F2 is a Canadian company that also has operations in Europe and invests in ICT. It has five partners, more than C\$ 300 million under management, and more than fifteen ventures in its current portfolio, and has successfully exited from more than twenty ventures.

The VC from firm F3 co-founded that firm and holds board positions in various firms. In more than ten years of venture capital experience, the VC mobilized about C\$ 200

⁴⁵ Finally, survey A2 contained rephrased items 8b, 10b, 11b, 11c, 12b, 20b, 25b, and 32b, and items 24, 26-30, 33-37, and 39; survey B2 contained those rephrased items and items 1, 3 to 7, 9, 13 to 15, 17, and 18.

million in venture capital and invested in twenty ventures many of which exited through acquisitions or Initial Public Offerings (IPOs). Firm F3 is based in Canada and is focused on life sciences ventures. It has five partners and there are five healthcare/biotechnology ventures in its current portfolio. The firm has also successfully exited from more than five ventures.

The VC from firm F4 has more than five years of experience as a VC, also as a board member, and several years of experience as a high ranking private equity investment banker and as a consultant for large companies in the ICT sector. Firm F4 is a Canadian company operating in multiple locations with diverse interests in ICT, green technologies, and life sciences among others but with partners usually focused on specific sectors. About fifteen partners take care of more than C\$ 500 million under management in numerous portfolio companies.

The VC from firm F5 has ten years of experience as a VC. He/She is a member in boards, has extensive experience in all facets of venture capital deals—valuation, structuring, and closing, and also has several years of industry experience. Firm F5 is Toronto based and invests in growth ventures in the ICT sector. It has five partners currently overseeing more than fifteen portfolio companies. It has already exited successfully from more than twenty ventures.

The VC from firm F6 combines more than fifteen years of experience as a technologist, an entrepreneur, a VC, and a board member, and that experience also includes corporate venture capital investing. Having been a start-up CEO, this VC focuses on evaluating the entrepreneurial team. Firm F6 is part of a large US based venture capital group and operates from Quebec with a focus on the ICT sector. It has three partners, complemented by more than ten partners in the parent company, overseeing about C\$ 100 million under management in more than ten current portfolio companies.

We administered the survey to two VCs from firm F7. One of them cofounded that firm and has been a VC for about ten years, prior to which that VC held CEO/CFO or board positions in several technology start-ups and negotiated the sale of one of those ventures for about half a billion dollars. The other has also been a VC for about ten years and also has senior management experience including as a board member in technology start-up environment. Firm F7 is Ontario based and focused on the ICT sector, has three partners overseeing about C\$ 100 million under management. It has more than ten ventures in its current portfolio and has had successful exits through acquisitions and IPOs.

The foregoing discussion suggests that the VCs who responded to our survey are highly accomplished venture capital investors who are experts in transforming technology start-ups into successful companies through all growth stages. Most often they also bring

entrepreneurial or operational experience from technology start-ups. Most importantly, they are seasoned in negotiating and closing deals. It is apparent that these respondents are highly qualified to comment on the venture capital deal process.

4.4 DISCUSSION OF FINDINGS

In this section, we discuss how our predictions compare with our survey findings. Appendix F presents the distribution of responses for each of the thirty nine survey items and also the rephrased items. By assigning values ranging from 7 to 1 (in steps of one) to the response choices ranging from “Strongly Agree” to “Strongly Disagree,” we computed an average score for each of the items.⁴⁶ We use those scores in the following discussion of findings, where an average score greater than 4 indicates agreement with the item and less than 4 indicates disagreement while an average score of 4 indicates a neutral position.

Model Assumptions

We now report how two central assumptions of our model compare with the survey findings. The first such assumption is that the VC takes on a belief about the entrepreneur’s minimum effort level e_{min} in order to determine the offer—the modeling feature that enabled us to deal with private information on entrepreneurial characteristics. In fact, the respondents agreed to the item (statement) “The VC’s judgment, at the time of making the offer, about the entrepreneur’s future performance is ultimately the most important factor affecting his/her return from the investment” (Q29 in Appendix F) with an average score of 5.2, which supports that VCs use judgment in their decision-making (Messica, 2008; Levie and Gimmon, 2008; Metrick, 2007) and specifically that the VC’s judgment about e_{min} is central to his/her decision-making, a major departure from the optimal contract literature but one that is consistent with the “VC method.” Our second central assumption is that the VC’s belief on e_{min} is likely hazy and belongs to an interval so there may be room for the VC to improve that belief in the course of the deal negotiations which in turn would enable the VC to revise a rejected offer. The respondents disagreed with the item “VCs do not revise offers rejected by first-time entrepreneurs” (Q2) with an average score of 2.375, which supports that assumption because a revision must necessarily be preceded by an improvement in the VC’s belief on e_{min} . We recall that the VC’s offer (i.e., the VC’s ownership share α) is a unique solution dependent on e_{min} for given values of the rest of the parameters per §2.3.1 and further that the VC can revise a rejected offer if α decreases when e_{min} increases per propositions P1 and P2 in §2.4. In other words, this small set of VCs support our central modeling approach. Table 4.1 summarizes the above findings.

⁴⁶ The average score of an item is its weighted average score, weights being the number of respondents choosing a particular level of agreement or disagreement with that item (statement).

TABLE 4.1
Summary of Survey Findings for Assumptions

Assumption	Questionnaire Item to Test Assumption [†]	Result
1. VC takes on a belief on e_{min} to determine the offer.	Q29: The VC's judgment, at the time of making the offer, about the entrepreneur's future performance is ultimately the most important factor affecting his/her return from the investment. (Agree)	Q29: Support (we know from an agreement to this statement that VCs take on a belief on entrepreneurial effort)
2. VC's belief on e_{min} likely belongs to an interval so the VC may revise a rejected offer.	Q2: VCs do not revise offers rejected by first-time entrepreneurs. (Disagree)	Q2: Support (we know from a disagreement that VCs may revise rejected offers, which is only possible with an update of the VC's belief on e_{min})

[†]The average response the questionnaire item received is noted in parentheses for each item.

Propositions

Proposition 1 (P1) proposed that, when the marginal change ds/de_{min} in the VC's service level is negative (as his/her belief about the entrepreneur's minimum effort level improves), the VC should revise a rejected offer if and only if $ds/de_{min} > -\frac{\alpha R_{e_{min}}}{c} \equiv \Lambda$. As noted in Table 2.3, lower time constraints and higher ownership share (in the rejected offer) for the VC and higher entrepreneurial productivity anticipated by the VC all relax Λ and facilitate revision and deal closure. However, on the contrary, the statement "VCs under greater time constraints are less likely to revise rejected offers" (Q20) was disagreed with an average score of 2.5. The rephrased statement in the second round survey "VCs under greater time constraints may be less likely to find it feasible to revise rejected offers though they can find the time required to revise such offers" was also disagreed with a score of 2 (for a combined average of 2.4). The statement "The VC would be more inclined to revise a rejected offer if the VC's ownership share in the rejected offer is high" (Q39) received a neutral response with an average score of 4. One plausible explanation for the above apparent inconsistency is that VCs minimize the negative impact of time constraints on their deal-making ability—that is, they keep the marginal return to service c as low as possible (c can approach 0) so that Λ relaxes considerably and there is *effectively* no lower bound for ds/de_{min} .⁴⁷ In that case the revision decision would become insensitive to the parameters α , $R_{e_{min}}$, and c . Recall from Table 3.11 that a high c is undesirable for the VC because that tends to reduce the entrepreneur's effort level and the VC's actual excess profit. In fact, VCs employ analysts and investment managers to help them (e.g., Metrick, 2007) and may also outsource service to paid "entrepreneurs-in-residence" (Schwarzkopf et al., 2010)—practices that should help them deal with time-constraints.

⁴⁷ Since $c \geq 0$, $\alpha > 0$, and, per Eq. (1), $R_{e_{min}} \equiv R_e > 0$, the lower bound on ds/de_{min} will approach $-\infty$ as c approaches 0.

P1 also proposed that, when the marginal change ds/de_{min} in the VC's service level is positive (as his/her belief about the entrepreneur's minimum effort level improves), the VC should revise a rejected offer if and only if $ds/de_{min} < \frac{R_{se_{min}}}{|R_{ss}|} \equiv \Delta$. As noted in Table 2.3, a larger effect of the entrepreneur's effort on the marginal productivity of the VC (i.e., more effective teamwork) and a smaller effect of service level on the marginal productivity of the VC (i.e., less severe concavity of revenue with respect to the VC's service) both relax Δ and facilitate revision and deal closure. While the statement "VCs who specialize in the venture's industry are more likely to invest than those who do not" (Q19) was agreed with an average score of 6.25, the one VC who responded to the statement "The entrepreneur's ability to work well with the VC is one of the most important factors influencing whether the VC will make an offer" (Q11c) agreed with that statement with a score of 6, both broadly consistent with P1. We recall that when VCs specialize in industries they can maintain high productivities even at high levels of service (i.e., $|R_{ss}|$ would be low) since their advisory capacity will increase. In fact, the respondents also agreed that "VCs who specialize in industries are likely to provide high quality advising/monitoring" (Q38) with an average score of 6.

Proposition 3 (P3) proposed that "Everything else being equal, if the VC increases the entrepreneur's base salary, then that VC's ownership share and service level should increase. The resulting increase in the VC's ownership share does not necessarily decrease the entrepreneur's optimal effort level, nor does the increase in the base salary necessarily increase the entrepreneur's return, decrease the VC's excess profit, or decrease the investment-deal welfare." Indeed, the respondents disagreed with the statement "The entrepreneur's performance is usually sensitive to the size of the base salary he/she receives" (Q28) with an average score of 2.8, which supports P3 that the entrepreneur's effort level may not (indirectly) decrease as a result of an increase in the entrepreneur's base salary. The respondents also disagreed with the statement "An increase in the entrepreneur's base salary would necessarily increase the entrepreneur's overall return" (Q13) with an average score of 3, which supports P3 that an increase in the entrepreneur's base salary need not increase his/her return. The respondents further disagreed with the statement "An increase in the entrepreneur's base salary would necessarily decrease the VC's return" (Q 17) with an average score of 2.5, which also supports P3 that an increase in the entrepreneur's base salary need not decrease the VC's excess profit. Despite the above supports to P3, the respondents were neutral with the statement "If the entrepreneur requires a higher base salary, the VC would demand a larger ownership share" (Q31) with an average score of 4, which does not firmly support P3 that an increase in the entrepreneur's salary will lead to an increase in the VC's ownership share. A plausible explanation for this ambiguity is that the entrepreneur is likely paid a modest base salary that is primarily meant to cover his/her living expenses, so

any increase on that salary would be even more modest. Such a modest increase is unlikely to lead to a considerable (perceptible) increase in the ownership share that the VC should demand. In fact, our regression in Table 3.5 predicts that a 1% increase in base salary would only lead to an about 0.05% increase in the VC’s ownership share.⁴⁸ Table 4.2 summarizes the above findings.

TABLE 4.2
Summary of Survey Findings for Propositions

Proposition	Questionnaire Item to Test Proposition [†]	Result [‡]
P1: $-\frac{\alpha R_{e_{min}}}{c} < \frac{ds}{de_{min}} < \frac{R_{se_{min}}}{ R_{ss} }$	<p><i>Lower Bound</i></p> Q20a: VCs under greater time constraints are less likely to revise rejected offers. (Disagree) Q20b: VCs under greater time constraints may be less likely to find it feasible to revise rejected offers though they can find the time required to revise such offers. (Disagree) Q39: The VC would be more inclined to revise a rejected offer if the VC’s ownership share in the rejected offer is high (Neutral) <p><i>Upper Bound</i></p> Q19: VCs who specialize in the venture’s industry are more likely to invest than those who do not. (Agree) Q11c: The entrepreneur’s ability to work well with the VC is one of the most important factors influencing whether the VC will make an offer. (Agree) Q38: VCs who specialize in industries are likely to provide high quality advising/monitoring. (Agree)	<p><i>Lower Bound</i></p> Q20a/b: Reject? Q39: Neutral? <p><i>Upper Bound</i></p> Q19: Support Q11a: Support Q38: Support
P3: Everything else being equal, if the VC increases the entrepreneur’s base salary, then that VC’s ownership share and service level should increase. The resulting increase in the VC’s ownership share does not necessarily decrease the entrepreneur’s optimal effort level, nor does the increase in the base salary necessarily increase the entrepreneur’s return, decrease the VC’s excess profit, or decrease the investment-deal welfare.	Q28: The entrepreneur’s performance is usually sensitive to the size of the base salary he/she receives. (Disagree) Q13: An increase in the entrepreneur’s base salary would necessarily increase the entrepreneur’s overall return. (Disagree) Q17: An increase in the entrepreneur’s base salary would necessarily decrease the VC’s return. (Disagree) Q31: If the entrepreneur requires a higher base salary, the VC would demand a larger ownership share. (Neutral)	Q28: Support Q13: Support Q17: Support Q31: Neutral?

[†]The average response the questionnaire item received is noted in parentheses for each item.

[‡]Results with a question mark are explained in the discussion of findings.

⁴⁸ The elasticities noted in this chapter are from our regressions in Chapter 3 and pertain to the large hypercube.

Conjecture

Based on our simulation, we conjectured that $e_{minP} \leq e_{minW} \leq e_{minE}$ (where e_{minP} , e_{minW} , and e_{minE} are the VC's beliefs on the entrepreneur's minimum effort level that respectively maximize the VC's actual excess profit P , the deal welfare W , and the entrepreneur's return E) and that $\alpha_E \leq \alpha_W \leq \alpha_P$ (where α_E , α_W , and α_P are the VC's ownership shares that respectively maximize E , W , and P) in VC investment scenarios where a deal closure is possible. In fact, the respondents agreed with the statement "If the VC is highly confident about a first-time entrepreneur's performance, it would normally work to the advantage of that entrepreneur" (Q30) with an average score of 5.4, which supports the conjecture by implying that a high e_{min} (resulting from the VC's high confidence) is more likely to maximize E than P to the advantage of the entrepreneur. The respondents further agreed that "Making entrepreneurial characteristics (e.g., commitment and competence) more transparent to VCs can benefit entrepreneurs" (Q37) with an average score of 5, which also supports the conjecture because a well-informed VC need not underestimate e_{min} in order to safeguard his/her investment. Moreover, the respondents agreed that "It is desirable for VCs to hold a moderate ownership share (say, 20% to 60%) in early-stage ventures of first-time entrepreneurs" (Q18) and that "The entrepreneur would normally like to own a larger share of the venture than what is offered by the VC" (Q1) with average scores of 5.25 and 5.5 respectively, consistent with the conjecture that there exists unique α_P and that $\alpha_E < \alpha_P$. We note that Q18 implies that P is an inverted-U shape with respect to α where it is maximized for some value of α . Table 4.3 summarizes the above findings.

TABLE 4.3
Summary of Survey Findings for Conjecture

Conjecture	Questionnaire Item to Test Conjecture [†]	Result
There exist unique "critical" values of e_{min} and α such that, where a deal can close, $e_{minP} \leq e_{minW} \leq e_{minE}$ and $\alpha_E \leq \alpha_W \leq \alpha_P$.	Q30: If the VC is highly confident about a first-time entrepreneur's performance, it would normally work to the advantage of that entrepreneur. (Agree) Q37: Making entrepreneurial characteristics (e.g., commitment and competence) more transparent to VCs can benefit entrepreneurs. (Agree) Q18: It is desirable for VCs to hold a moderate ownership share (say, 20% to 60%) in early-stage ventures of first-time entrepreneurs. (Agree) Q1: The entrepreneur would normally like to own a larger share of the venture than what is offered by the VC. (Agree)	Q30: Support Q37: Support Q18: Support Q1: Support

[†]The average response the questionnaire item received is noted in parentheses for each item.

Probabilities of VC Making an Offer and Entrepreneur Accepting an Offer

For a deal to close, the VC should make an offer and the entrepreneur should ultimately accept an offer. Our regression results in Tables 3.4 and 3.7 predict, respectively, how the model parameters would influence the probability of VC making an offer and the probability of entrepreneur accepting an offer. A 1% increase in the entrepreneur's effectiveness in teamwork ε_2 (effectiveness in solo-work ε_1) would increase the probability of VC making an offer by 1% (0.59%) and the probability of entrepreneur accepting an offer by 3.95% (2.52%). In fact, the respondents agreed with the statement "For VC financing to materialize, the entrepreneur's ability to work well with the VC is more important than the entrepreneur's ability to work well independently of the VC" (Q14) with an average score of 4.5 and disagreed that "For encouraging the VC to make an offer, the entrepreneur's ability to work well independently of the VC is more important than the entrepreneur's ability to work well with the VC" (Q3) with an average score of 2.5. They also agreed that "The entrepreneur's ability to work well independently of the VC encourages the VC to make an offer" (Q33) with an average score of 4.6. All those responses support the above predictions. The respondents further agreed that "The VC is more likely to invest if the entrepreneur's effort is expected to be highly productive" (Q21) with an average score of 6.25 consistent with the predictions that these two probabilities are highly sensitive to the two parameters ε_2 and ε_1 .

However, though as per regression coefficients "the entrepreneur's effectiveness in teamwork (ε_2) is the most important factor influencing whether the VC will make an offer," the respondents disagreed with the statement "the entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer" (Q11a) with an average score of 2.75, but were neutral with the statement "Apart from the commercial potential of the venture, the entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer" (Q11b). A plausible reason for the inconsistency is that the phrase "the entrepreneur's ability to work well with the VC" may not unambiguously convey "the entrepreneur's effectiveness in teamwork (ε_2)"; rather, the respondents might have sometimes interpreted that phrase to mean how cooperative the entrepreneur is with the VC, which is indeed unlikely to be more important than the entrepreneur's competence itself (the other factor contributing to ε_2 and the only factor contributing to the entrepreneur's effectiveness in solo-work ε_1). That explanation is consistent with the respondents' agreement with the statement "The entrepreneur's ability to work well with the VC is one of the most important factors influencing whether the VC will make an offer" (Q11c).

The respondents also agreed that "VCs who specialize in the venture's industry are more likely to invest than those who do not" (Q19) with an average score of 6.25 and disagreed that "A VC expecting to be influential in advising/monitoring would be less likely

to finance the venture” (Q36) with an average score of 2.4 both supporting the regression predictions that the probabilities of VC making an offer and entrepreneur accepting an offer would increase, respectively, by 0.21% and 0.55% when the VC’s effectiveness σ increases by 1%. We recall that VCs become more effective in their service when they specialize in industries. The respondents further agreed that “The size of the base salary offered affects whether the deal will close” (Q22) with an average score of 5.25. Though the sensitivity of the probability of VC making an offer with respect to base salary is low (a 1% increase in the base salary only reduces that probability by about 0.03%) and the sensitivity of the probability of entrepreneur accepting an offer is ambiguous, the former sensitivity is statistically significant at a 5% confidence level.

Regressions also predict that a 1% increase in the investment amount would decrease the probability of VC making an offer by about 0.6% though the effect on the probability of entrepreneur accepting an offer is ambiguous. Though the respondents, on the contrary, disagreed that “The VC would be reluctant to make an offer when the investment amount is large” (Q8a) with an average score of 1.5, the lone VC responding in the second round agreed, consistent with that prediction, that “VCs would like entrepreneurs to ask for an investment amount that is only absolutely essential, not any more” (Q8b). We note that the sensitivity of offer made with respect to investment amount is *after* controlling for the parameters $k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma$ that represent the revenue (i.e., commercial) potential of the venture, so we may infer that VCs are ready to invest large sums but those sums should be commensurate with the commercial potential of the venture. Table 4.4 summarizes the above findings.

VC’s Ownership share

Our regression results in Table 3.5 predict that a 1% increase in the VC’s belief on e_{min} would decrease the VC’s ownership share α by 0.87%. When there is large uncertainty about the venture’s success, the VC would estimate a low probability of successful exit in the “VC method” (equivalently, a low e_{min} in our model) and consequently a high α . In fact, respondents agreed that “The VC would demand a large ownership share to invest in ventures with large uncertainty” (Q4) with an average score of 5.25. Respondents also agreed that “The VC would demand a larger ownership share when the investment amount is larger” (Q23) and disagreed that “A VC under greater time constraints would demand a smaller ownership share” (Q26) with average scores of 1.6, both consistent with our predictions that a 1% increase in the investment amount I and marginal return to service c would respectively increase α by 0.9% and 0.05%.

TABLE 4.4
Summary of Survey Findings for the Probabilities of VC Making an Offer and Entrepreneur Accepting an Offer

Regression Prediction	Questionnaire Item to Test Prediction [†]	Result [‡]
1. A 1% increase in the entrepreneur's effectiveness in teamwork (ε_2) (effectiveness in solo-work (ε_1)) would increase the probability of VC making an offer by 1% (0.59%) and the probability of entrepreneur accepting an offer by 3.95% (2.52%).	Q14: For VC financing to materialize, the entrepreneur's ability to work well with the VC is more important than the entrepreneur's ability to work well independently of the VC. (Agree) Q3: For encouraging the VC to make an offer, the entrepreneur's ability to work well independently of the VC is more important than the entrepreneur's ability to work well with the VC. (Disagree) Q33: The entrepreneur's ability to work well independently of the VC encourages the VC to make an offer. (Agree) Q21: The VC is more likely to invest if the entrepreneur's effort is expected to be highly productive. (Agree)	Q14: Support Q3: Support Q33: Support Q21: Support
2. The entrepreneur's effectiveness in teamwork (ε_2) is the most important factor influencing whether the VC will make an offer.	Q11a: The entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer. (Disagree) Q11b: Apart from the commercial potential of the venture, the entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer. (Neutral) Q11c: The entrepreneur's ability to work well with the VC is one of the most important factors influencing whether the VC will make an offer. (Agree)	Q11a: Reject? Q11b: Neutral? Q11c: Support
3. The probabilities of VC making an offer and entrepreneur accepting an offer would increase, respectively, by 0.21% and 0.55% when the VC's effectiveness σ increases by 1%.	Q19: VCs who specialize in the venture's industry are more likely to invest than those who do not. (Agree) Q36: A VC expecting to be influential in advising/monitoring would be less likely to finance the venture. (Disagree)	Q19: Support Q36: Support
4. A 1% increase in the base salary reduces the probability of VC making an offer by about 0.03%.	Q22: The size of the base salary offered affects whether the deal will close. (Agree)	Q22: Support
5. A 1% increase in the investment amount would decrease the probability of VC making an offer by about 0.6%.	Q8a: The VC would be reluctant to make an offer when the investment amount is large. (Disagree) Q8b: VCs would like entrepreneurs to ask for an investment amount that is only absolutely essential, not any more. (Agree)	Q8a: Reject? Q8b: Support

[†]The average response the questionnaire item received is noted in parentheses for each item.

[‡]Results with a question mark are explained in the discussion of findings.

The importance of teamwork for VC financing was reiterated by the respondents' disagreement with the statements "If the VC is confident that the entrepreneur will work well with him/her, the VC would demand a larger ownership share" (Q9) and "If the VC-entrepreneur teamwork is critical to the venture's success, the VC would demand a larger ownership share" (Q15) with average scores of 2.75 and 3.5 respectively, both consistent with our regression predictions that a 1% increase each in the entrepreneur's effectiveness in teamwork ε_2 and the relative importance of teamwork k_2 would respectively decrease α by 2.2% and 1%.

However, the respondents agreed with the statement "The VC would demand a large ownership share if the VC's advising/monitoring is of high quality" (Q32a) with an average score of 5 and the lone VC who responded in the second round strongly disagreed with the statement "Consider a situation where a VC may invest but demand a large ownership share in a first-time entrepreneur's venture with a large uncertainty. Now assume that the VC's advising/monitoring is of high quality and larger revenue would be generated because of that high quality advising/monitoring. Then, that high quality would enable that VC to reduce to some extent the ownership share demanded" (Q32b). "High quality" of advising/monitoring (arising from the VC's competence) and how cooperative the VC is with the entrepreneur both contribute to the VC's effectiveness σ , a 1% increase in which our regression predicts would lead to a 1.22% reduction in α . Given that teamwork in general helps to reduce α (as suggested by the discussion on ε_2 in the previous paragraph), probably there are two effects on the sensitivity of α with respect to σ —a negative effect from the VC's teamwork (cooperation) with the entrepreneur and a positive effect from the VC's quality of advising/monitoring. If that is the case, a dominant negative effect would reconcile the survey finding with the regression predictions; it would also reiterate the importance of teamwork in VC financing by suggesting that not only the entrepreneur's teamwork with the VC but also the VC's teamwork with the entrepreneur is important (i.e., both parties should cooperate).

Finally, the respondents disagreed that "The VC would demand a large ownership share if his/her time is highly valuable" (Q12a) with an average score of 3 and the lone respondent in the second round also somewhat disagreed with the statement "Consider a situation where a VC has determined the ownership share he/she should demand if he/she were to invest in a venture. Then, if the VC's time were more valuable than what it actually is, the VC would increase to some extent the ownership share demanded" (Q12b), both inconsistent with the regression prediction that a 1% increase in the unit cost of service (i.e., the unit cost for the VC's time) w would increase the VC's ownership share α by 0.27%. A plausible reason for the discrepancy is that, though significant, w is one of the least important factors predicted to influence α , so VCs are unlikely to be categorical about the influence of

w on α . In fact, the responses to the two statements were widely dispersed from “somewhat agree” to “strongly disagree” (with no two VCs exhibiting same level of agreement or disagreement). Table 4.5 summarizes the above findings.

TABLE 4.5
Summary of Survey Findings for the VC’s Ownership Share

Regression Prediction	Questionnaire Item to Test Prediction [†]	Result [‡]
1. A 1% increase in e_{min} would decrease the VC’s ownership share α by 0.87%.	Q4: The VC would demand a large ownership share to invest in ventures with large uncertainty. (Agree)	Q4: Support
2. A 1% increase in the investment amount I would increase α by 0.9%.	Q23: The VC would demand a larger ownership share when the investment amount is larger. (Agree)	Q23: Support
3. A 1% increase in marginal return to service c would increase α by 0.05%.	Q26: A VC under greater time constraints would demand a smaller ownership share. (Disagree)	Q26: Support
4. A 1% increase in the entrepreneur’s effectiveness in teamwork ε_2 would decrease α by 2.2%.	Q9: If the VC is confident that the entrepreneur will work well with him/her, the VC would demand a larger ownership share. (Disagree)	Q9: Support
5. A 1% increase in the relative importance of teamwork k_2 would decrease α by 1%.	Q15: If the VC-entrepreneur teamwork is critical to the venture’s success, the VC would demand a larger ownership share. (Disagree)	Q15: Support
6. A 1% increase in the VC’s effectiveness σ would decrease α by 1.22%.	Q32a: The VC would demand a large ownership share if the VC’s advising/monitoring is of high quality. (Agree) Q32b: Consider a situation where a VC may invest but demand a large ownership share in a first-time entrepreneur’s venture with a large uncertainty. Now assume that the VC’s advising/monitoring is of high quality and larger revenue would be generated because of that high quality advising/monitoring. Then, that high quality would enable that VC to reduce to some extent the ownership share demanded. (Disagree)	Q32a/b: Reject?
7. A 1% increase in the unit cost of service w would increase α by 0.27%.	Q12a: The VC would demand a large ownership share if his/her time is highly valuable. (Disagree) Q12b: Consider a situation where a VC has determined the ownership share he/she should demand if he/she were to invest in a venture. Then, if the VC’s time were more valuable than what it actually is, the VC would increase to some extent the ownership share demanded. (Disagree)	Q12a/b: Reject?

[†]The average response the questionnaire item received is noted in parentheses for each item.

[‡]Results with a question mark are explained in the discussion of findings.

VC’s Service Level

As per our regression predictions in Table 3.5, a 1% increase in the VC’s effectiveness σ , the entrepreneur’s effectiveness in teamwork ε_2 , and the latter’s base salary b each would respectively increase the VC’s service level s by 2.27%, 1.81%, and 0.08%. Consistent with those predictions, our respondents agreed that “If the VC’s advising/monitoring is influential,

the VC would increase advising/monitoring” (Q27) and disagreed with the statements “If the entrepreneur works well with the VC, the VC would reduce advising/ monitoring” (Q24) and “The VC would reduce advising/monitoring when the entrepreneur is paid a high base salary” (Q5) with average scores respectively of 4.4, 2.6, and 1.25.

The respondents however disagreed that “The VC would increase advising/monitoring when the investment amount is large” (Q10a) with an average score of 3.25 and the lone VC responding in the second round also somewhat disagreed with the statement “Consider a situation where a VC may invest in a first-time entrepreneur’s venture. Now assume that the venture requires an investment that is larger for its level of expected revenue. Then, the VC would expect to advise/monitor more if he/she were to invest” (Q10b) while the regression predicts on the contrary that a 1% increase in the investment amount I would increase the VC’s service level s by 1.43% (I being one of the most important predictors of s). We note that, since revenue-related parameters $k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma$ have all been controlled for in the regression, the above sensitivity refers to investment relative to the revenue potential of the venture. Now recall that the lone VC responding in the second round had somewhat agreed that “VCs would like entrepreneurs to ask for an investment amount that is only absolutely essential, not any more” (Q8b). In any case, it is reasonable to expect that VCs would take necessary steps in due diligence to verify the investment amount asked for and only invest an amount that does not have a significant slack (since surplus investment would pose a risk of larger loss in the event of venture failure). If that is the case, service level may not significantly be sensitive to investment amount (whether large or small). Table 4.6 summarizes the above findings.

TABLE 4.6
Summary of Survey Findings for the VC’s Service Level

Regression Prediction	Questionnaire Item to Test Prediction [†]	Result [‡]
1. A 1% increase in the VC’s effectiveness σ , the entrepreneur’s effectiveness in teamwork ε_2 , and the latter’s base salary b each would respectively increase the VC’s service level s by 2.27%, 1.81%, and 0.08%.	Q27: If the VC’s advising/monitoring is influential, the VC would increase advising/monitoring. (Agree) Q24: If the entrepreneur works well with the VC, the VC would reduce advising/ monitoring. (Disagree) Q5: The VC would reduce advising/monitoring when the entrepreneur is paid a high base salary. (Disagree)	Q27: Support Q24: Support Q5: Support
2. A 1% increase in the investment amount I would increase s by 1.43%.	Q10a: The VC would increase advising/monitoring when the investment amount is large. (Disagree) Q10b: Consider a situation where a VC may invest in a first-time entrepreneur’s venture. Now assume that the venture requires an investment that is larger for its level of expected revenue. Then, the VC would expect to advise/monitor more if he/she were to invest. (Disagree)	Q10a/b: Reject?

[†]The average response the questionnaire item received is noted in parentheses for each item.

[‡]Results with a question mark are explained in the discussion of findings.

Entrepreneur's Effort Level

The respondents agreed that “The entrepreneur puts in more effort if VC-entrepreneur teamwork is critical to the venture’s success” (Q6) with an average score of 4.25 consistent with the prediction in Table 3.6 that a 1% increase in the parameter k_2 would lead to a 4.58% increase in the entrepreneur’s optimal effort level and a 2.3% increase in the probability of entrepreneur exerting best effort. Recall that k_2 is the relative importance of teamwork (i.e., the weight of teamwork in the revenue function) while k_1 is the relative importance of the entrepreneur’s solo-work. On a related note, we also recall that our various regressions predict that k_2 is more important than k_1 in determining the various deal outcomes —namely, the probability of VC making an offer (Table 3.4), the VC’s ownership share and service level (Table 3.5), the entrepreneur’s effort level and the probability of entrepreneur exerting best effort (Table 3.6), the probability of entrepreneur accepting an offer (Table 3.7), the entrepreneur’s expected return (Table 3.8), and investment deal welfare (Table 3.10). This implies that VC financing is more likely for ventures where teamwork is important (i.e., where the VC can meaningfully contribute).

Furthermore, the respondents disagreed that “The entrepreneur puts in less effort if the VC’s advising and monitoring is of high quality” (Q34) with an average score of 2.6 consistent with the prediction that a 1% increase in the VC’s effectiveness σ would lead to a 2.62% increase in the entrepreneur’s effort level (though its influence on the probability of entrepreneur exerting best effort is ambiguous). As already noted, the quality of the VC’s advising and monitoring arising from his/her competence contributes to the VC’s effectiveness. The respondents also disagreed that “The entrepreneur would exert best effort only when allocated a large ownership share (say, above 80%)” (Q7) with an average score of 1.25, consistent with our finding from our illustrative example in Table 2.2 where the entrepreneur’s optimal effort level reaches its maximum even when the VC takes as large as 46% of the ownership share leaving only about 54% for the entrepreneur. Finally, as we already noted in §4.4.2 with reference to our Proposition 3, the respondents disagreed that “The entrepreneur’s performance is usually sensitive to the size of the base salary he/she receives” (Q28) with an average score of 3.25, which is also consistent with our regression prediction that base salary does not significantly influence either the entrepreneur’s optimal effort level or the probability of entrepreneur exerting best effort.

Table 3.6 also predicts that a 1% increases each in the entrepreneur’s effectiveness in teamwork ε_2 and his/her effectiveness in solo-work ε_1 would respectively increase the probability of entrepreneur exerting best effort by about 4.09% and 2.82%. In fact, ε_2 is the second most important parameter (after the entrepreneur’s unit cost of effort ω but ahead of the entrepreneur’s effectiveness in solo-work ε_1) predicted to influence whether the entrepreneur will put in his/her best effort in the invested venture. However, our respondents

disagreed that “For encouraging the entrepreneur to exert best effort, the entrepreneur’s ability to work well with the VC is more important than the entrepreneur’s ability to work well independently of the VC” (Q25a) with an average score of 3.75. The lone VC responding in the second round also disagreed with the statement “The entrepreneur’s ability to work well with the VC is more influential than the entrepreneur’s ability to work well independently of the VC in determining whether the entrepreneur will exert best effort” (Q25b). A plausible reason for this apparent discrepancy is that, as already noted, the respondents could have interpreted the phrase “the entrepreneur’s ability to work well with the VC” to mean how cooperative the entrepreneur is with the VC rather than how effective he/she is in teamwork, which is also influenced by the entrepreneur’s competence. An entrepreneur who is ready to cooperate with the VC but lacking in competence is less likely to display superior performance. Table 4.7 summarizes the above findings.

TABLE 4.7
Summary of Survey Findings for the Entrepreneur’s Effort Level

Regression Prediction	Questionnaire Item to Test Prediction [†]	Result [¥]
1) A 1% increase in the relative importance of teamwork k_2 would lead to a 4.58% increase in the entrepreneur’s optimal effort level and a 2.3% increase in the probability of entrepreneur exerting best effort.	Q6: The entrepreneur puts in more effort if VC-entrepreneur teamwork is critical to the venture’s success. (Agree)	Q6: Support
2) A 1% increase in the VC’s effectiveness σ would lead to a 2.62% increase in the entrepreneur’s effort level.	Q34: The entrepreneur puts in less effort if the VC’s advising and monitoring is of high quality. (Disagree)	Q34: Support
3) The entrepreneur may exert best effort even when not allocated a large ownership share (per Table 2.2).	Q7: The entrepreneur would exert best effort only when allocated a large ownership share (say, above 80%). (Disagree)	Q7: Support
4) Base salary does not significantly influence either the entrepreneur’s optimal effort level or the probability of entrepreneur exerting best effort.	Q28: The entrepreneur’s performance is usually sensitive to the size of the base salary he/she receives. (Disagree)	Q28: Support
5) 1% increases each in the entrepreneur’s effectiveness in teamwork ε_2 and his/her effectiveness in solo-work ε_1 would respectively increase the probability of entrepreneur exerting best effort by about 4.09% and 2.82%.	Q25a: For encouraging the entrepreneur to exert best effort, the entrepreneur’s ability to work well with the VC is more important than the entrepreneur’s ability to work well independently of the VC. (Disagree) Q25b: The entrepreneur’s ability to work well with the VC is more influential than the entrepreneur’s ability to work well independently of the VC in determining whether the entrepreneur will exert best effort. (Disagree)	Q25a: Reject?

[†]The average response the questionnaire item received is noted in parentheses for each item.

[¥]Results with a question mark are explained in the discussion of findings.

Entrepreneur's Return and VC's Excess Profit

Our respondents agreed that “The entrepreneur’s ability to work well independently of the VC affects his/her return from the venture” (Q16) and that “The VC-entrepreneur teamwork highly influences the entrepreneur’s return” (Q35) with average scores respectively of 5 and 5.4, consistent with our predictions in Table 3.8 that a 1% increase each in the entrepreneur’s effectiveness in solo-work ε_1 and the relative importance of teamwork k_2 would respectively increase the entrepreneur’s return E by about 0.66% and 1%. Moreover, as noted in §4.4.2, the respondents disagreed that “An increase in the entrepreneur’s base salary would necessarily increase the entrepreneur’s overall return” (Q13) with an average score of 3, consistent with Proposition 3 and our regression prediction where the influence of base salary b on E is ambiguous. Furthermore, as noted in §4.4.2, they agreed with the statements “If the VC is highly confident about a first-time entrepreneur’s performance, it would normally work to the advantage of that entrepreneur” (Q30) and “Making entrepreneurial characteristics (e.g., commitment and competence) more transparent to VCs can benefit entrepreneurs” (Q37) with average scores respectively of 5.4 and 5, supporting our conjecture and regression prediction that a 1% increase in the VC’s belief about the entrepreneur’s minimum effort level e_{min} would lead to a 0.47% increase in the latter’s return. With better information about entrepreneurial characteristics, VCs are less likely to underestimate e_{min} .

As per our regression results for Model 1 in Table 3.9, the VC’s belief on the entrepreneur’s minimum effort level e_{min} is the most important predictor of the VC’s excess profit P (i.e., P is most sensitive to e_{min}). Specifically, a 1% increase in e_{min} is predicted to reduce P by 2.48%. In fact, as noted in §4.4.1, the respondents agreed to the statement “The VC’s judgment, at the time of making the offer, about the entrepreneur’s future performance is ultimately the most important factor affecting his/her return from the investment” (Q29) with an average score of 5.2 consistent with the above prediction. Furthermore, as noted in §4.4.2, the respondents disagreed that “An increase in the entrepreneur’s base salary would necessarily decrease the VC’s return” (Q17) with an average score of 2.5, consistent with Proposition 3 and our regression that predicts that a 1% increase in the entrepreneur’s base salary b would in fact increase P by 0.1%. We recall that, when b increases, the ownership share α the VC should demand will increase (as per the proof for Proposition 3 in Appendix B), which in turn may cause P to either increase or decrease depending on whether α moves close to or away from α_P that maximizes P . Table 4.8 summarizes the above findings.

TABLE 4.8

Summary of Survey Findings for the Entrepreneur’s Return and the VC’s Excess Profit

Regression Prediction	Questionnaire Item to Test Prediction [†]	Result [‡]
1) 1% increases each in the entrepreneur’s effectiveness in solo-work ε_1 and the relative importance of teamwork k_2 would respectively increase the entrepreneur’s return E by about 0.66% and 1%.	Q16: The entrepreneur’s ability to work well independently of the VC affects his/her return from the venture. (Agree) Q35: The VC-entrepreneur teamwork highly influences the entrepreneur’s return. (Agree)	Q16: Support Q35: Support
2) The influence of base salary b on E is ambiguous	Q13: An increase in the entrepreneur’s base salary would necessarily increase the entrepreneur’s overall return. (Disagree)	Q13: Support
3) A 1% increase in the VC’s belief about the entrepreneur’s minimum effort level e_{min} would lead to a 0.47% increase in the latter’s return.	Q30: If the VC is highly confident about a first-time entrepreneur’s performance, it would normally work to the advantage of that entrepreneur. (Agree) Q37: Making entrepreneurial characteristics (e.g., commitment and competence) more transparent to VCs can benefit entrepreneurs. (Agree)	
4) The VC’s belief on the entrepreneur’s minimum effort level e_{min} is the most important predictor of the VC’s excess profit P .	Q29: The VC’s judgment, at the time of making the offer, about the entrepreneur’s future performance is ultimately the most important factor affecting his/her return from the investment. (Agree)	Q29: Support
5) A 1% increase in the entrepreneur’s base salary b would increase P by 0.1%.	Q17: An increase in the entrepreneur’s base salary would necessarily decrease the VC’s return. (Disagree)	Q17: Support

[†]The average response the questionnaire item received is noted in parentheses for each item.

[‡]Results with a question mark are explained in the discussion of findings.

Overall Summary of Survey Findings vis-à-vis Predictions

Table 4.9 summarizes how our survey findings compare with our regression predictions on the parameter sensitivities of various deal outcomes. This table is essentially a replication of Table 3.11 that summarizes those predictions, but in the new table we also show which of those predictions are supported by our survey findings using square brackets for support and parentheses for possible support. We recall that a few questionnaire items did not apparently support their corresponding predictions but we reasoned why that need not be the case (and uncovered new insights while doing so). The cells containing such predictions are enclosed with parentheses to indicate possible support.

TABLE 4.9
Summary of Survey Findings vis-à-vis the Predictions

	Probability of VC making an offer	VC's ownership share	VC's service level	Entrepreneur's effort level	Probability of entrepreneur exerting best effort	Probability of entrepreneur accepting an offer	Entrepreneur's return	VC's excess profit	Deal welfare
r	-	+	+	N.A.	N.A.	N.A.	N.A.	+	+
I	(-)	[+]	(+)	-?	+?	+?	+?	+	+
w	+	(+)	-	-	-?	-	-?	N. A.	-?
c	+	[+]	-	-	-	-	-	-	-
b	[-]	+	[+]	[N.A.]	[N.A.]	+?	[+?]	[+]	+?
k_1	+	-	-	+	+	+	+	+?	+
k_2	+	[-]	+	[+]	[+]	+	[+]	+?	+
ε_1	[+]	-	-	+	+	[+]	[+]	+	+
ε_2	[+]	[-]	[+]	+	(+)	[+]	+	+?	+
σ	[+]	(-)	[+]	[+]	+?	[+]	+	-	+
ω	N.A.	N.A.	N.A.	-	-	-	-	-	-
e_{min}	+	[-]	-	+	+	-	[+]	[-]	+

Legend: "+" indicates positive influence; "-" negative; "?" possibly; and "N. A." Not affected. Predictions in square brackets are supported by survey findings and those in parentheses are possibly supported. The rest were not tested.

4.5 CONCLUSION

We conducted an online survey of VCs to see how our predictions compare with practice. We asked eight accomplished VCs located in Toronto, Waterloo, and Montreal to answer thirty-nine questionnaire items that concerned our major assumptions and predictions from our propositions, conjecture, and regressions (that used synthetic data from our simulation).

Though the number of respondents was small and the individual survey items only had a maximum of five responses (one had eight), the survey exercise appears to have served an important purpose. Specifically, this (mini) survey has revealed support for our two central assumptions and also for a vast majority of our predictions. Particularly, our modeling of the VC deal process as an iterative process, a substantial departure within the VC contracting literature dominated by optimal contracts (where an offer made is immediately acceptable to the entrepreneur) and our use of belief on the part of the VC (in line with the "VC method") as the basis of that iterative process seem to have received credence from the survey findings. This kind of support (from a small sample of VCs) suggests that the model has face validity and, possibly, some preliminary empirical support.

That small sample size is the key drawback of the survey exercise. However, a large sample would only be needed in situations such as when weaker relationships are to be detected and when the variables have large variance (Garson, 2009). Our need to limit the

survey length forced us to exclude insignificant and ambiguous relationships, so our survey did not have to detect weak relationships. We further note that, since the average score would normally converge as the sample size increases, a small sample may not be a problem where the average score is not close to the neutral score of 4 and strong relationships are being detected. In our case, only 10 of the 47 items (including the second round items) have average score close to neutral (specifically, more than 3 but less than 5).

Another issue might be selection bias arising from non-random sampling, but such a sample need not be unrepresentative of the population (Trochim, 2006). The reason is that ours is not a convenience (availability) sample of VCs. The recruited VCs represent an expert sample because they are experts in deal negotiation. For that reason, our sampling frame of VCs located in Toronto, Waterloo, and Montreal should not affect the generalizability of our predictions (Garson, 2009).

Finally, the survey is readily scalable. The current survey may be considered as a preliminary work to support a major survey (e.g., one supported by a Social Sciences and Humanities Research Council Grant) since it would be fruitful to administer it to a large number of VCs in the future. Before doing so, the few items with phrases that might have sometimes been misunderstood may be rephrased.

Chapter 5

Conclusion and Future Research

5.1 CONCLUSION

Having presented a detailed overview in Chapter 1, we only briefly summarize the thesis here. We studied how the venture capital deal process may unfold when the entrepreneur has private information about his/her disutility of effort but the VC has the bargaining power. In a double-sided moral hazard framework where we also considered one-sided private information, we let the VC take on a belief about the entrepreneur's minimum effort level to determine the offer. The entrepreneur evaluates that offer using his/her private information to accept/reject it. We also identified the conditions under which the VC may revise a rejected offer. Furthermore, we studied the impacts of a base salary on deal outcomes. A simulation based on our theoretical model revealed that there exist critical values of the VC's belief and ownership share that maximize the returns to the two parties and the deal welfare, and also that there exists an ordering relationship among those critical values. Notably, the VC's return is an inverted U-shape with respect to the VC's ownership share. Using synthetic data from another simulation for regression analyses, we generated predictions about how different factors would affect various deal outcomes. The entrepreneur's effectiveness in teamwork and the relative importance of teamwork to the venture are the major factors enabling VC financing. The size of the value created and how that value is shared between the two parties are highly sensitive to the VC's belief; but the entrepreneur's disutility of effort negatively affects that value. Finally, an online survey of eight seasoned VCs offered support for most of our predictions.

5.2 FUTURE RESEARCH

Our modeling of the VC deal process in sync with the "VC method" of valuation popular among VCs is a major departure from the optimal contracting literature and we hope that this thesis will encourage future research in a new direction. We now identify some such future research, a few of which are direct extensions of the thesis while others are new streams of research inspired by the thesis.

Ex-post efficient VC Contracts under private information

Our thesis conjectures that there exist critical values of the VC's ownership share that maximize the returns to the two parties and overall deal welfare. Hence the VC (when

possessing the bargaining power) may wish to maximize his/her excess profit or, if altruistic, the deal welfare. However, the private information available with the entrepreneur precludes the VC from knowing those critical values. Consequently, the VC's use of a belief (judgment) to determine the offer is *ex-ante* efficient because that approach enables the VC to put forth an offer even while facing private information and to have a chance at clinching a potentially attractive deal. Nevertheless, as our illustrative example and Simulation I revealed, that approach may lead to deals that are *ex-post* inefficient because an incorrect ownership share will result in suboptimal deal welfare and suboptimal excess profit for the VC. For that reason, future research could explore if and how this inefficiency can be eliminated or minimized under private information. We propose these ideas, but it is not clear if they solve the problem: (1) The VC puts forth a package of offers such that the offer chosen by the entrepreneur reveals the latter's disutility of effort; (2) The VC requires the entrepreneur to put forth an offer; and (3) Using milestone-based payments. We note that financing in sequential rounds only helps to minimize or eliminate this inefficiency for subsequent rounds. Consequently, that research can be valuable to practitioners since the "VC method" uses judgment in decision-making.

Factors influencing critical values of the VC's belief and ownership share

Though the VC does not know the critical values of his/her belief and ownership share under private information, we can extend this thesis research to shed light on the parameter sensitivities of those critical values through regression analyses using the synthetic data from Simulation I. Recall that in Simulation I we found the above (unique) critical values for 5,200 scenarios. In other words, for any given venture capital deal scenario, there is unique critical value for the VC's belief (and corresponding ownership share) that maximizes his/her excess profit. We can estimate those critical values on the eleven model parameters that define a deal scenario. Such regressions will reveal the sensitivity of those critical values with respect to individual parameters. We note that the VC cannot estimate those critical values (for the scenario that he/she faces) using the coefficients obtained from the above regressions since one of those eleven parameters—namely, the entrepreneur's unit cost of effort—is not known to the VC. Nevertheless, the regressions can enhance our understanding of the critical values and help VCs improve their judgment in determining the offer terms.

Closed form solutions for the model and proof for the conjecture

A more tedious alternative to the regressions is algebraic derivations. Recall that, though we used a specific functional form for revenue in our illustrative example and simulations, however we used a generic function while formulating and solving our theoretical model. Thus we avoided the derivations of closed-form solutions for the VC's optimal ownership share and service level, the entrepreneur's optimal effort level, and the two parties returns (as

a function of the VC's belief on the entrepreneur's minimum effort level). If we have such solutions, we can then find the critical values by maximizing, for example, the VC's excess profit with respect to that belief. We note that the resulting closed-form solutions for the critical values would be functions of the privately known entrepreneurial unit cost of effort. Nevertheless, such an exercise can further enhance our understanding of those critical values. Furthermore, with the closed-form solutions, we can attempt to prove our conjecture by demonstrating that for any given value of entrepreneurial unit cost of effort the ordering relationships among those critical values hold as per that conjecture.

Further inquiry on the properties of the deal space under private information

Using the synthetic data, we can further scrutinize the properties of the deal space in several ways. We note that, since values for each parameter were drawn independently of those for the rest of the parameters, any sub-set of the data with respect to one parameter will still fill the entire deal space with respect to the rest of the parameters. First, we may study whether the properties of the deal space change if the VC systematically underestimates the entrepreneurial effort level. Since the VC's belief can significantly misrepresent the true effort level either positively or negatively (a point we noted in §2.2), Simulation II quasi-randomly chose values for that belief. We can use a sub-set of our data (say, the observations where the VC's belief is below a certain value) for regressions and look for any changes in the deal space properties when the VC systematically underestimates the entrepreneurial effort. Other sub-sets can be generated—for example, where the VC's marginal return to service is below a certain value (to study how properties change if VCs minimize their time constraints) or where the teamwork is less important than the entrepreneur's solo-work.

Private information with the VC

Our thesis concerns the VC deal process when the entrepreneur alone possesses private information. We could study the double-sided private information case where the entrepreneur does not have full information about the VC that is necessary for evaluating the VC's offer (e.g. the VC's unit cost of service and the VC's minimum required rate of return). If the entrepreneur cannot correctly evaluate the offer, he/she cannot know precisely what the VC's expectation is about his/her minimum effort level and also the service level the VC expects to allocate to the venture. Under these conditions, it might be appropriate for the entrepreneur to accept the offer if his/her optimal effort level is high enough for whatever level of the VC's service. One situation where that might happen is when the VC offers a fairly high ownership share to the entrepreneur. Such extensions can further enhance our understanding of deals under private information.

Modeling angel investment

With angel investment (also known as informal venture capital), relational rents from empathy between the angel and the entrepreneur play a key role; both parties not only care about their monetary return but also to some extent about the other party's monetary return. Thus, the angel investment model should have utility functions that are combinations of the two parties' returns. Since angels are known to be heterogeneous (unlike VCs), some may advise and monitor their entrepreneur while others may not. For that reason, we could consider the two cases separately and study how the deal process would evolve under private information about the entrepreneur's disutility of effort. While in the former case the angel would choose his/her ownership share and service level to maximize his/her utility, the entrepreneur would choose his/her effort level (for the offered ownership share and the angel's service level), the angel would only choose his/her ownership share in the latter case and the entrepreneur his/her effort level (for the offered ownership share). With these modifications, we might be able to model and also simulate the angel investment deal process under private information to uncover new insights concerning angel investment.

Appendix A

Relating the Revenue Function to the Probability of Successful Exit

From the VC method, let TV be the total valuation, EV the exit valuation, M the value multiple and ERP the expected retention percentage. Then, $TV = EV \times \frac{ERP}{M}$. Exit valuation EV is taken exogenously and it measures the commercial potential of the venture (e.g., the VC considers firms with similar products that have already gone through an initial public offering and takes the average of these firms' valuation as an estimated value for EV). ERP is the proportion (total for the VC and the entrepreneur) of current number of shares to the number of shares at the time of exit, which decreases if new shares are issued subsequent to the initial investment by the VC (e.g., if the current number of shares is 1M with 500,000 each to be taken by the VC and the entrepreneur, but later another 2M shares are issued to other investors, then the proportion at the time of exit is 1M/3M or 33.33%). With a discount factor of $\frac{1}{[1+r]^T}$, where r is the cost of capital and T the investment timeframe, and p being the probability of successful exit, $M = \frac{[1+r]^T}{p}$. Substituting in TV for M , we obtain $TV = EV \times ERP \times \frac{p}{[1+r]^T}$. The expected revenue from the new venture can be expressed by $R = [1+r]^T TV$, and substituting the latter expression for TV in the revenue function yields $R = EV \times ERP \times p$. Since the variables we focus on only affect the probability of successful exit p , there exists a direct proportional relationship between R and p , allowing us to use R in our formal model to ease interpretation.

Appendix B

Proofs for the Propositions

Proposition 1 (revising the offer by decreasing α , but keeping b fixed). While the VC revises the investment offer (α, b) , his/her expected return from the venture portfolio must be maximized (i.e., Equation 3 must hold) and his/her participation constraint in Equation 5 (with $P = 0$) must be satisfied. The VC's decisions—ownership share α and service level s —depend on his/her belief on e_{min} , which is therefore the main determinant of the offer terms. The VC can revise the offer if and only if there is room for upwardly adjusting that belief. Therefore, we must characterize the range of values for $\frac{ds}{de_{min}}$ (also depending on $\frac{d\alpha}{de_{min}}$ for Proposition 1) that enables a revision to take place.

The VC's service level s and ownership share α change with an additional unit of e_{min} . Rearranging Equation 5 (with $P = 0$) yields

$$(1 + r)(I + b) + s(e_{min})w = \alpha(e_{min})R(e_{min}, s(e_{min})).$$

Differentiating both sides with respect to e_{min} , we obtain $\frac{ds}{de_{min}}w = \alpha \frac{dR}{de_{min}} + R \frac{d\alpha}{de_{min}} = \alpha \left(R_{e_{min}} + R_s \frac{ds}{de_{min}} \right) + R \frac{d\alpha}{de_{min}}$. Letting $\frac{ds}{de_{min}} = x$ and $\frac{d\alpha}{de_{min}} = y$,

$$xw = \alpha \left(R_{e_{min}} + R_s x \right) + R y. \quad (\text{A1})$$

Similarly, the VC's portfolio return must be maximized and Equation 3 must hold, which yield $\alpha(e_{min})R_s(e_{min}, s(e_{min})) = c + w$. Differentiating both sides with respect to e_{min} , we obtain $\alpha \frac{dR_s}{de_{min}} + R_s y = 0$. That is,

$$\alpha \left(R_{se_{min}} + R_{ss} x \right) + R_s y = 0. \quad (\text{A2})$$

Solving Equations A1 and A2 simultaneously for x yields $x = \frac{\alpha (R_s R_{e_{min}} - R R_{se_{min}})}{R_s w - \alpha (R_s^2 - R R_{ss})}$. Since

$R_s = \frac{c+w}{\alpha}$, after rearranging and simplifying, $x = \frac{(c+w)(R R_{se_{min}} - R_s R_{e_{min}})}{c R_s^2 - (c+w) R R_{ss}}$. Since $c, w, R,$

$R_{se_{min}}, R_s$ and $R_{e_{min}} = R_e$ are all positive but $R_{ss} < 0$, we note that $x > 0$ if and only if

$R R_{se_{min}} > R_s R_{e_{min}}$, i.e., if and only if $R_{se_{min}} > \frac{R_s R_{e_{min}}}{R}$.

From Equation A1, $y = \frac{xw - \alpha(R_{e_{min}} + R_s x)}{R}$. Since the VC can revise the offer only by decreasing α (b is kept fixed) and since e_{min} increases during a revision, we must have $y < 0$ for a revision to take place and thus $xw < \alpha R_{e_{min}} + \alpha R_s x$. Substituting $(c + w)$ for αR_s yields $xw < \alpha R_{e_{min}} + (c + w)x$. After rearranging and simplifying, we obtain $x > -\frac{\alpha R_{e_{min}}}{c} \equiv \Lambda(\alpha) (< 0)$, which provides a negative lower bound for x (Case a). From Equation A2, $y = -\frac{\alpha(R_{se_{min}} + R_{ss}x)}{R_s}$. Since $y < 0$ and since α and R_s are both positive, we must have $R_{se_{min}} + R_{ss}x > 0$, which leads to $x < -\frac{R_{se_{min}}}{R_{ss}} \equiv \Delta$. Since $R_{ss} < 0$, this upper bound on x is positive (Case b). Consequently, the range of values for $\frac{ds}{de_{min}}$ that allows for a revision to take place are between $\Lambda (< 0)$ and $\Delta (> 0)$.

We also note that since Λ depends on α , a threshold condition on α , which depends on x , can equivalently be established for Case (a). Specifically, from $x > -\frac{\alpha R_{e_{min}}}{c} \equiv \Lambda$, we obtain $\alpha > -\frac{c \cdot x}{R_{e_{min}}}$. If $x < 0$ (Case a), then α must exceed $\frac{c \cdot |x|}{R_{e_{min}}} \equiv \Phi$, which is positive since $c > 0$ and $R_{e_{min}} > 0$.

Proposition 2 (revising the offer by increasing b , but keeping α fixed). In this case, only the VC's service level s changes with an additional unit of e_{min} . We now begin with the VC's incentive compatibility constraint in Equation 3, which can be written as $\alpha R_s(e_{min}, s(e_{min})) = c + w$. Differentiating both sides with respect to e_{min} yields $\alpha \left(R_{se_{min}} + R_{ss} \frac{ds}{de_{min}} \right) = 0$, which after rearranging leads to $\frac{ds}{de_{min}} = -\frac{R_{se_{min}}}{R_{ss}} = \left| \frac{R_{se_{min}}}{R_{ss}} \right| > 0$ since $R_{se_{min}} > 0$ and $R_{ss} < 0$. Similarly, the VC's excess profit in Equation 5 equals zero when $b(e_{min}) = \frac{\alpha R(e_{min}, s(e_{min})) - s(e_{min})w}{1+r}$. Differentiating with respect to e_{min} yields $\frac{db}{de_{min}} = \frac{\alpha \left(R_{e_{min}} + R_s \frac{ds}{de_{min}} \right) - \frac{ds}{de_{min}} w}{1+r}$. Since the offer is revised by increasing b and since e_{min} increases during a revision, we must have $\frac{db}{de_{min}} > 0$ for a revision to take place. Hence,

$$\alpha \left(R_{e_{min}} + R_s \frac{ds}{de_{min}} \right) > \frac{ds}{de_{min}} w. \text{ Since } R_{e_{min}} > 0, R_s > 0, \frac{ds}{de_{min}} > 0, \text{ and since } \frac{ds}{de_{min}} = \frac{\left| \frac{R_{se_{min}}}{R_{SS}} \right|}{R_{e_{min}} + R_s \left| \frac{R_{se_{min}}}{R_{SS}} \right|} \equiv \Theta > 0.$$

Proposition 3 (increasing b for a given e_{min}). Everything else being equal, when the VC increases b he or she must increase α to keep the excess profit non-negative. Hence, $\frac{d\alpha}{db} > 0$. The VC's incentive compatibility constraint in Equation 3 can be written as $\alpha(b)R_s(e_{min}, s(b)) = c + w$. Differentiating both sides with respect to b yields $\frac{d\alpha}{db}R_s + R_{SS} \frac{ds}{db} \alpha = 0$. Since $\frac{d\alpha}{db} > 0, R_s > 0, R_{SS} < 0,$ and $\alpha > 0,$ we must have $\frac{ds}{db} > 0$.

The entrepreneur's incentive compatibility constraint in Equation 7 can be written as $R_e(e(b), s(b)) = \frac{\omega}{1-\alpha(b)}$. Differentiating both sides with respect to b yields $\left(R_{ee} \frac{de}{db} + R_{es} \frac{ds}{db} \right) (1 - \alpha(b)) + \left(-\frac{d\alpha}{db} \right) R_e = 0$. Multiplying both sides by $\frac{db}{d\alpha}$ yields $\left(R_{ee} \frac{de}{d\alpha} + R_{es} \frac{ds}{d\alpha} \right) (1 - \alpha(b)) - R_e = 0$. After rearranging, $\frac{de}{d\alpha} = \frac{R_{es} \frac{ds}{d\alpha} - \frac{R_e}{(1-\alpha(b))}}{|R_{ee}|}$. Since $\frac{ds}{db} > 0$ and $\frac{d\alpha}{db} > 0,$ we obtain $\frac{ds}{d\alpha} > 0$. The sign of $\frac{de}{d\alpha}$ is, however, ambiguous because $R_{es} > 0, \frac{ds}{d\alpha} > 0, R_e > 0,$ and $(1 - \alpha(b)) > 0$.

The entrepreneur's expected return E in Equation 6 can be rewritten as $E(b) = b + (1 - \alpha(b))R(e(b), s(b)) - e(b) \omega$. Differentiating with respect to b yields $\frac{dE}{db} = 1 - \frac{d\alpha}{db} R + \left(R_e \frac{de}{db} + R_s \frac{ds}{db} \right) (1 - \alpha(b)) - \frac{de}{db} \omega$. Since, from Equation 7, $R_e(1 - \alpha(b)) = \omega,$ we obtain $\frac{dE}{db} = 1 + R_s \frac{ds}{db} (1 - \alpha(b)) - \frac{d\alpha}{db} R$. The sign of $\frac{dE}{db}$ is ambiguous because $R_s, \frac{ds}{db}, (1 - \alpha(b)), \frac{d\alpha}{db}$ and R are positive. We note that the sign of $\frac{dE}{db}$ does not depend on the sign of $\frac{de}{d\alpha}$.

The VC's excess profit in Equation 5 can be rewritten as $P(b) = \alpha(b)R(e(b), s(b)) - (1 + r)(I + b) - s(b) w,$ noting that VC's ownership share and service level, as well as the entrepreneur's optimal effort level, are all affected by a change in the base salary for a given e_{min} . Differentiating with respect to b yields $\frac{dP}{db} = \frac{d\alpha}{db} R + \alpha(b) \left(R_e \frac{de}{db} + R_s \frac{ds}{db} \right) - (1 + r) - \frac{ds}{db} w$. Since $\alpha(b)R_s = c + w,$ we can rearrange to

obtain $\frac{dP}{db} = \frac{d\alpha}{db}R + \alpha(b)R_e \frac{de}{db} + (c + w - w) \frac{ds}{db} - (1 + r) = \frac{d\alpha}{db}R + \alpha(b)R_e \frac{de}{db} + c \frac{ds}{db} - (1 + r)$. The sign of $\frac{dP}{db}$ is ambiguous because $\frac{d\alpha}{db} > 0$, $R > 0$, $\alpha(b) > 0$, $R_e > 0$, $c \geq 0$, $\frac{ds}{db} > 0$, $r > 0$, and also because the sign of $\frac{de}{db} = \frac{de}{d\alpha} \frac{d\alpha}{db}$ is ambiguous (because so is the sign of $\frac{de}{d\alpha}$).

The investment-deal welfare is $W(b) = P(b) + E(b)$. Differentiating with respect to b yields $\frac{dW}{db} = \frac{dP}{db} + \frac{dE}{db}$, and because the signs of $\frac{dP}{db}$ and $\frac{dE}{db}$ are both ambiguous, so is the sign of $\frac{dW}{db}$.

Appendix C

Pseudo-code

Part I

1. Create in a table (Table A) the following parameters: $r, I, w, c, b, k_1, k_2, \varepsilon_1, \varepsilon_2, \sigma, \omega, e_{min0}, \alpha_0, s_0, R_{0VC}, e_0, R_{0ENT}, E_0, ACCEPT_0, e_{min1}, \alpha_1, s_1, X_0, XPOSITIVE_0, R_{s0}, R_{e_{min0}}, R_{se_{min0}}, CROSSDERIVLIMIT_0, CROSSDERIVHIGH_0, XCONDITIONPOS_0, Y_0, REVISED_0, LAMBDA_0, R_{ss0}, XWITHINBOUNDS_0, PROP1HOLDS_0, PHI_0, ALPHAABOVELIMIT_0, e_1, R_{1ENT}, E_1, ACCEPT_1, e_{min2}, \alpha_2, s_2, X_1, XPOSITIVE_1, R_{s1}, R_{e_{min1}}, R_{se_{min1}}, CROSSDERIVLIMIT_1, CROSSDERIVHIGH_1, XCONDITIONPOS_1, Y_1, REVISED_1, LAMBDA_1, R_{ss1}, XWITHINBOUNDS_1, PROP1HOLDS_1, PHI_1, ALPHAABOVELIMIT_1, e_2, R_{2ENT}, E_2, ACCEPT_2$.
2. Quasi-randomly draw 10,400 combinations of parameters (records or synthetic observations) from within the specified domains and store them.

Parameter	Minimum	Maximum
r	0	1
I	500,000	10,000,000
w	500	10,000
c	0	10,000, but $c \leq w$ always
b	0	500,000
k_1	1	100,000
k_2	1	100,000
ε_1	0	0.99
ε_2	0	0.99
σ	0	0.99, but $\varepsilon_2 + \sigma \leq$ 0.99 always
ω	1	80,000
e_{min}	1	4,000

3. Label the records with number (1 to 10400).

Part II

4. Take record 1 of Table A.
5. Solve the following two equations simultaneously for α_0 and s_0 , and store the solutions:

$$\alpha_0(k_1 e^{\varepsilon_1} + k_2 e^{\varepsilon_2} s_0^\sigma) - (1+r)(I+b) - s_0 w = 0$$

$$k_2 e_{min0}^{\varepsilon_2} \sigma s_0^{\sigma-1} = \frac{c + w}{\alpha_0}$$

6. Evaluate $R_{0VC} = k_1 e_{min0}^{\varepsilon_1} + k_2 e_{min0}^{\varepsilon_2} s_0^\sigma$ and store.
7. Solve the following equation for e_0 and store the solution:

$$k_1 \varepsilon_1 e_0^{\varepsilon_1-1} + k_2 \varepsilon_2 e_0^{\varepsilon_2-1} s_0^\sigma = \frac{\omega}{1 - \alpha_0}$$

8. Evaluate $R_{0ENT} = k_1 e_0^{\varepsilon_1} + k_2 e_0^{\varepsilon_2} s_0^\sigma$ and store.
9. Evaluate E_0 as per the following equation and store:

$$E_0 = b + (1 - \alpha_0)R_{0ENT} - e_0 \omega$$

10. Check if $e_0 \geq e_{min0}$ and $E_0 \geq 0$. If yes, assign 1 to $ACCEPT_0$ and store. If no, assign 0 and store.
11. Take the next record and execute steps (5) to (11). When the last record is done, go to the next step.

Part III

12. Create a table (Table B) with records of Table A for which $ACCEPT_0 = 0$.
13. Take the first record of Table B.
14. Set $N = 0$
15. Evaluate $e_{minN+1} = e_{minN} + 100$ and store.
16. Solve the following two equations simultaneously for α_{N+1} , and s_{N+1} , and store the solutions:

$$\alpha_{N+1}(k_1 e_{minN+1}^{\varepsilon_1} + k_2 e_{minN+1}^{\varepsilon_2} s_{N+1}^\sigma) - (1 + r)(I + b) - s_{N+1} w = 0$$

$$k_2 e_{minN+1}^{\varepsilon_2} \sigma s_{N+1}^{\sigma-1} = \frac{c + w}{\alpha_{N+1}}$$

17. Evaluate $R_{N+1VC} = k_1 e_{minN+1}^{\varepsilon_1} + k_2 e_{minN+1}^{\varepsilon_2} s_{N+1}^\sigma$ and store.
18. Evaluate $X_N = \frac{(s_{N+1} - s_N)}{(e_{minN+1} - e_{minN})}$ and store.
19. Check if $X_N > 0$. If yes, assign 1 to $XPOSITIVE_N$ and store; if no, assign 0 and store.
20. Evaluate $R_{sN} = k_2 e_{minN}^{\varepsilon_2} \sigma s_N^{\sigma-1}$ and store.
21. Evaluate $R_{e_{minN}} = k_1 \varepsilon_1 e_{minN}^{\varepsilon_1-1} + k_2 \varepsilon_2 e_{minN}^{\varepsilon_2-1} s_N^\sigma$ and store.
22. Evaluate $R_{se_{minN}} = k_2 \varepsilon_2 e_{minN}^{\varepsilon_2-1} \sigma s_N^{\sigma-1}$ and store.
23. Evaluate $CROSSDERIVLIMIT_N = \frac{R_{sN} R_{e_{minN}}}{R_{NVC}}$ and store.

24. Check if $R_{se_{minN}} > CROSSDERIVLIMIT_N$. If yes, assign 1 to $CROSSDERIVHIGH_N$ and store; if no, assign 0 and store.
25. Check if $XPOSITIVE_N = CROSSDERIVHIGH_N$. If yes, assign 1 to $XCONDITIONPOS_N$ and store; if no, assign 0 and store.
26. Evaluate $Y_N = \frac{(\alpha_{N+1} - \alpha_N)}{(e_{minN+1} - e_{minN})}$ and store.
27. Check if $Y_N < 0$. If yes, assign 1 to $REVISED_N$ and store; if no, assign 0 and store.
28. Evaluate $LAMBDA_N = -\frac{\alpha_N R_{e_{minN}}}{c}$ and store.
29. Evaluate $R_{ssN} = k_2 e_{minN}^{\varepsilon_2} \sigma(\sigma - 1) s_N^{\sigma-2}$ and store.
30. Evaluate $DELTA_N = -\frac{R_{se_{minN}}}{R_{ssN}}$ and store.
31. Check if $LAMBDA_N < X_N < DELTA_N$. If yes, assign 1 to $XWITHINBOUNDS_N$ and store; if no, assign 0 and store.
32. Check if $REVISED_N = XWITHINBOUNDS_N$. If yes, assign 1 to $PROPIHOLDS_N$ and store; if no, assign 0 and store.
33. Check if $REVISED_N = 1$. If yes, go to step (34); if no, take the next record and go to step (14).
34. Check if $XPOSITIVE_N = 1$. If yes, go to step (37). If no, go to step (35).
35. Evaluate $PHI_N = \frac{c|X_N|}{R_{e_{minN}}}$ and store.
36. Check if $\alpha_N > PHI_N$. If yes, assign 1 to $ALPHAABOVELIMIT_N$ and store; if no, assign 0 and store. Go to step (38)
37. Assign 1 to $ALPHAABOVELIMIT_N$ and store.
38. Solve the following equation for e_{N+1} and store the solution:
- $$k_1 \varepsilon_1 e_{N+1}^{\varepsilon_1-1} + k_2 \varepsilon_2 e_{N+1}^{\varepsilon_2-1} s_{N+1}^\sigma = \frac{\omega}{1 - \alpha_{N+1}}$$
39. Evaluate $R_{N+1ENT} = k_1 e_{N+1}^{\varepsilon_1} + k_2 e_{N+1}^{\varepsilon_2} s_{N+1}^\sigma$ and store.
40. Evaluate E_{N+1} as per the following equation and store:
- $$E_{N+1} = b + (1 - \alpha_{N+1})R_{N+1ENT} - e_{N+1} \omega$$
41. Check if $e_{N+1} \geq e_{minN+1}$ and $E_{N+1} \geq 0$. If yes, go to step (42). If no, go to step (44).
42. Assign 1 to $ACCEPT_{N+1}$ and store.
43. Take the next record and go to step (14).
44. Assign 0 to $ACCEPT_{N+1}$ and store.
45. Check if $N < 2$. If yes, go to step (46); if no, go to step (47).
46. Set $N = N + 1$ and go to step (15).
47. Take the next record and go to step (14).
48. When all records of Table B are done, stop.

Appendix D

Simulation Code

```
#include "stdafx.h"
#include <fstream>
#include <stdlib.h>
#include <math.h>
#include <algorithm>
#include <cmath>
#include <ctime>
#include <vector>
#include <iostream>
#include <sstream>
#include <string>
#include <stdexcept>
#include <limits>
#include <iomanip>

class BadConversion : public std::runtime_error {
public:
    BadConversion(const std::string& s)
        : std::runtime_error(s)
    { }
};

inline double convertToDouble(const std::string& s,
                              bool failIfLeftoverChars = true)
{
    std::istringstream i(s);
    double x;
    char c;
    if (!(i >> x) || (failIfLeftoverChars && i.get(c)))
        throw BadConversion("convertToDouble(\"" + s + "\")");
    return x;
}

#define PI 3.141592654

double newtonRaphson1(double alpha0guess, double s0guess, double r, double
I, double w, double c, double b0, double k1, double k2,
                    double e1, double e2, double sigma, double
emin0, int i, std::vector<double>& properCheck);
double newtonRaphson2(double x0, double k1, double k2, double e1, double
e2,
                    double s0, double sigma, double omega,
double alpha0);
void fillInCell(int i, std::vector<double>& variable, std::stringstream&
ls1);

using namespace std;
int main(int argc, char* argv[])
{
```

```

int totalCombos=260000;

std::vector<double>
rVec(260000),IVec(260000),wVec(260000),cVec(260000),b0Vec(260000),k1Vec(26
0000),k2Vec(260000),
e1Vec(260000),e2Vec(260000),sigmaVec(260000),omegaVec(260000),emin0Vec(260
000),alpha0(260000),s0(260000),offerInfeasible(260000);

std::vector<double> R_vc0(260000),e0(260000),
eLimited0(260000),R_ent0(260000), R_entLimited0(260000),
E0(260000), ELimited0(260000), ACCEPT0(260000),PLimited0(260000),
WLimited0(260000),RecordCounter(260000);

ifstream
fin("C:\\thesis\\simulation\\LargeSimulation3rdAprilPartIV\\AuxTable3rdApr
ilFourthPart.csv");

string line;
getline(fin,line);
stringstream ls(line);
string dummyString;

for(int i=0;i<26; i++)
{
getline(ls,dummyString,',');
}

for(int j=0; j<260000; j++)
{
    cout<<"Record Number:"<<j+1<<endl;
getline(fin,line);
stringstream ls1(line);
string firstCell;

fillInCell(j,RecordCounter,ls1);
fillInCell(j,rVec, ls1);
fillInCell(j,IVec, ls1);
fillInCell(j,wVec, ls1);
fillInCell(j,cVec, ls1);
fillInCell(j,b0Vec, ls1);
fillInCell(j,k1Vec, ls1);
fillInCell(j,k2Vec, ls1);
fillInCell(j,e1Vec, ls1);
fillInCell(j,e2Vec, ls1);
fillInCell(j,sigmaVec, ls1);
fillInCell(j,omegaVec, ls1);
fillInCell(j,emin0Vec, ls1);
fillInCell(j,alpha0, ls1);
fillInCell(j,s0, ls1);
fillInCell(j,offerInfeasible, ls1);
fillInCell(j,R_vc0, ls1);

```



```

fillInCell(j,e0, ls1);
fillInCell(j,eLimited0, ls1);
fillInCell(j,R_ent0, ls1);
fillInCell(j,R_entLimited0, ls1);
fillInCell(j,E0, ls1);
fillInCell(j,ELimited0, ls1);
fillInCell(j,ACCEPT0, ls1);
fillInCell(j,PLimited0, ls1);
fillInCell(j,WLimited0, ls1);
}

std::vector<double>
recordCountE(1300),maxELimited0(1300),recordCountP(1300),maxPLimited0(1300)
),recordCountW(1300),maxWLimited0(1300);

for(int i=0; i<1300; i++)
{
    maxELimited0[i]= -500000000.0;
    maxPLimited0[i]= -500000000.0;
    maxWLimited0[i]= -500000000.0;
    recordCountE[i]=1;
    recordCountP[i]=1;
    recordCountW[i]=1;

    for(int k=i*200,count=0; count<200; k++,count++)
    {

        if(maxELimited0[i]<=ELimited0[k])
        {
            if(maxELimited0[i]==ELimited0[k])
            {recordCountE[i]=recordCountE[i]+1;
            }else
            {recordCountE[i]=1;
            }

            maxELimited0[i]=ELimited0[k];
        }

        if(maxPLimited0[i]<=PLimited0[k])
        {
            if(maxPLimited0[i]==PLimited0[k])
            {recordCountP[i]=recordCountP[i]+1;
            }else
            {recordCountP[i]=1;
            }

            maxPLimited0[i]=PLimited0[k];
        }

        if(maxWLimited0[i]<=WLimited0[k])
        {

            if(maxWLimited0[i]==WLimited0[k])
            {recordCountW[i]=recordCountW[i]+1;
            }else
            {recordCountW[i]=1;
            }
        }
    }
}

```

```

        }

        maxWLimited0[i]=WLimited0[k];
    }

}

int recordCounterP=0, recordCounterW=0, recordCounterE=0;

for(int i=0; i<1300; i++)
{
recordCounterP=recordCounterP+recordCountP[i];
recordCounterW=recordCounterW+recordCountW[i];
recordCounterE=recordCounterE+recordCountE[i];
}

std::vector<double>
emin0E(recordCounterE),emin0P(recordCounterP),emin0W(recordCounterW);

std::vector<int> recordNumE(recordCounterE),
recordNumP(recordCounterP),recordNumW(recordCounterW);

std::vector<double>
rVecE(recordCounterE),IVecE(recordCounterE),wVecE(recordCounterE),cVecE(re
cordCounterE),b0VecE(recordCounterE),k1VecE(recordCounterE),k2VecE(recordC
ounterE),
e1VecE(recordCounterE),e2VecE(recordCounterE),sigmaVecE(recordCounterE),om
egaVecE(recordCounterE),alpha0E(recordCounterE),s0E(recordCounterE),
eLimited0E(recordCounterE);

std::vector<double>
R_vc0E(recordCounterE),e0E(recordCounterE),R_ent0E(recordCounterE),
R_entLimited0E(recordCounterE),E0E(recordCounterE),
ACCEPT0E(recordCounterE),offerInfeasibleE(recordCounterE),ELimited0E(recor
dCounterE),PLimited0E(recordCounterE),WLimited0E(recordCounterE);

std::vector<double>
rVecP(recordCounterP),IVecP(recordCounterP),wVecP(recordCounterP),cVecP(re
cordCounterP),b0VecP(recordCounterP),k1VecP(recordCounterP),k2VecP(recordC
ounterP),
e1VecP(recordCounterP),e2VecP(recordCounterP),sigmaVecP(recordCounterP),om
egaVecP(recordCounterP),alpha0P(recordCounterP),s0P(recordCounterP),
eLimited0P(recordCounterP);

std::vector<double>
R_vc0P(recordCounterP),e0P(recordCounterP),R_ent0P(recordCounterP),
R_entLimited0P(recordCounterP),E0P(recordCounterP),
ACCEPT0P(recordCounterP),offerInfeasibleP(recordCounterP),ELimited0P(recor
dCounterP),PLimited0P(recordCounterP),WLimited0P(recordCounterP);

std::vector<double>
rVecW(recordCounterW),IVecW(recordCounterW),wVecW(recordCounterW),cVecW(re

```

```

cordCounterW), b0VecW(recordCounterW), k1VecW(recordCounterW), k2VecW(recordCounterW),
e1VecW(recordCounterW), e2VecW(recordCounterW), sigmaVecW(recordCounterW), omegaVecW(recordCounterW), alpha0W(recordCounterW), s0W(recordCounterW),
eLimited0W(recordCounterW);

```

```

std::vector<double>
R_vc0W(recordCounterW), e0W(recordCounterW), R_ent0W(recordCounterW),
R_entLimited0W(recordCounterW), E0W(recordCounterW),
ACCEPT0W(recordCounterW), offerInfeasibleW(recordCounterW), ELimited0W(recordCounterW),
PLimited0W(recordCounterW), WLimited0W(recordCounterW);

```

```

for(int j=0, i=0; j<1300; j++)
{
    for(int k=j*200, count=0; count<200; k++, count++)
    {
        if(maxELimited0[j]==-500000000.0)
        {
            rVecE[i]=rVec[k];
            IVecE[i]=IVec[k];
            wVecE[i]=wVec[k];
            cVecE[i]=cVec[k];
            b0VecE[i]=b0Vec[k];
            k1VecE[i]=k1Vec[k];
            k2VecE[i]=k2Vec[k];
            e1VecE[i]=e1Vec[k];
            e2VecE[i]=e2Vec[k];
            sigmaVecE[i]=sigmaVec[k];
            omegaVecE[i]=omegaVec[k];

            if(count==199)
            {i++;}

        }

        if(maxELimited0[j]==ELimited0[k])
        {
            recordNumE[i]=RecordCounter[k];
            alpha0E[i]=alpha0[k];
            s0E[i]=s0[k];
            eLimited0E[i]=eLimited0[k];

            rVecE[i]=rVec[k];
            IVecE[i]=IVec[k];
            wVecE[i]=wVec[k];
            cVecE[i]=cVec[k];
            b0VecE[i]=b0Vec[k];
            k1VecE[i]=k1Vec[k];
            k2VecE[i]=k2Vec[k];
            e1VecE[i]=e1Vec[k];
            e2VecE[i]=e2Vec[k];
            sigmaVecE[i]=sigmaVec[k];
            omegaVecE[i]=omegaVec[k];

            offerInfeasibleE[i]=offerInfeasible[k];

```

```

R_vc0E[i]=R_vc0[k];
e0E[i]=e0[k];
R_ent0E[i]=R_ent0[k];
R_entLimited0E[i]=R_entLimited0[k];
E0E[i]=E0[k];
ACCEPT0E[i]=ACCEPT0[k];
ELimited0E[i]=ELimited0[k];
PLimited0E[i]=PLimited0[k];
WLimited0E[i]=WLimited0[k];
emin0E[i]=emin0Vec[k];
i++;
}
}
}
for(int j=0,i=0; j<1300; j++)
{
    for(int k=j*200,count=0; count<200; k++,count++)
    {
        if(maxPLimited0[j]==-500000000.0)
        {
            rVecP[i]=rVec[k];
            IVecP[i]=IVec[k];
            wVecP[i]=wVec[k];
            cVecP[i]=cVec[k];
            b0VecP[i]=b0Vec[k];
            k1VecP[i]=k1Vec[k];
            k2VecP[i]=k2Vec[k];
            e1VecP[i]=e1Vec[k];
            e2VecP[i]=e2Vec[k];
            sigmaVecP[i]=sigmaVec[k];
            omegaVecP[i]=omegaVec[k];

            if(count==199)
            {i++;
            }

            if(maxPLimited0[j]==PLimited0[k])
            {
                recordNumP[i]=RecordCounter[k];
                emin0P[i]=emin0Vec[k];
                alpha0P[i]=alpha0[k];
                s0P[i]=s0[k];
                eLimited0P[i]=eLimited0[k];
                ELimited0P[i]=ELimited0[k];
                PLimited0P[i]=PLimited0[k];
                WLimited0P[i]=WLimited0[k];

                rVecP[i]=rVec[k];
                IVecP[i]=IVec[k];
                wVecP[i]=wVec[k];
                cVecP[i]=cVec[k];
                b0VecP[i]=b0Vec[k];
            }
        }
    }
}

```

```

        k1VecP[i]=k1Vec[k];
        k2VecP[i]=k2Vec[k];
        e1VecP[i]=e1Vec[k];
        e2VecP[i]=e2Vec[k];
        sigmaVecP[i]=sigmaVec[k];
        omegaVecP[i]=omegaVec[k];
        offerInfeasibleP[i]=offerInfeasible[k];
        R_vc0P[i]=R_vc0[k];
        e0P[i]=e0[k];
        R_ent0P[i]=R_ent0[k];
        R_entLimited0P[i]=R_entLimited0[k];
        E0P[i]=E0[k];
        ACCEPT0P[i]=ACCEPT0[k];
        i++;
    }
}

for(int j=0,i=0; j<1300; j++)
{
    for(int k=j*200,count=0; count<200; k++,count++)
    {
        if(maxWLimited0[j]==-500000000.0)
        {
            rVecW[i]=rVec[k];
            IVecW[i]=IVec[k];
            wVecW[i]=wVec[k];
            cVecW[i]=cVec[k];
            b0VecW[i]=b0Vec[k];
            k1VecW[i]=k1Vec[k];
            k2VecW[i]=k2Vec[k];
            e1VecW[i]=e1Vec[k];
            e2VecW[i]=e2Vec[k];
            sigmaVecW[i]=sigmaVec[k];
            omegaVecW[i]=omegaVec[k];

            if(count==199)
            {i++;}

        }

        if(maxWLimited0[j]==WLimited0[k])
        {
            recordNumW[i]=RecordCounter[k];
            emin0W[i]=emin0Vec[k];
            alpha0W[i]=alpha0[k];
            s0W[i]=s0[k];
            eLimited0W[i]=eLimited0[k];

            rVecW[i]=rVec[k];
            IVecW[i]=IVec[k];
            wVecW[i]=wVec[k];
            cVecW[i]=cVec[k];
            b0VecW[i]=b0Vec[k];
            k1VecW[i]=k1Vec[k];
            k2VecW[i]=k2Vec[k];

```

```

        e1VecW[i]=e1Vec[k];
        e2VecW[i]=e2Vec[k];
        sigmaVecW[i]=sigmaVec[k];
        omegaVecW[i]=omegaVec[k];
        ELimited0W[i]=ELimited0[k];
        PLimited0W[i]=PLimited0[k];
        WLimited0W[i]=WLimited0[k];
        offerInfeasibleW[i]=offerInfeasible[k];
        R_vc0W[i]=R_vc0[k];
        e0W[i]=e0[k];
        R_ent0W[i]=R_ent0[k];
        R_entLimited0W[i]=R_entLimited0[k];
        E0W[i]=E0[k];
        ACCEPT0W[i]=ACCEPT0[k];
        i++;
    }
}

ofstream
fout1("C:\\thesis\\simulation\\tableExtranewSimulation16thAugFourthPart.csv");
fout1 << "Record Number, r, I, w, c, b0, k1, k2, e1, e2, sigma,
omega,Records with maxELimited0, Records with maxPLimited0, Records with
maxWLimited0" << endl;
fout1.precision(20);

for(int i=0;i<1300; i++)
{
    fout1<<i+1<<","<<rVecE[i]<<","<<IVecE[i]<<","<<wVecE[i]<<","<<cVecE[i]<<","
    "<<b0VecE[i]<<","<<k1VecE[i]<<","<<k2VecE[i]<<",";
    fout1<<e1VecE[i]<<","<<e2VecE[i]<<","<<sigmaVecE[i]<<","<<omegaVecE[i]<<","
    "<<recordCountE[i]<<","<<recordCountP[i]<<","<<recordCountW[i]<<endl;
}

fout1<<flush;
fout1.close();

ofstream
fout2("C:\\thesis\\simulation\\tableInewSimulation16thAugFourthPart.csv");
fout2 << "Record Number, Parent Record Number, r, I, w, c, b0, k1, k2, e1,
e2, sigma, omega, emin0, alpha0, s0, Offer Infeasible,R_vc0, e0,
eLimited0,R_ent0, R_entLimited0, E0, ELimited0, ACCEPT0,PLimited0,
WLimited0" << endl;
fout2.precision(20);

for(int i=0; i<recordCounterE; i++)
{
    if(maxELimited0[i]==-500000000.0)
        {maxELimited0[i]=0;
        }

    fout2<<i+1<<","<<recordNumE[i]<<","<<rVecE[i]<<","<<IVecE[i]<<","<<wVecE[i]
    ]<<","<<cVecE[i]<<","<<b0VecE[i]<<","<<k1VecE[i]<<","<<k2VecE[i]<<",";
}

```

```

fout2<<e1VecE[i]<<","<<e2VecE[i]<<","<<sigmaVecE[i]<<","<<omegaVecE[i]<<","
"<<emin0E[i]<<","<<alpha0E[i]<<","<<s0E[i]<<","<<offerInfeasibleE[i]<<","";
fout2<<R_vc0E[i]<<","<<e0E[i]<<","<<eLimited0E[i]<<","<<R_ent0E[i]<<","<<
R_entLimited0E[i]<<","<<E0E[i]<<","<<maxELimited0[i]<<","<<
ACCEPT0E[i]<<","";
fout2<<PLimited0E[i]<<","<<WLimited0E[i]<<endl;
}

fout2<<flush;
fout2.close();

ofstream
fout3("C:\\thesis\\simulation\\tableIInewSimulation16thAugFourthPart.csv")
;
fout3<< "Record Number, Parent Record Number, r, I, w, c, b0, k1, k2, e1,
e2, sigma, omega, emin0, alpha0, s0, Offer Infeasible,R_vc0, e0,
eLimited0,R_ent0, R_entLimited0, E0, ELimited0, ACCEPT0,PLimited0,
WLimited0" << endl;
fout3.precision(20);

for(int i=0; i<recordCounterP; i++)
{
if(maxPLimited0[i]==-500000000.0)
    {maxPLimited0[i]=0;
    }

fout3<<i+1<<","<<recordNumP[i]<<","<<rVecP[i]<<","<<IVecP[i]<<","<<wVecP[i
]<<","<<cVecP[i]<<","<<b0VecP[i]<<","<<k1VecP[i]<<","<<k2VecP[i]<<","";
fout3<<e1VecP[i]<<","<<e2VecP[i]<<","<<sigmaVecP[i]<<","<<omegaVecP[i]<<","
"<<emin0P[i]<<","<<alpha0P[i]<<","<<s0P[i]<<","<<offerInfeasibleP[i]<<","";
fout3<<R_vc0P[i]<<","<<e0P[i]<<","<<eLimited0P[i]<<","<<R_ent0P[i]<<","<<
R_entLimited0P[i]<<","<<E0P[i]<<","<<ELimited0P[i]<<","<<
ACCEPT0P[i]<<","";
fout3<<maxPLimited0[i]<<","<<WLimited0P[i]<<endl;
}

fout3<<flush;
fout3.close();

ofstream
fout4("C:\\thesis\\simulation\\tableIIInewSimulation16thAugFourthPart.csv"
);
fout4<< "Record Number, Parent Record Number, r, I, w, c, b0, k1, k2, e1,
e2, sigma, omega, emin0, alpha0, s0, Offer Infeasible,R_vc0, e0,
eLimited0,R_ent0, R_entLimited0, E0, ELimited0, ACCEPT0,PLimited0,
WLimited0" << endl;
fout4.precision(20);

for(int i=0; i<recordCounterW; i++)
{
if(maxWLimited0[i]==-500000000.0)
    {maxWLimited0[i]=0;
    }
}

```

```

fout4<<i+1<<","<<recordNumW[i]<<","<<rVecW[i]<<","<<IVecW[i]<<","<<wVecW[i]
]<<","<<cVecW[i]<<","<<b0VecW[i]<<","<<k1VecW[i]<<","<<k2VecW[i]<<",";
fout4<<e1VecW[i]<<","<<e2VecW[i]<<","<<sigmaVecW[i]<<","<<omegaVecW[i]<<","
"<<emin0W[i]<<","<<alpha0W[i]<<","<<s0W[i]<<","<<offerInfeasibleW[i]<<",";
fout4<<R_vc0W[i]<<","<<e0W[i]<<","<<eLimited0W[i]<<","<<R_ent0W[i]<<","<<
R_entLimited0W[i]<<","<<E0W[i]<<","<<ELimited0W[i]<<","<<
ACCEPT0W[i]<<",";
fout4<<PLimited0W[i]<<","<<maxWLimited0[i]<<endl;
}

```

```

fout4<<flush;
fout4.close();

```

```

ofstream
fout5("C:\\thesis\\simulation\\tableIVnewSimulation16thAugFourthPart.csv")
;
fout5<< "Record Number, r, I, w, c, b0, k1, k2, e1, e2, sigma, omega,
emin0_E, alpha0_E, s0_E,eLimited0_E, max ELimited0,ACCEPT0 E,offer
Infeasible E,emin0_P, alpha0_P, s0_P, eLimited0_P,max PLimited0,ACCEPT0
P,offer Infeasible P,emin0_W, alpha0_W, s0_W, eLimited0_W, max
WLimited0,ACCEPT0 W, offer Infeasible W" << endl;
fout5.precision(20);

```

```

for(int j=0,i=0; j<1300; j++)
{

```

```

fout5<<j+1<<","<<rVecE[j]<<","<<IVecE[j]<<","<<wVecE[j]<<","<<cVecE[j]<<","
"<<b0VecE[j]<<","<<k1VecE[j]<<","<<k2VecE[j]<<",";
fout5<<e1VecE[j]<<","<<e2VecE[j]<<","<<sigmaVecE[j]<<","<<omegaVecE[j]<<","
";

```

```

for(int k=0;
k<max(recordCountE[j],max(recordCountP[j],recordCountW[j]));k++)
{
if(recordCountE[j]<k+1 && recordCountP[j]>=k+1 && recordCountW[j]>=k+1)
{
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"
NA"<<",";
fout5<<emin0P[i]<<","<<alpha0P[i]<<","<<s0P[i]<<","<<eLimited0P[i]<<","<<m
axPLimited0[i]<<","<<ACCEPT0P[i]<<","<<offerInfeasibleP[i]<<",";
fout5<<emin0W[i]<<","<<alpha0W[i]<<","<<s0W[i]<<","<<eLimited0W[i]<<","<<m
axWLimited0[i]<<","<<ACCEPT0W[i]<<","<<offerInfeasibleW[i]<<endl;
}else if(recordCountP[j]<k+1 && recordCountE[j]>=k+1 &&
recordCountW[j]>=k+1)
{fout5<<emin0E[i]<<","<<alpha0E[i]<<","<<s0E[i]<<","<<eLimited0E[i]<<","<<
maxELimited0[i]<<","<<ACCEPT0E[i]<<","<<offerInfeasibleE[i]<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"
NA"<<",";
fout5<<emin0W[i]<<","<<alpha0W[i]<<","<<s0W[i]<<","<<eLimited0W[i]<<","<<m
axWLimited0[i]<<","<<ACCEPT0W[i]<<","<<offerInfeasibleW[i]<<endl;
}else if(recordCountW[j]<k+1 && recordCountP[j]>=k+1 &&
recordCountE[j]>=k+1)
{fout5<<emin0E[i]<<","<<alpha0E[i]<<","<<s0E[i]<<","<<eLimited0E[i]<<","<<
maxELimited0[i]<<","<<ACCEPT0E[i]<<","<<offerInfeasibleE[i]<<",";

```



```

fout5<<emin0P[i]<<","<<alpha0P[i]<<","<<s0P[i]<<","<<eLimited0P[i]<<","<<maxPLimited0[i]<<","<<ACCEPT0P[i]<<","<<offerInfeasibleP[i]<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<endl;
}else if(recordCountW[j]<k+1 && recordCountP[j]>=k+1 &&
recordCountE[j]<k+1)
{
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<",";
fout5<<emin0P[i]<<","<<alpha0P[i]<<","<<s0P[i]<<","<<eLimited0P[i]<<","<<maxPLimited0[i]<<","<<ACCEPT0P[i]<<","<<offerInfeasibleP[i]<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<endl;
}else if(recordCountW[j]<k+1 && recordCountP[j]<k+1 &&
recordCountE[j]>=k+1)
{fout5<<emin0E[i]<<","<<alpha0E[i]<<","<<s0E[i]<<","<<eLimited0E[i]<<","<<maxELimited0[i]<<","<<ACCEPT0E[i]<<","<<offerInfeasibleE[i]<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<endl;
}else if(recordCountW[j]>=k+1 && recordCountP[j]<k+1 &&
recordCountE[j]<k+1)
{
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<",";
fout5<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<","<<"NA"<<",";
fout5<<emin0W[i]<<","<<alpha0W[i]<<","<<s0W[i]<<","<<eLimited0W[i]<<","<<maxWLimited0[i]<<","<<ACCEPT0W[i]<<","<<offerInfeasibleW[i]<<endl;
}
else
{fout5<<emin0E[i]<<","<<alpha0E[i]<<","<<s0E[i]<<","<<eLimited0E[i]<<","<<maxELimited0[i]<<","<<ACCEPT0E[i]<<","<<offerInfeasibleE[i]<<",";
fout5<<emin0P[i]<<","<<alpha0P[i]<<","<<s0P[i]<<","<<eLimited0P[i]<<","<<maxPLimited0[i]<<","<<ACCEPT0P[i]<<","<<offerInfeasibleP[i]<<",";
fout5<<emin0W[i]<<","<<alpha0W[i]<<","<<s0W[i]<<","<<eLimited0W[i]<<","<<maxWLimited0[i]<<","<<ACCEPT0W[i]<<","<<offerInfeasibleW[i]<<endl;
}
}
i++;
}

}

fout5<<flush;
fout5.close();

return 0;
}

double newtonRaphson1(double alpha0guess,double s0guess,double r, double
I, double w,double c,double b0,double k1,double k2,
double e1,double e2,double sigma,double
emin0,int i, std::vector<double>& properCheck)
{

```

```

double
a,b,cJ,d,detj,detjinv,jinv11,jinv12,jinv21,jinv22,F1,F2,deltax,deltay;
double x,y;
double f = 0.1;
double xi=alpha0guess;
double yi=s0guess;
x = xi;
y = yi;
int check = 0, counter=0 ;

while ((check ==0)&&(counter<5000))
{
F1 =x*(k1*pow(emin0,e1)+k2*pow(emin0,e2)*pow(y,sigma))-(1+r)*(I+b0)-y*w;
F2 = k2*pow(emin0,e2)*sigma*pow(y,sigma-1)-(c+w)/x;
a = k1*pow(emin0,e1)+k2*pow(emin0,e2)*pow(y,sigma);
b = x*k2*pow(emin0,e2)*sigma*pow(y,sigma-1)-w;
cJ = (c+w)/pow(x,2);
d = k2*pow(emin0,e2)*sigma*(sigma-1)*pow(y,sigma-2);
detj = a*d - b*cJ;
jinv11 = d/detj;
jinv12 = -b/detj;
jinv21 = -cJ/detj;
jinv22 = a/detj;
detjinv = (((a*d)/(detj*detj)) - ((b*cJ)/(detj*detj)));
deltax = (jinv11*F1*f)+(jinv12*F2*f);
deltay = (jinv21*F1*f)+(jinv22*F2*f);
x = x-deltax;
y = y-deltay;
counter++;
if((fabs(F1) < 0.001) && (fabs(F2) < 0.001))
{ check = 1;
properCheck[i]=1;
}
}
return y;
}

double newtonRaphson2(double x0, double k1, double k2, double e1, double
e2,
double s0, double sigma, double omega,
double alpha0)
{
double x=x0;
double fx=k1*e1*pow(x,e1-1)+k2*e2*pow(x,e2-1)*pow(s0,sigma)-omega/(1-
alpha0);

double fpx;
int j=0;

while(fabs(fx)>0.001)
{
fx=(k1*e1*pow(x,(e1-1)))+(k2*e2*pow(x,(e2-1))*pow(s0,sigma))-(omega/(1-
alpha0));
fpx=k1*e1*(e1-1)*pow(x,(e1-2))+k2*e2*(e2-1)*pow(x,(e2-2))*pow(s0,sigma);
x= x - (fx/fpx);
}
}

```

```

j++;
}

return x;
}

void fillInCell(int i, std::vector<double>& variable, std::stringstream&
ls1)
{
    string entryInCell;
    getline(ls1, entryInCell, ',');

    if((entryInCell=="-1.#IND") || (entryInCell=="1.#QNAN") || (entryInCell=="-
1.#INF"))
    {variable[i]=numeric_limits<double>::quiet_NaN( );
    }else
    {variable[i]=convertToDouble(entryInCell);
    }
}
}

```

Appendix E

Survey Instrument (Sample)

Venture Capital Investment: Initiating and Revising the Deal - Survey A

INSTRUCTIONS

Please answer to what extent you agree with the statements presented in the following pages by picking the choice that corresponds to your level of agreement. Choices range from "Strongly Agree" to "Strongly Disagree".

Unless otherwise stated, questions refer to VC financing of early-stage ventures of first-time entrepreneurs. If you do not know the answer to a question, you may skip that question and proceed to the next.

Entrepreneurial effort refers to performance (where results are achieved), not hours spent on the job.

1. The entrepreneur would normally like to own a larger share of the venture than what is offered by the VC.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

2. VCs do not revise offers rejected by first-time entrepreneurs.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

3. For encouraging the VC to make an offer, the entrepreneur's ability to work well independently of the VC is more important than the entrepreneur's ability to work well with the VC.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

4. The VC would demand a large ownership share to invest in ventures with large uncertainty.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

5. The VC would reduce advising/monitoring when the entrepreneur is paid a high base salary.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

6. The entrepreneur puts in more effort if VC-entrepreneur team-work is critical to the venture's success.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

7. The entrepreneur would exert best effort only when allocated a large ownership share (say, above 80%).

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

8. The VC would be reluctant to make an offer when the investment amount is large.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

9. If the VC is confident that the entrepreneur will work well with him/her, the VC would demand a larger ownership share.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

10. The VC would increase advising/monitoring when the investment amount is large.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

11. The entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

12. The VC would demand a large ownership share if his/her time is highly valuable.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

13. An increase in the entrepreneur's base salary would necessarily increase the entrepreneur's overall return.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

14. For VC financing to materialize, the entrepreneur's ability to work well with the VC is more important than the entrepreneur's ability to work well independently of the VC.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

15. If the VC-entrepreneur team-work is critical to the venture's success, the VC would demand a larger ownership share.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

16. The entrepreneur's ability to work well independently of the VC affects his/her return from the venture.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

17. An increase in the entrepreneur's base salary would necessarily decrease the VC's return.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Venture Capital Investment: Initiating and Revising the Deal - Survey A

18. It is desirable for VCs to hold a moderate ownership share (say, 20% to 60%) in early-stage ventures of first-time entrepreneurs.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

19. VCs who specialize in the venture's industry are more likely to invest than those who do not.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

20. VCs under greater time constraints are less likely to revise rejected offers.

- Strongly Agree
- Agree
- Somewhat Agree
- Neither Agree nor Disagree
- Somewhat Disagree
- Disagree
- Strongly Disagree

Appendix F Survey Responses

Questionnaire Item Number	Statement	Number of responses	Strongly Agree [7]	Agree [6]	Somewhat Agree [5]	Neither Agree nor Disagree [4]	Somewhat Disagree [3]	Disagree [2]	Strongly Disagree [1]	Average Score
Q1	The entrepreneur would normally like to own a larger share of the venture than what is offered by the VC	4	1		3					5.5
Q2	VCs do not revise offers rejected by first-time entrepreneurs	8			2			3	3	2.375
Q3	For encouraging the VC to make an offer, the entrepreneur's ability to work well independently of the VC is more important than the entrepreneur's ability to work well with the VC	4				1		3		2.5
Q4	The VC would demand a large ownership share to invest in ventures with large uncertainty	4	1		2	1				5.25
Q5	The VC would reduce advising/monitoring when the entrepreneur is paid a high base salary	4						1	3	1.25
Q6	The entrepreneur puts in more effort if VC-entrepreneur teamwork is critical to the venture's success	4			1	3				4.25
Q7	The entrepreneur would exert best effort only when allocated a large ownership share (say, above 80%)	4						1	3	1.25
Q8a	The VC would be reluctant to make an offer when the investment amount is large	4						2	2	1.5
b	VCs would like entrepreneurs to ask for an investment amount that is only absolutely essential, not any more	1			1					5
Q9	If the VC is confident that the entrepreneur will work well with him/her, the VC would demand a larger ownership share	4			1			3		2.75
Q10a	The VC would increase advising/monitoring when the investment amount is large	4			2			1	1	3.25
b	Consider a situation where a VC may invest in a first-time entrepreneur's venture. Now assume that the venture requires an investment that is larger for its level of expected revenue. Then, the VC would expect to advise/monitor more if he/she were to invest.	1					1			3
Q11a	The entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer	4			1		1	1	1	2.75
b	Apart from the commercial potential of the venture, the entrepreneur's ability to work well with the VC is the most important factor influencing whether the VC will make an offer.	1				1				4
c	The entrepreneur's ability to work well with the VC is one of the most important factors influencing whether the VC will make an offer.	1		1						6

Questionnaire Item Number	Statement	Number of responses	Strongly Agree [7]	Agree [6]	Somewhat Agree [5]	Neither Agree nor Disagree [4]	Somewhat Disagree [3]	Disagree [2]	Strongly Disagree [1]	Average Score
12a	The VC would demand a large ownership share if his/her time is highly valuable	4			1	1		1	1	3
b	Consider a situation where a VC has determined the ownership share he/she should demand if he/she were to invest in a venture. Then, if the VC's time were more valuable than what it actually is, the VC would increase to some extent the ownership share demanded.	1					1			3
13	An increase in the entrepreneur's base salary would necessarily increase the entrepreneur's overall return	4			1	1		1	1	3
14	For VC financing to materialize, the entrepreneur's ability to work well with the VC is more important than the entrepreneur's ability to work well independently of the VC	4		1	2			1		4.5
15	If the VC-entrepreneur teamwork is critical to the venture's success, the VC would demand a larger ownership share	4			1	1	1	1		3.5
16	The entrepreneur's ability to work well independently of the VC affects his/her return from the venture	4		3				1		5
17	An increase in the entrepreneur's base salary would necessarily decrease the VC's return	4				1		3		2.5
18	It is desirable for VCs to hold a moderate ownership share (say, 20% to 60%) in early-stage ventures of first-time entrepreneurs	4		2	1	1				5.25
19	VCs who specialize in the venture's industry are more likely to invest than those who do not	4	3			1				6.25
20a	VCs under greater time constraints are less likely to revise rejected offers	4			1			2	1	2.5
b	VCs under greater time constraints may be less likely to find it feasible to revise rejected offers though they can find the time required to revise such offers.	1						1		2
21	The VC is more likely to invest if the entrepreneur's effort is expected to be highly productive	4	1	3						6.25
22	The size of the base salary offered affects whether the deal will close	4		2	1	1				5.25
23	The VC would demand a larger ownership share when the investment amount is larger	4		3	1					5.75
24	If the entrepreneur works well with the VC, the VC would reduce advising/ monitoring	5				1	1	3		2.6

Questionnaire Item Number	Statement	Number of responses	Strongly Agree [7]	Agree [6]	Somewhat Agree [5]	Neither Agree nor Disagree [4]	Somewhat Disagree [3]	Disagree [2]	Strongly Disagree [1]	Average Score
25a	For encouraging the entrepreneur to exert best effort, the entrepreneur's ability to work well with the VC is more important than the entrepreneur's ability to work well independently of the VC	4			1	2		1		3.75
b	The entrepreneur's ability to work well with the VC is more influential than the entrepreneur's ability to work well independently of the VC in determining whether the entrepreneur will exert best effort.	1					1			3
26	A VC under greater time constraints would demand a smaller ownership share	5						3	2	1.6
27	If the VC's advising/monitoring is influential, the VC would increase advising/monitoring	5			2	3				4.4
28	The entrepreneur's performance is usually sensitive to the size of the base salary he/she receives	5			1	1	1		2	2.8
29	The VC's judgment, at the time of making the offer, about the entrepreneur's future performance is ultimately the most important factor affecting his/her return from the investment	5		2	2	1				5.2
30	If the VC is highly confident about a first-time entrepreneur's performance, it would normally work to the advantage of that entrepreneur	5	1	1	2	1				5.4
31	If the entrepreneur requires a higher base salary, the VC would demand a larger ownership share	4				4				4
32a	The VC would demand a large ownership share if the VC's advising/monitoring is of high quality	4		1	2	1				5
b	Consider a situation where a VC may invest but demand a large ownership share in a first-time entrepreneur's venture with a large uncertainty. Now assume that the VC's advising/monitoring is of high quality and larger revenue would be generated because of that high quality advising/monitoring. Then, that high quality would enable that VC to reduce to some extent the ownership share demanded.	1							1	1
33	The entrepreneur's ability to work well independently of the VC encourages the VC to make an offer	5		1	3			1		4.6
34	The entrepreneur puts in less effort if the VC's advising and monitoring is of high quality	5				1	1	3		2.6
35	The VC-entrepreneur teamwork highly influences the entrepreneur's return	5	1	1	2	1				5.4
36	A VC expecting to be influential in advising/monitoring would be less likely to finance the venture	5				1		4		2.4

Questionnaire Item Number	Statement	Number of responses	Strongly Agree [7]	Agree [6]	Somewhat Agree [5]	Neither Agree nor Disagree [4]	Somewhat Disagree [3]	Disagree [2]	Strongly Disagree [1]	Average Score
37	Making entrepreneurial characteristics (e.g., commitment and competence) more transparent to VCs can benefit entrepreneurs	5		3	1			1		5
38	VCs who specialize in industries are likely to provide high quality advising/monitoring	4	1	2	1					6
39	The VC would be more inclined to revise a rejected offer if the VC's ownership share in the rejected offer is high	5		1		3		1		4

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