Venture Capital and Capital Allocation*

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Abstract

In this paper, I explore the effects of venture capitalists' career concerns. I find that when firms are backed by more career-concerned VCs, adverse-selection-induced market breakdowns are less likely and price volatility is lower. This is due to the feedback between the behavior of uninformed VCs and adverse selection in the IPO market. Because uninformed VCs want to appear skilled, they are biased toward withholding capital—by withholding capital, VCs avoid taking bad firms to market, which would ultimately reveal their lack of information. In equilibrium, this implies that VCs provide capital only to high-value firms, which creates a certification effect that helps firms to go public efficiently. My model's predictions are consistent with a number of stylized facts about the venture capital industry.

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1 Introduction

Motivation, research question, and key results. Institutional investors wish to be perceived as skilled in order to attract "flows," to attract new investors and retain existing ones. Thus, their *career-concerns* make them act as if they have good private information, even when they do not. Dasgupta and Prat (2006, 2008), Dow and Gorton (1997), and Guerrieri and Kondor (2012) have shown that these career-concerns lead institutional investors to trade inefficiently in secondary markets. Uninformed institutional investors churn their portfolios—they trade excessively in an attempt to appear skilled. Their excessive trading may decrease the informativeness of secondary market prices. The importance of delegated investors' career concerns, however, is not limited to secondary markets. Delegated investors also play an important role in primary markets, where the funding decisions of venture capital funds (VCs) have direct effects on real efficiency—they determine which projects go ahead. This leads to the main question I ask in this paper: do VCs' career concerns lead to inefficiencies in primary markets? Specifically, relative to purely profit-motivated investors, do career-concerned VCs misallocate capital in an attempt to appear skilled?

In this paper, I develop a model to address this question. I show that uninformed career-concerned VCs make relatively inefficient investment decisions. They are biased toward withholding capital, relative to the case in which they are purely profit-motivated. Uninformed career-concerned VCs pass up positive NPV investment opportunities to avoid taking bad firms to market, which can ultimately expose their lack of information. However, these inefficient individual investment decisions *improve* aggregate investment efficiency in equilibrium. Because uninformed career-concerned VCs are biased against investing, VC investments are made mainly by skilled VCs with positive information. This creates a *certification effect* for VC-backed firms which mitigates adverse selection problems, increasing efficiency.

Model preview. In the model, a penniless entrepreneur requires outside finance for a project that may be either good or bad. He looks for seed capital from a VC. If he receives the seed capital, he gives the VC an equity stake in his firm and invests in his project. Later, the entrepreneur takes his firm public in an IPO. The IPO suffers from adverse selection problems as in the standard model of Rock (1986). As a result, the issuing firm must set the IPO price at a discount to induce IPO bidders to participate. At the time of the IPO, the VC unwinds his position in the firm.[1] Finally, the long-run value of the entrepreneur's project is realized.

[1]In reality, VCs typically do not unwind their positions at the IPO but, rather, after a short "lock-up period." In footnote 10 I argue that this timing is a good approximation of reality despite this simplifying assumption and in Subsection 5.4 I show that for reasonable parameters the assumption does not affect the main results.

The VC can be either skilled or unskilled. It can observe whether the entrepreneur's project is good or bad only if it is skilled, and not if it is unskilled. I consider two cases. First, I consider the case in which the VC wishes to fund an entrepreneur whenever it can make a profit from taking the firm public in an IPO; I refer to this VC as profit motivated. Second, I consider the case in which the VC wishes to maximize the market's belief that it is skilled, in order to maximize the delegated capital it receives from outside investors.[2] I refer to this VC as career-concerned.

Results preview. I begin by characterizing the equilibrium with a profit-motivated VC. In this case, the equilibrium is always pooling, in the sense that if any type of VC invests so do the other types of VC. The reason is that when the VC is profit-motivated, its decision of wether to invest depends only on the amount of money it can raise in the IPO, i.e. on the IPO price. Thus, if the skilled VC finds it profitable to fund the entrepreneur, so does the unskilled VC, since it is costless for it to imitate the skilled VC. As a result, the skilled VC's information is not transmitted to the market. In other words, the VC's private information cannot overcome the adverse selection problems associated with taking the firm public. This implies that, unless the ex ante likelihood that the project is good is high enough, there is a market breakdown in which any type of VC withholds capital and positive NPV projects are denied funding.

What changes if the VC is career-concerned? In this case, when the VC makes its investment decision, it cares not only about the project's quality, but also about investors' perception of its own skill. In particular, the VC is especially averse to investing in a project that might end up being bad. This is because VC investors will learn that it made a poor investment decision and ultimately withdraw their funds as a result. In contrast, the VC is less averse to *not* investing in a project that might end up being good. This is because investors will never learn that the VC passed up a good investment. Thus, the market cannot determine whether the VC was correct in withholding capital, whereas they can determine whether the VC was correct in investing. In other words, the market cannot distinguish between false negatives and correct negatives, but can distinguish between false positives and correct positives. This biases the unskilled VC toward "negatives," i.e. toward withholding capital.

The unskilled career-concerned VC acts inefficiently by withholding capital from positive NPV investments.[3] However, career concerns enhance aggregate efficiency.

[2]In the baseline model, I do not explicitly model the behavior of outside investors who delegate their wealth to VCs. Rather, I model VCs' career-concerns in reduced form by assuming that the VC acts to maximize the market's perception of its skill. However, I extend the model to include these outside investors in Subsection 5.1 and I show that these reduced-form preferences arise endogenously in equilibrium: a VC tries to maximize the market's belief that it is skilled in order to maximize its fees.

[3]This social inefficiency of withholding capital implicitly relies on the assumption that the average project has positive NPV. However, there is an analogous social inefficiency if the average project has negative NPV. Then, the unskilled VC *provides* capital to too many projects. In fact, my main results about the benefits

Because the unskilled career-concerned VC is likely to withhold capital, most VC investments reflect the skilled VC's positive information. Thus, the career-concerned VC's investment constitutes a "certification" of the firm, which mitigates adverse selection problems at the IPO. This contrasts with the case of a profit-motivated VC, when all equilibria are pooling and the skilled VC's information is not transmitted to the market. Hence, career concerns improve efficiency by decreasing the IPO discount, thereby decreasing the likelihood that the IPO market breaks down. They also decrease price volatility and, for reasonable parameters, increase aggregate output. Behind all of these efficiency results is the fact that career concerns mitigate an existing distortion by inducing a new distortion—they mitigate adverse selection at the time of the IPO by withholding capital and thereby making VC investment an informative signal about firm quality.

In summary, my analysis reveals that reputation in financial markets can be a double-edged sword. On the one hand, reputation hurts when the career-concerned VC invests directly at the seed-capital stage, since the unskilled VC abstains from investment to try to enhance its reputation. This effect arises because abstaining from investment is a relatively safe strategy, since the VC is unlikely to be proved wrong. On the other hand, reputation helps when the career-concerned VC sells his stake at the IPO stage, since this same force reduces asymmetric information after the initial investment is made.

Further results. I extend my model in four directions. First, I consider a repeated version of my model in which VC investors observe the outcomes of VCs' investments and allocate their funds to maximize next period profit. I show that investors' capital chases VCs' past returns and that as a result VCs' career concerns arise endogenously. Second, I consider the case of a firm with assets in place in addition to the new project to be financed. Assets in place allow the market to make an inference about the VC's skill even when the firm fails to raise finance. Thus, the market may observe when a VC passes up a good project. However, as long as the the firm's assets in place are not perfectly correlated with its new project, my findings remain. Further, the case in which the correlation is perfect provides a useful benchmark for my findings. In this case, the firm's quality is always revealed, regardless of VC financing. I find that the unskilled VC randomizes fifty-fifty between providing and withholding capital in equilibrium. This shows that my result that the unskilled VC withholds capital relatively frequently is a result only of the feedback effect between VC capital provision and firm investment. Third, I consider the case in which skilled and unskilled VCs have imperfect information about the the firm quality, the skilled VC's information

of career-concerns are even stronger in this negative-average-NPV case (cf. Proposition 8). I focus on the positive-average-NPV case in the Introduction because it simplifies the argument and still captures the intuition behind the mechanism.

being more precise. With career concerns, the skilled VC acts as in the baseline model, investing only when it has positive information. The unskilled VC's behavior is also analogous to the baseline, but more subtle. It withholds capital when it is has negative information, but when it has positive information it randomizes and provides capital most of the time but sometimes withholds capital. Thus, on average the unskilled VC withholds capital more often than it provides capital, so the career-concerned VC's investment constitutes a certification of the firm, as in the baseline model. Last, I consider the variation of my model in which the VC retains its stake in the firm after the IPO and show that my main results are robust.

Empirical Implications. My model's empirical implications are consistent with a number of stylized facts. Notably, it implies that: (i) more reputable VCs[4] are more likely to lead their portfolio companies to a successful IPO (see Nahata (2008)); (ii) VC-backed firms[5] are less likely to be underpriced at IPO than non-VC-backed firms (see Barry, Muscarella, Peavy, and Vetsuypens (1990) and Megginson and Weiss (1991)); (iii) for VC-backed firms, IPO underpricing decreases with VC reputation (see Gompers (1996)). My results are also broadly consistent with the findings in Puri and Zarutskie (2012) who find that VC-backed companies are more likely to go public and Hsu (2004) who finds that they are more likely to go public in an IPO, especially when backed by a more reputable VC. The analysis also yields new empirical predictions about the effects of VCs' compensation contracts. Specifically, that higher-powered VC contracts (those with lower fixed fees) should lead to larger IPO discounts and more market failures.

Related literature. My paper is related to the literature on career-concerned institutional investors, such as Dasgupta and Prat (2006, 2008) and Guerrieri and Kondor (2012). In these papers, the distorted trades of uninformed career-concerned institutions typically increase mispricing and reduce efficiency. In my paper, the distorted behavior of the career-concerned VC results in decreased mispricing and increased efficiency. This difference is due to the endogeneity of firms' investment decisions to VCs' funding decisions.[6] As a result, this effect is present in the primary market but not in the secondary market.

Dow and Gorton (1997) show that there may be a positive effect of institutional investors' "endogenous noise trade." In their model, more institutional noise trade provides more risk-sharing opportunities. The reason is that when institutions are "churning" their portfolios, uninformed hedgers are more willing to participate in financial

[4]Within my model, I measure a VC's reputation as the market's ex ante belief that it is skilled.

[5]Within my model, I equate VC-backing with backing by a career-concerned investor and non-VC-backing with banking by a profit-motivated investor.

[6]In particular, in Dasgupta and Prat (2006, 2008) the unskilled delegated investors churn symmetrically, randomizing fifty-fifty between buying and selling. In my model, the feedback effect between VCs' decisions and the payoffs of the investments induces VCs to "churn asymmetrically," providing capital less often than withholding capital. This difference leads my findings to contrast with theirs.

markets. This not only provides insurance for hedgers, but also provides more market depth for informed traders, which allows them to invest on a larger scale. The positive side of institutional churning in my model works by mitigating adverse selection rather than providing market depth, and it improves real investment rather than risk-sharing.

In my model, the fact that VCs' actions affect the outcome of firms' investments leads to asymmetric learning about VCs' ability, in the sense that the market learns whether a VC made the right investment decision only if it funds a firm, so that the firm's quality is ultimately observable. The effect of such asymmetric learning is also present in some earlier models of career concerns, most notably in Milbourn, Shockley, and Thakor (2001) and Hirshleifer and Thakor (1994).

Milbourn, Shockley, and Thakor (2001) study how a manager's career concerns affect his decision to acquire information. The asymmetry is that any good project that is passed up incorrectly is never observed by the labor market, but a bad project that is chosen can show the manager in poor light ex post. There, the manager over-invests in information, because this improves the odds of rejecting a bad project. This makes him allocate capital correctly, but this decreases overall efficiency relative to first best. In my model, the unskilled VC under-invests in firms, frequently allocating capital incorrectly, but this ultimately increases efficiency in equilibrium. These contrasting incentives are the result of the fact that I assume that the VC knows whether it is skilled, whereas Milbourn, Shockley, and Thakor assume that the manager does not know his ability.

In Hirshleifer and Thakor (1994), skilled managers are reluctant to undertake projects that might fail conspicuously. As a result, they play it safe, taking lower NPV projects that are less likely to reveal their bad decisions to the market. This is similar to my finding that the unskilled VC is reluctant to invest. However, unlike that paper, I find that this distortion can increase aggregate efficiency. This is because the VC's decision feeds back into the firm's ability to raise capital at IPO.

My model is also related to the theoretical literature on the feedback effects between financial markets and investment (see, for example, Boot and Thakor (1997), Bond, Goldstein, and Prescott (2010), Dow and Rahi (2003), Dow, Goldstein and Guembel (forthcoming), Edmans, Goldstein, and Jiang (2015), Fulghieri and Lukin (2001), Goldstein and Yang (2014), Goldstein and Guembel (2008) and Subrahmanyam and Titman (2001)). This literature has documented inefficiencies induced by secondary market trading in the presence of feedback effects. For example, in Goldstein and Guembel (2008), a speculator sells a firm too often to manipulate its manager's investment decisions. This price manipulation is profitable for the speculator but leads to inefficient real investments. My model suggests that in the presence of career concerns this result may be reversed: in my model, withholding capital (the analogy of selling) leads to

increased investment efficiency.

The unskilled career-concerned VC in my model makes a suboptimal decision in order to hide the fact that it is uninformed. This is reminiscent of the literature in which career concerns induce unskilled agents to undertake inefficiently conservative actions in order to pool with skilled agents (see, for example, Prendergast and Stole (1996) and Zwiebel (1995)). Crain (2013) calibrates a model in this category to study the venture capital market. Unlike in these papers, in my paper the agent's inefficient decisions at the individual level lead to an increase in efficiency at the aggregate level due to the feedback between the VCs' decisions and IPO success.

My paper falls into the category of career-concerns models in which an agent's type determines his ability to understand the state of the world, which also includes the papers discussed above. Seminal papers in this literature include Gibbons and Murphy (1992), Holmstrom and Ricart i Costa (1986), and Scharfstein and Stein (1990). There are other types of reputation models, such as those based on repeated games, that have been used to study financial intermediation. For example, Chemmanur and Fulghieri (1994) study the reputation of investment banks in the underwriting market and Neus and Walz (2005) study how reputation affects VC exit.

Layout. The rest of the paper is organized as follows. In Section 2, I present the model. In Section 3, I characterize the equilibria of the model, both in the case in which the VC is profit motivated and in which it is career concerned. In Section 4, I compare the profit-motivation equilibria and the career-concerns equilibria. I show the benefits of career concerns to prevent market breakdowns, reduce the IPO discount, decrease price volatility, and increase aggregate output. In Section 5, I extend the model to include VC investors, firms' assets in place, imperfect signals for VCs, and VCs' retaining a stake in the firm after the IPO. In Section 6, I discuss the empirical content of the analysis including new empirical predictions about the effects of VC contracts. I conclude in Section 7.

2 Model

In this section I present the model. In the model, a firm raises initial capital from a VC that takes an equity stake in the firm. Later, the VC takes the firm public in an IPO. After the IPO, the true value of the firm is realized. Critically, the VC's incentives reflect *profit motivation* and *career concerns*.

2.1 Players

Firms. In my model economy, there is a firm that is of one of two qualities $\theta \in \{g, b\}$, where g stands for "good" and b for "bad." The firm is good with probability 1/2. The final value of the firm of type θ is V_θ, where $V_g > V_b$. For this value to be realized, the firm requires initial investment c from a venture capitalist and additional capital I which is raised in an IPO. I refer to the net present value of a firm of type θ as $\text{NPV}_\theta := V_\theta - I$. If the firm fails to raise the seed capital from the venture capitalist or if it does not successfully IPO, it is worth zero.[7]

VCs. There is a venture capitalist (VC) that can be one of two types, denoted by $\tau \in \{s, u\}$, where s stands for "skilled" and u for "unskilled." The VC is skilled with probability γ. The difference between a skilled VC and an unskilled VC is that the skilled VC knows the quality of the firm whereas the unskilled VC does not.[8] The VC provides the initial capital c to the firm in exchange for ownership of n shares in the firm.[9] I sometimes refer to a skilled VC that observes $\theta = g$ as "positively informed" and to a skilled VC that observes $\theta = b$ as "negatively informed." I denote the VC's action as $a = 1$ if it provides capital and $a = 0$ if it does not provide capital. The VC exits by selling its shares in an IPO.[10]

2.2 IPO

If the VC has provided capital, the firm goes public via an IPO to raise the additional capital I. Two types of bidders provide capital in the IPO, informed bidders and uninformed bidders. Informed bidders know the quality of the firm whereas uninformed bidders know only the public information—i.e. the uninformed bidders observe only

[7] In Subsection 5.2 I explore an extension in which the unfunded firm has "assets in place" with non-zero value. The results are qualitatively the same as in the baseline model.

[8] In Subsection 5.3 I relax this assumption by allowing both the skilled VC and the unskilled VC to observe imperfect signals about the quality of the firm. The results are qualitatively the same as in the baseline model.

[9] Note that I assume that (i) the number of shares n that the VC gets is exogenous and that (ii) the VC owns all of the shares in the firm after it provides capital. These assumptions are mainly for simplicity: if the VC received a fixed fraction of the shares in the firm, none of the results would be affected; this fraction could potentially be endogenized as the result of a split-the-surplus bargaining protocol. In the profit-motivated case with a skilled VC, there is transferable utility and complete information, so this is just the outcome of Nash bargaining; unfortunately, however, it is unclear which protocol would be appropriate in the other cases. Thus, I take n as exogenous.

[10] In reality, VCs do indeed exit successful investments by taking them public in an IPO. However, they usually do not sell shares exactly at the time of the IPO, but rather after a "lock-up" period of several months (see Gompers and Lerner (1998)). However, I argue that the assumption that VCs exit at IPO is reasonable for the following two reasons: (i) the lock-up period is relatively short and the price at which the VC sells is likely to be close to the IPO price p, relative to the long-run or "true" value of the firm V_θ, and (ii) in Subsection 5.4, I consider the variation of the model in which the VC retains its stake after the IPO. I show that all of the main results go though in this setting under reasonable assumptions.

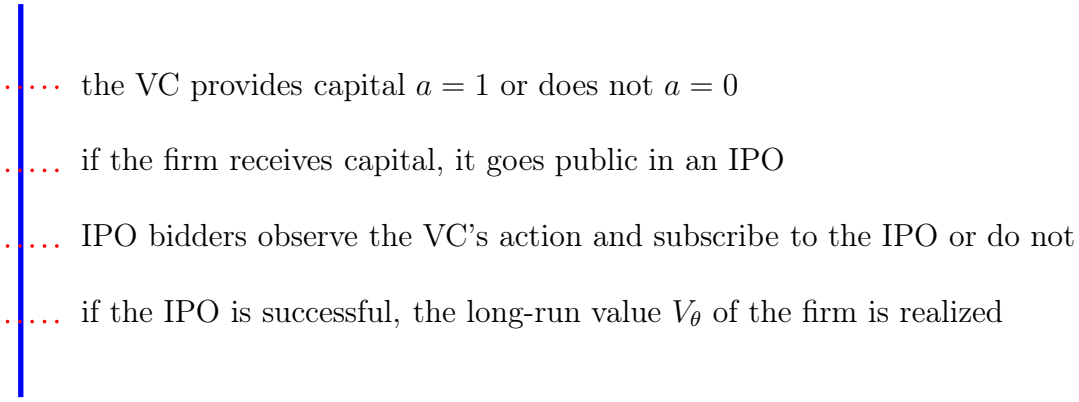
whether the VC has provided capital to the firm.

I model the IPO following the standard model of Rock (1986). The IPO price p is set to ensure that enough bidders subscribe to the IPO while taking into account the public information. At the time of the IPO, the VC sells its n shares and the firm raises the additional capital I by issuing n' new shares. After the number of shares $n + n'$ and the price of the firm p are set, bidders submit bids. Bidding is modeled as either subscribing or not subscribing to the IPO, where the informed bidders bid for n_{I} shares and the uninformed bidders bid for n_{U} shares (n_{I} and n_{U} are exogenous). If the offering is oversubscribed—i.e. the number of bids exceeds $n + n'$—then shares are distributed to participants pro rata. If enough bidders bid in the IPO, then the IPO is successful. I use the variable ι to indicate the success of the IPO. Specifically, I write $\iota = 1$ if the IPO is successful and $\iota = 0$ otherwise—note that $\iota = 0$ both if the VC takes the firm to IPO but the IPO fails and if the VC does not invest capital c in the firm to begin with.

2.3 Timeline

The sequence of moves is as follows. First, the VC either provides capital c to the firm, $a = 1$, or does not, $a = 0$. Second, if the VC has provided capital, the firm goes public via an IPO. In the IPO, competitive bidders buy shares in the firm. Some bidders are uninformed, but they can observe wether the VC has provided capital, which enables them to update their beliefs about that quality of the firm. If there are enough bidders bidding in the IPO, then the IPO is successful, $\iota = 1$, whereas if there are not enough bidders bidding in the IPO, then IPO is unsuccessful, $\iota = 0$, and the value of the firm is zero. Finally, if the IPO is successful, the long-run value of the firm V_θ is realized and publicly observed. The sequence of moves is illustrated in Figure 1.

Figure 1: Timeline Representation of the Sequence of Moves



2.4 The VC's Payoff—Profit Motivation and Career Concerns

A VC's payoff takes different forms in different parts of the paper. This reflects the different preferences of VCs in reality. Today VCs' compensation is composed of two parts: a fixed fee and a variable fee, called performance fee; this variable fee is typically a fixed fraction of the VC's profits. These fees vary from VC to VC. For example, younger VCs charge a higher fixed fee and a lower performance fee than older and larger VCs. The fixed portion of compensation is usually between 1.5% and 3% of the net asset value and the variable portion is usually about 20% of profits (see Gompers and Lerner (1999)).

Whereas the ability to make profits is key to obtaining the performance fee, the ability to build a good *reputation* is key to obtaining the fixed fee. In other words, VCs can increase their compensation by improving their reputation as skilled investors. This allows them to increase their committed capital by retaining old investors and winning new ones. As a result, VCs whose contracts are based on fixed fees behave differently from VCs whose rewards depend entirely on profits.

The following payoff U^τ captures the two components of VC compensation described above. U^τ has a component called Π^τ_{PM} that reflects only the VC's desire to maximize its cash flow; the subscript PM stands for "profit motivation." U^τ also has a component called Π^τ_{CC} that reflects the VC's desire to be perceived as skilled; the subscript CC stands for "career concerns." This total payoff is a weighted average of these components,

$$U^\tau = w_{\text{PM}}\Pi^\tau_{\text{PM}} + w_{\text{CC}}\Pi^\tau_{\text{CC}}, \tag{1}$$

where w_{PM} and w_{CC} are weights reflecting the relative importance of profit motivation and career concerns. The term Π^τ_{PM} is standard, and given by the monetary payoff to the VC. Specifically, if a VC provides capital c then

$$\Pi^\tau_{\text{PM}} = \begin{cases} \dfrac{n}{n+n'}\,p - c & \text{if IPO succeeds,} \\ -c & \text{if IPO fails.} \end{cases} \tag{2}$$

If the VC does not invest then $\Pi^\tau_{\text{PM}} = 0$.

The term Π^τ_{CC}, which reflects a VC's reputation, is equal to the market's belief that a VC is skilled, given all available information,

$$\Pi^\tau_{\text{CC}} = \mathbb{P}\left[\text{ skilled } \mid \text{ public information }\right] = \mathbb{P}\left[s \,|\, \iota V_\theta, a\right]. \tag{3}$$

This expression says that a VC's reputation consists of the market's belief that the VC is skilled based on all observables: the VC's action a and potentially the long-run realized value of the firm V_θ. Note, however, that V_θ is observable only if the firm receives

funding and undertakes its projects, or $\iota = 1$. Hence, the belief above is conditional on ιV_θ (and not V_θ).

Reputation concerns for delegated investors, such as VCs, arise endogenously in a number of models (see, for example, Dasgupta and Prat (2006)). Typically VCs seek to maximize their reputation to maximize their fees in the future—because VC investors want to invest their money with skilled VCs, high-reputation VCs receive more capital. For most of the paper, I take these preferences as given to focus on the VC's relationship with the firms it invests in, rather than the investors that invest in it. Nevertheless, in Subsection 5.1 I consider a dynamic extension of the model which includes investors delegating their capital to VCs. I show that the incentives in equation (3) arise endogenously because VCs want to maximize revenue from fees.

In the analysis I study the two limiting cases of a pure profit-maximizer ($w_{\text{CC}} = 0$) and a pure careerist ($w_{\text{PM}} = 0$).

2.5 Equilibrium Definition

The solution concept that I use is Perfect Bayesian Equilibrium. This consists of the action $a \in \{0, 1\}$ for each type of VC as a function of its information and the action to bid or not in the IPO for informed and uninformed IPO bidders. All players actions must be sequentially rational and beliefs must be updated according to Bayes's rule on the equilibrium path.

2.6 Parameter Restrictions

In this subsection I make two restrictions on parameters. The first says that the good firm has a positive NPV project whereas the bad firm has a negative NPV project. Note that I impose no restriction on the average NPV of the project. The second restriction says that informed bidders do not bid for enough shares themselves for the IPO to be successful. If the informed bidders could bid for all of the shares in the IPO, there would be no IPO underpricing.

Parameter Restriction 1.

$$\text{NPV}_g > 0 > \text{NPV}_b. \tag{4}$$

Parameter Restriction 2.

$$n_{\text{I}} < \frac{nI}{\text{NPV}_g}. \tag{5}$$

3 Equilibrium Characterizations

In this section, I solve the model. The main results of the section are (i) a characterization of the equilibrium given that the VC is purely profit motivated and (ii) a characterization of the equilibrium given that the VC is purely career concerned. The analysis proceeds as follows. First, I solve for the IPO price. This price depends on the market's belief about the proportions of good and bad firms that receive seed funding from the VC. Second, I solve for the funding decisions of the skilled VC and the unskilled VC and determine the proportions of good and bad firms that indeed receive funding in equilibrium.

It may be worth noting that almost all of the analysis centers around the actions of the VC, since the IPO bidders actions are straightforward to solve for.

3.1 IPO Price

In this subsection, I solve for the IPO price. In the main result of this subsection, I express the number of shares issued and the IPO price as a function of the public information available in the market.

I begin the analysis of the IPO with a preliminary result that says that the IPO price must be sufficiently low to induce uninformed bidders to bid. This is analogous to saying that the uninformed bidders are the "marginal" buyers in the IPO. The reason for this is that the informed bidders do not bid for enough shares themselves for the IPO to be successful (as a consequence of Parameter Restriction 2). This is summarized in the next lemma.

Lemma 1. (Uninformed Bidders Are Marginal in the IPO) *The IPO succeeds if and only if the uninformed bidders bid in the IPO.*

Given the lemma above, the key to characterizing the IPO price is to solve for the break-even condition of uninformed bidders. In order to induce uninformed bidders to subscribe to the issue, the issuer must offer shares at a discount. The reason for this is that uninformed bidders are subject to a form of the winner's curse, which works as follows. If the firm is bad, then informed bidders do not bid in the IPO and, as a result, the uninformed receive all the shares. In contrast, if the firm is good, then both uninformed and informed bidders bid, and uninformed bidders receive fewer shares, due to the pro rata rule. Thus, uninformed bidders obtain a smaller proportion of good firms than of bad firms. Specifically, the proportion of the firm they obtain is given by

$$\alpha_{\mathrm{U}} = \begin{cases} 1 & \text{if } \theta = b, \\ \beta & \text{if } \theta = g \end{cases} \tag{6}$$

where $\beta := n_{\mathrm{U}}/(n_{\mathrm{I}} + n_{\mathrm{U}})$. Hence, the uninformed bidders' participation constraint is

$$\mathbb{E}\left[\alpha_{\mathrm{U}}\left(V_\theta - p\right) \,\middle|\, a = 1\right] \geq 0 \tag{7}$$

(keep in mind that α_{U} is random and correlated with the firm value V_θ). This inequality binds in equilibrium since the value for the inside shareholders must be maximized. This gives an expression for the IPO price p, given in Lemma 2 below. Note this expression for p does not depend on the number of shares raised in the IPO.

Lemma 2. (IPO Price) *The IPO price of the firm p is given by*

$$p = \frac{\mathbb{E}\left[\alpha_{\mathrm{U}} V_\theta \,|\, a = 1\right]}{\mathbb{E}\left[\alpha_{\mathrm{U}} \,|\, a = 1\right]}. \tag{8}$$

The IPO succeeds if and only if the firm can sell enough shares to successfully invest I in the project. That is to say that the total money raised p minus the money that goes to the VC must be at least I. Since the VC receives a fraction $n/(n + n')$ of the firm, this amounts to saying that it must be that

$$p - \frac{n}{n + n'}\, p \geq I \tag{9}$$

or

$$\frac{n'}{n + n'}\, p \geq I. \tag{10}$$

Since $n'/(n + n')$ goes to one as n' goes to infinity, the IPO will succeed if and only if the IPO price is greater than the cost of investing in the project I,

$$p > I. \tag{11}$$

This is because, as long as this condition holds, the firm can always issue enough shares—can make n' large enough—to ensure that the IPO succeeds. The firm minimizes the number of new shares issued, thus inequality (10) binds, giving an expression for n'.

Lemma 3. (Number of New Shares Issued in the IPO) *If the IPO is successful, the number of new shares issued n' is given by*

$$n' = \frac{nI}{p - I}. \tag{12}$$

3.2 Equilibrium Characterization with a Profit-motivated VC

In this subsection, I characterize the equilibrium with a purely profit-motivated VC, which I refer to as the *profit-motivation equilibrium.* I first show a preliminary result,

that all types of VC take the same action, i.e. that the VC always plays a pooling strategy. Then, I characterize the equilibrium, i.e. I determine the IPO price and the number of shares issued. Finally, as a corollary, I describe when the market breaks down—i.e. when there is no equilibrium in which any firm goes public successfully. The following results characterize the equilibrium and market break-down conditions formally.

Lemma 4. (With a Profit-motivated VC All Equilibria Are Pooling) *If the VC is purely profit-motivated ($w_{\text{CC}} = 0$) all types of VC take the same action in any strict equilibrium.*[11]

The intuition behind the lemma is as follows. A VC's payoff does not depend on the long-run value V_θ of the firm, but only on the price p at which it sells its shares in the IPO. As a result, if it is profitable for one type of VC to provide capital—to pay cost c and take the firm public at price p—then it is profitable for the other types of VC to provide capital as well. For example, if only the positively informed VC provides capital, the VC takes the firm public at a high IPO price. Thus, the other types of VC have the incentive to exploit this high IPO price and provide capital, even if they are negatively informed about the true quality of the firm.

Proposition 1. (Equilibrium Characterization with a Profit-motivated VC) *Suppose the VC is purely profit motivated ($w_{\text{CC}} = 0$). If*

$$\beta\big(\text{NPV}_g - c\big) + \text{NPV}_b - c > 0, \tag{13}$$

then the VC always funds the firm, the IPO is always successful, the IPO price is

$$p = \frac{\beta V_g + V_b}{\beta + 1}, \tag{14}$$

and the number of shares issued in the IPO is

$$n' = \frac{\beta + 1}{\beta \text{NPV}_g + \text{NPV}_b} nI. \tag{15}$$

If inequality (13) is violated, then the VC does not provide capital to any firm.

Since the profit-motivated VC always plays a pooling action (Lemma 4), we have that there are two types of equilibria: either the VC always provides capital or it never does. The proposition above characterizes the parameters for which there is an equilibrium in with the VC provides capital. Otherwise, the VC does not provide capital and the

[11] By "strict equilibrium" I mean a Perfect Bayesian Equilibrium in which no VC is indifferent to deviation. In Subsection 3.2.1 I argue that all reasonable profit-motivation equilibria are strict.

firm never undertakes its project, i.e. there is a market breakdown, as stated in the next corollary.

Corollary 1. (Market Breakdown with a Profit-motivated VC) *Suppose the VC is purely profit-motivated ($w_{\text{CC}} = 0$). If*

$$\beta\big(\text{NPV}_g - c\big) + \text{NPV}_b - c \leq 0, \tag{16}$$

then the IPO is not successful, $\iota = 0$.

Observe that the market breaks down even though the VC may be skilled and may have good information about the underlying quality of the firm. This is because the unskilled VC pools with the skilled VC, preventing the skilled VC's action from transmitting information to the IPO bidders. VC pooling thus exacerbates the winner's curse in the IPO, and prevents uninformed bidders from providing the necessary capital.

3.2.1 A Note on Equilibrium Selection in the Profit-motivation Equilibrium

In Proposition 1, I focus on strict profit-motivation equilibria, i.e. I do not study equilibria in which a profit-motivated VC is indifferent between providing capital and withholding capital. Such additional equilibria exist. However, they are unappealing in two senses. First, *all* types of VC must be indifferent between providing capital and withholding capital. Second, these equilibria are not robust in the sense that introducing a refinement will rule them out. In particular, if I add that the VC has a small stake in the long-term value of the firm, I can rule out these equilibria. I formalize this in this section.

Suppose that the VC sells a fraction $1-\epsilon$ of the firm in the IPO but retains a fraction ϵ of the firm. I will focus on the limit in which ϵ goes to zero. In the baseline model, $\epsilon = 0$. I first establish equilibrium conditions for mixed-strategy profit-motivation equilibria in the baseline model with $\epsilon = 0$. I then show that if $\epsilon > 0$ none of these equilibria exist.

In the baseline profit-motivation model, there are equilibria in which the IPO price is so low that the VC is indifferent between providing capital and withholding capital. Because all types of VC have the same payoff (recall the argument following Lemma 4), this implies that all types of VC must be indifferent between providing capital and withholding capital. It may seem like this is a knife-edge case, and such equilibria can exist only for a non-generic set of parameters. While I argue below that it is indeed a knife-edge case, such equilibria in fact exist for a relatively broad range of parameters. The reason is that the VC's mixing probabilities feedback into the price. Since all types of VC are indifferent, their mixing probabilities are arbitrary—for each type of VC there is a degree of freedom—and can be chosen to construct an equilibrium.

Lemma 5. (Multiple Profit-motivation Equilibria) *There is an equilibrium in which the positively informed VC provides capital with probability μ_+, the negatively informed VC provides capital with probability μ_-, and the uninformed VC provides capital with probability μ, whenever μ_+, μ_-, and μ are between zero and one and solve the following equation*

$$\beta\big(\gamma\mu_+ + (1-\gamma)\mu\big)(\text{NPV}_g - c) + \big(\gamma\mu_- + (1-\gamma)\mu\big)(\text{NPV}_b - c) = 0. \tag{17}$$

The union of the set of these equilibria with the set of equilibria described in Proposition 1 is the set of all profit-motivation equilibria.

Whereas Lemma 5 says that there may be many weak profit-motivation equilibria, the next result says that none of these equilibria is robust in the sense that these equilibria no longer exist if the VC retains an arbitrarily small fraction ϵ of the firm following the IPO.

Proposition 2. (Refining Profit-motivation Equilibria) *If $\epsilon > 0$ all profit-motivation equilibria are strict. In particular, none of the equilibria in Lemma 5 exist.*

This result says that the weak equilibria described in Lemma 5 are fragile. They are fragile because all types of VC must be indifferent. If the VC retains a small fraction of the project then a positively informed VC is more inclined to provide capital to a good firm then to a bad firm, which I think is a realistic condition. Given this condition, the strict profit-motivation equilibria I focus on in the baseline model are all the equilibria.

3.3 Equilibrium Characterization with a Career-concerned VC

In this subsection, I characterize the equilibrium with a purely career-concerned VC, which I refer to as the *career-concerns equilibrium.* In this equilibrium, the VC partially separates. The positively informed VC provides capital and the negatively informed VC does not. On the other hand, the unskilled VC plays a mixed strategy, providing capital sometimes and not providing it other times. Critically, the unskilled VC provides capital less often then it does not provide capital. This finding is central to the welfare analysis in the next section (Section 4).

In the results below, I first characterize the equilibrium, i.e. I determine the IPO price and the number of shares issued. Then, I characterize when the market breaks down and no firm can raise capital, i.e. when there is no equilibrium in which firms successfully go public.

Proposition 3. (Equilibrium Characterization with a Career-concerned VC) *Suppose the VC is purely career concerned ($w_{\text{PM}} = 0$). As long as either $\gamma \geq 2/3$*

or

$$\beta(2+\gamma)\text{NPV}_g + (2-3\gamma)\text{NPV}_b > 0, \tag{18}$$

there is an equilibrium in which a VC behaves as follows. If it is positively informed it provides capital, if it is negatively informed it does not provide capital, and if it is unskilled it provides capital with probability μ^**, where*

$$\mu^* = \max\left\{0\,,\ \frac{2-3\gamma}{4(1-\gamma)}\right\}. \tag{19}$$

The IPO price p *is*

$$p = \frac{\beta\big(\gamma+(1-\gamma)\mu^*\big)V_g + (1-\gamma)\mu^* V_b}{\beta\big(\gamma+(1-\gamma)\mu^*\big) + (1-\gamma)\mu^*} \tag{20}$$

and the number of shares issued in the IPO is

$$n' = \frac{\beta\big(\gamma+(1-\gamma)\mu^*\big) + (1-\gamma)\mu^*}{\beta\big(\gamma+(1-\gamma)\mu^*\big)\text{NPV}_g + (1-\gamma)\mu^*\text{NPV}_b} nI. \tag{21}$$

If $\gamma < 2/3$ *and inequality (18) is violated, then a VC does not provide capital to any firm.*

The intuition for this result relies on the skilled career-concerned VC trying to show off that it is informed and on the unskilled career-concerned VC trying to hide that it is uninformed. To show off its information, the skilled VC "follows its signal," providing capital when positively informed and not providing capital when negatively informed. On the other hand, to hide its information, the unskilled VC has incentive not to provide capital. In fact, an important take-away from the proposition above is that the unskilled VC provides capital less frequently than it does not. This corollary follows directly from equation (19).

Corollary 2. (The Unskilled VC Provides Capital Infrequently) *The unskilled VC provides capital less than half the time,* $\mu^* < 1/2$.

What is the intuition behind this result that $\mu^* < 1/2$? The unskilled career-concerned VC is effectively withholding capital from the firm, even though the firm may have a positive NPV project on average. Why? Because if the VC withholds capital, the firm's project is not undertaken. As a result, the firm's true quality never becomes public information and the market can never infer that the VC is in fact unskilled. In other words, when the VC does not provide capital, an inference channel is shut: the market bases its inference only on the VC's action $a = 0$, but cannot use the value V_θ of the firm to update its beliefs. Thus, by playing $a = 0$, the unskilled VC can *always pool* with the skilled (negatively informed) VC. In Subsection 5.2, I consider the benchmark in which the firm's type is revealed regardless of whether it receives funding from the

VC. In this benchmark, the unskilled VC mixes with probability $\mu^* = 1/2$. This finding reaffirms the intuition that the reason the VC withholds capital more often than it provides capital is exactly to prevent the market from learning the firm's type.

The argument above explains why the unskilled VC does not want to provide capital to the firm—it allows it to pool with the skilled VC. This implies that $\mu^* < 1/2$. But why doesn't the unskilled VC *always* play $a = 0$? The reason is that if it always withholds capital, then the market believes that only the skilled VC is providing firms with capital, and the VC's payoff from pooling with the skilled positively informed VC is very high—if it provides capital to a firm that turns out to be good, then the market believes that it is skilled for sure. For some parameters, this high upside payoff from providing capital and being right compensates for the risk of providing capital and being wrong, revealing itself as unskilled. This leads to mixing in equilibrium.

Even though the VC's types partially separate in equilibrium, potentially impounding good information into prices (see Subsection 4.1 below), the market can still break down, at least for certain parameters. This is summarized in the next result.

Corollary 3. (Market Breakdown with a Career-concerned VC) *Suppose the VC is purely career-concerned ($w_{\text{PM}} = 0$). If*

$$\beta(2+\gamma)\text{NPV}_g + (2-3\gamma)\text{NPV}_b \leq 0 \tag{22}$$

then no IPO is successful, $\iota = 0$.

3.3.1 A Note on Equilibrium Selection in the Career-concerns Equilibrium

In Proposition 3, I characterize the equilibria in which providing capital to good firms sends a positive signal about the VC's type. However, there may be other equilibria. In this subsection I introduce a refinement and I argue that any other equilibrium is either unreasonable—i.e. it is ruled out by the refinement—or perverse—i.e. the market views providing capital to good firms as a negative signal and providing capital to bad firms as a positive signal. In other words, Proposition 3 characterizes all reasonable equilibria in which the VC's skill is not associated with trading against the interests of its investors (cf. Subsection 5.1).

Here I extend the model to include a small number of behavioral types in order to refine away equilibria that are supported by "unreasonable" beliefs off the equilibrium path. Specifically, suppose that with probability η the skilled VC "follows its signal," i.e. it provides capital if the firm is good and withholds capital if the firm is bad. I also assume that if the VC provides capital, the true type of the firm is revealed with probability δ.[12] I will focus on the limit in which η and δ go to zero. $\eta = \delta = 0$ in the

[12]Including assets in place as in Subsection 5.2 provides a micro-foundation for this assumption.

baseline model. By introducing "noise" in this way, I ensure that there is not an action $a \in \{0, 1\}$ that is always off the equilibrium path. Thus I no longer have to deal with off-the-equilibrium path beliefs.

I now define a *perverse* equilibrium.

Definition 1. (Perverse Equilibrium) *An equilibrium is perverse if beliefs are such that providing capital to a good firm is viewed as a negative signal about VC skill and providing capital to a bad firm is viewed as a positive signal about VC skill, i.e.*

$$\mathbb{P}\left[s|a = 1, V_b\right] \geq \mathbb{P}\left[s|a = 1, V_g\right]. \tag{23}$$

I restrict attention to non-perverse equilibria, since in perverse equilibria the unskilled VC would make higher profit than the skilled VC and hence investors would prefer to invest with the unskilled VC rather than with the skilled VC (cf. Subsection 5.1). The next result says that the equilibria characterized in Proposition 3 above constitute all reasonable non-perverse equilibria.

Proposition 4. (All Non-perverse Career-concerns Equilibria) *For $\eta \to 0^+$ and $\delta \to 0^+$, all non-perverse equilibria are characterized in Proposition 3.*

4 The Benefits of Career Concerns

In this section, I compare the profit-motivation equilibrium and the career-concerns equilibrium. I show that career concerns are beneficial in the following four senses. (i) IPO prices are higher when the VC is career concerned than when it is profit motivated. (ii) Market breakdowns are less likely when the VC is career concerned than when it is profit motivated. (iii) Prices are less volatile when the VC is career concerned than when it is profit motivated. Finally, for reasonable parameters, (iv) utilitarian welfare is higher when the VC is career concerned than when it is profit motivated.

4.1 The IPO Price Is Higher when the VC Is Career Concerned

In this subsection, I compare the IPO price in the profit-motivation equilibrium with the IPO price in the career-concerns equilibrium. I show that career concerns lead to higher IPO prices and, additionally, that the more the unskilled VC withholds capital the higher is the price premium associated with career concerns—in other words, the price premium is amplified by the fact that the unskilled VC withholds capital more often than it provides it (Corollary 2).

Proposition 5. (The IPO Price Is Higher with Career Concerns than with Profit Motivation) *The IPO price p is higher when the VC is career concerned than*

when it is profit motivated, or

$$p_{\big|\text{CC}} > p_{\big|\text{PM}}. \tag{24}$$

The price premium associated with career concerns is the result of two effects. The first effect is the behavior of the skilled negatively informed VC. When it is career concerned, it prefers not to provide capital—it does not want to be perceived as funding bad firms. In contrast, when it is profit motivated, it prefers to provide capital and pool with the positively informed VC at the IPO, even though it will be revealed that it funded a bad firm. As a result, the skilled career-concerned VC filters out bad firms and, hence, the average quality of a VC-backed firm is higher with a career-concerned VC, leading to a higher IPO price. The second effect is the behavior of the unskilled VC. The unskilled VC's inclination to withhold capital improves the quality of firms going public even further, amplifying this price premium.

Corollary 4. (With Career Concerns, Less VC Capital Provision Implies Higher IPO Prices) *In the career-concerns equilibrium, the lower is the probability μ with which an unskilled career-concerned VC provides capital, the higher is the IPO price, or*

$$\frac{\partial p}{\partial \mu} < 0. \tag{25}$$

The result above says that the less the unskilled VC provides capital, the higher is the IPO price in the career-concerns equilibrium.[13] Even though the direct effect of this behavior may decrease efficiency—the unskilled VC withholds capital most of the time, even when the firm is positive NPV on average—its aggregate effect increases efficiency—when the unskilled VC withholds capital, it increases the informativeness, or "certification value" of the VC's capital provision, because capital is relatively likely to come from a skilled VC. Intuitively, the more the unskilled career-concerned VC tries to hide by pooling with the negatively informed VC, the higher are IPO prices. This is because the unskilled VC biases the quality of firms that do receive capital upwards by withholding capital. To see this in another way, observe that there are are two ways that a firm raises capital in equilibrium: (i) the VC is skilled *and* the firm is good and (ii) the VC is unskilled *and* it provides capital randomly, without any information, which occurs with probability μ. Thus, the higher is the probability μ that the unskilled career-concerned VC provides capital randomly, the more likely (ii) is relative to (i)—the more likely it is that capital comes from a skilled VC and, therefore, the more likely it is that the firm is good if it has received capital from the VC. In summary, the fact that career concerns induce the unskilled VC to withhold capital leads to higher IPO prices. This has important positive welfare implications, as I demonstrate below.

[13]Note that this comparative static is off equilibrium. By differentiating with respect to the mixing probability, I am changing the behavior of the unskilled VC exogenously, away from its equilibrium strategy, assuming all other players play best responses.

4.2 Career Concerns Prevent Market Breakdowns

In this subsection, I compare the likelihood of a market breakdown in the profit-motivation equilibrium with the likelihood of a market breakdown in the career-concerns equilibrium. I find that career concerns make market breakdowns less likely, as stated in the next proposition.

Proposition 6. (Career Concerns Prevent Market Breakdowns) *Market breakdowns are less likely with a career-concerned VC, in the sense that there is a market breakdown with a profit-motivated VC whenever there is a market breakdown with a career-concerned VC.*

This result underscores one of the main positive roles that the VC's career concerns play in the model. It says that a VC's career concerns alleviate the information frictions that prevent firms from being able to raise capital and fund positive NPV projects. With a profit-motivated VC, the unskilled VC and the negatively informed VC provide capital to pool with the positively informed VC and sell at a high price at IPO. Thus, when a profit-motivated VC provides capital to a firm, it does not provide the market with information about the firm's type—the VC funds the firm no matter its quality. This says that having VC seed capital does not provide a certification of the quality of the firm that could mitigate adverse selection.

In contrast, when a career-concerned VC provides a firm with capital, it does constitute a certification. This is because the career-concerned VC does not want to provide capital to a bad firm, since, when the market eventually learns that the firm is bad, it will update negatively about the VC's skill. Thus, the career-concerned VC funds more good firms than bad firms. This mitigates the averse selection problem when the firm goes IPO, preventing the market from breaking down.

The fact that the unskilled VC withholds capital more often than it provides capital (Corollary 2 that $\mu^* < 1/2$) also helps prevent the market from breaking down. The unskilled VC randomizes, which obfuscates the action of the skilled VC. However, it favors withholding capital. Whereas this makes withholding capital relatively uninformative, it makes proving capital relatively informative. It is this information revealed by providing capital that prevents the market from breaking down, because it allows uninformed IPO bidders to infer that the firm is likely to be good. As a result, the way that the unskilled VC randomizes—withholding capital most of the time—is central to mitigating the averse selection problem.

The reason that the behavior of the unskilled career-concerned VC prevents market breakdowns is to note that the market breaks down if and only if the firm cannot raise enough capital at IPO to fund its project, or if $p < I$ (inequality (11)). Recall that Proposition 5 says that p is decreasing in μ. Thus, we can state that decreasing μ

makes market breakdowns less likely.

Corollary 5. (With Career Concerns, Less VC Capital Provision Implies Market Breakdowns Are Less Likely) *In the career-concerns equilibrium, the lower is the probability μ with which an unskilled career-concerned VC provides capital, the less likely it is that the market breaks down.*

4.3 Prices Are Less Volatile when the VC Is Career Concerned

In this subsection, I compare the post-IPO price volatility in the profit-motivation equilibrium with the post-IPO price volatility in the career-concerns equilibrium. I show that career concerns lead to a decrease in price volatility, as stated in the next proposition.

Proposition 7. (Career Concerns Decrease Price Volatility) *Price volatility is lower in the career-concerns equilibrium than in the profit-motivated equilibrium,*

$$\text{Var}\left[V_\theta \,|\, \iota = 1\right]\big|_{\text{CC}} < \text{Var}\left[V_\theta \,|\, \iota = 1\right]\big|_{\text{PM}}. \tag{26}$$

This result says that the variance of long-term prices is relatively lower in the career-concerns equilibrium than in the profit-motivation equilibrium. In other words, the IPO price is a better signal of fundamentals in the equilibrium in which a VC is career-concerned. The reason is that the career-concerned VC filters out bad firms when it provides capital. Thus, when a career-concerned VC takes a firm to IPO, it constitutes an informative signal ("certification") about the firm's long-run value. This signal provides the market with additional information about the firm and, therefore, reduces the uncertainty about its long-term value. This leads to lower long-run volatility.

As in the subsections above, the benefits of career concerns are amplified by the asymmetric behavior of the unskilled career-concerned VC. Here, the reason is that the more the unskilled VC withholds capital, the more informative is the VC's provision of capital—the more likely the VC is positively informed. Hence, the lower is the mixing probability μ of the unskilled, the lower is the long-run price volatility. This is summarized in the next corollary.

Corollary 6. *In the career-concerns equilibrium, the lower is the probability μ with which an unskilled career-concerned VC provides capital, the less volatile are prices,*

$$\frac{\partial}{\partial \mu}\text{Var}\left[V_\theta \,|\, \iota = 1\right]\big|_{\text{CC}} < 0. \tag{27}$$

Low variance post IPO reflects the fact that the IPO price is informative—variance conditional on the IPO is low because a lot of information about fundamentals is

contained in the IPO price. Thus, this result can be interpreted as suggesting that career-concerns reduce mispricing. This contrasts with some previous results in the literature. For example, in Dasgupta and Prat (2008) career-concerns decrease realized price volatility because trades are *un*informative: career-concerned traders trade without information and as a result prices do not move in response to these trades. In my model, career concerns make trades more informative and forward-looking volatility is low because prices reflect this.

4.4 Welfare Is Higher when the VC Is Career Concerned

In this subsection, I define welfare as net output. I then compare welfare in the profit-motivation equilibrium with welfare the career-concerns equilibrium. I show that career concerns lead to an increase in welfare under reasonable parameters (although not for all parameters, for reasons I discuss below).

I now give the definition of welfare.

Definition 2. *Define welfare as total output minus total input, or*

$$W := \iota\big(V_\theta - I\big) - ac. \tag{28}$$

W measures net output because the cost c is invested in the project only if the VC provides capital or $a = 1$ and the NPV $V_\theta - I$ is realized only if I is successfully raised in the IPO, or $\iota = 1$.[14]

Proposition 8. (Career Concerns Increase Welfare) *If there is a market breakdown, career concerns always weakly improve expected welfare (as defined in Definition 2) by Proposition 6.*

If there is not a market breakdown, expected welfare is strictly higher when the VC is career concerned than when the VC is profit motivated as long as firms' average NPV is not too high, specifically as long as

$$\gamma \mathrm{NPV}_g + 2\mu^*(1-\gamma)\Big(\overline{\mathrm{NPV}} - c\Big) > 2\overline{\mathrm{NPV}} - (2-\gamma)c. \tag{29}$$

The reason career concerns can improve welfare is that with career concerns VCs filter out bad projects, increasing the quality of projects that are undertaken. If firms have negative NPV on average, then the value of filtering out the bad firms is especially high; in fact, the condition in equation (29) is always satisfied. The reason that the condition in equation (29) is necessary is that if the average NPV of projects is very high, it may

[14] I think that W is a natural measure of welfare—it basically coincides with GDP. However, it is worth noting that this is not a transferable utility model, and career-concerned VCs have preferences not only over consumption but also over reputation, so there is no perfect cardinal measure of welfare here.

be better just to have all projects undertaken indiscriminately, as occurs in the profit-motivation equilibrium, than to undertake only a selection of better projects, as occurs in the career-concerns equilibrium. However, I suggest that the condition in equation (29) is relatively weak, since in reality the average *potential* investment probably has rather low NPV—whereas positive NPV projects are scarce and require skill to find, negative NPV projects are abundant. Thus, I think that it is "reasonable" to assume that the condition in equation (29) is satisfied.

5 Extensions and Robustness

In this subsection, I extend the baseline model in several ways. The following extensions verify the robustness of the results above and also provide additional results. (i) I add investors allocating their wealth to VCs in a dynamic version of my model; this verifies that the payoff function of the career-concerned VC (equation (3)) arises endogenously from the incentive to attract investment flows from investors. (ii) I consider the model in which the firm has "assets in place," so its value is positive even if it does not receive VC funding. In this model, raising capital from a VC and doing an IPO allow the firm to invest in an additional project. As long as the value of the assets in place is not perfectly correlated with the final value of the firm, the qualitative results above hold. In the limit in which the firm's assets in place are indeed perfectly correlated with the final value of the firm, the VC's decision to provide capital does not affect the market's ability to learn about the quality of the firm—since the market observes the assets in place, it always learns the firm's true quality. This limiting case provides a useful benchmark to contrast the baseline model with. (iii) I consider the case in which skilled and unskilled VCs have imperfect information about the the firm quality, the skilled VC's information being more precise. I show that the career-concerned VC's investment constitutes a certification of the firm, as in the baseline model. (iv) I consider the variation of my model in which the VC retains its stake in the firm after the IPO and show that my main results are robust.

5.1 Does Capital Chase Profits?

In this subsection, I provide a simple justification for the reduced-form way in which I model the incentives of the career-concerned VC above (equation (3)). Specifically, I show that the VC's objective to maximize the market's perception of its skill (equation (3)) arises endogenously from its incentive to maximize its fees from outside investors.

In order to incorporate outside investors' delegating their wealth in the model, I consider the following extension. There are infinitely many periods and a large number

of VCs. In each period, each VC is matched with a new firm. The firms' qualities are i.i.d. across VCs and periods, but VC types are persistent. Within each period, the timeline is as in the model above (Subsection 2.3). At the end of each period, investors observe the VCs' actions a and the realized values V_θ of funded firms.[15] Competitive investors then pay a fee f to VCs to invest their wealth on their behalf in the next period. Investors receive all of the investment profits and VCs receive only the fee.

I now show that the career-concerns equilibrium in each period is an equilibrium of this extended model. To do this, I suppose it is an equilibrium and verify that VCs have no profitable deviation. It suffices to show that given the equilibrium behavior, VCs have incentive to maximize the market's belief that they are skilled in each period. In other words, VCs incentives in each period are exactly as in the career-concerns equilibrium, so the career-concerns equilibrium is an equilibrium of the stage game of the extended model.

Note first that the expected profits of each type of VC—i.e. skilled VCs and unskilled VCs—are constant in time. This follows from the fact that the supposed equilibrium is stationary and firm qualities are i.i.d., whereas VC types are persistent. Since investors are competitive, they make zero profit on average, i.e., denoting the expected profit that the VC makes from investing by π,

$$\mathbb{E}\left[\pi \mid a, \iota V_\theta\right] - f = 0. \tag{30}$$

This says that investors pay VCs fees equal to their per-period expected profit, given their information about VCs' types. If investors know VCs' types, then they set the fee equal to the expected profits conditional on these types. Denote the expected profit given the VC is skilled by $\pi_{|s}$ and the expected profit given the VC is unskilled by $\pi_{|u}$. If a VC provides capital, it pays the cost c and receives the fraction $n/(n+n')$ of the IPO price p. The skilled VC receives this payoff $np/(n+n') - c$ with probability half, since it provides capital only to good firms whereas the unskilled VC receives the payoff with probability μ^*, since it randomizes between providing capital and not with probability μ^*. Thus,

$$\pi_{|s} = \frac{1}{2}\left(\frac{np}{n+n'} - c\right) \tag{31}$$

and

$$\pi_{|u} = \mu^*\left(\frac{np}{n+n'} - c\right). \tag{32}$$

Observe that $\pi_{|s} > \pi_{|u}$ since $\mu^* < 1/2$ by Corollary 2. In equilibrium, investors do not know VCs' types perfectly, but infer what they can given the observed information.

[15] For simplicity, I assume that investors do not observe VCs' entire histories, but only their actions within a period. This keeps the model stationary.

Thus, the equilibrium fee is the following convex combination of the expected profits above:

$$f = \mathbb{E}\left[\pi \mid a, \iota V_\theta\right] \tag{33}$$

$$= \mathbb{P}\left[s \mid a, \iota V_\theta\right] \pi_{|s} + \left(1 - \mathbb{P}\left[s \mid a, \iota V_\theta\right]\right) \pi_{|u} \tag{34}$$

$$= \pi_{|u} + \mathbb{P}\left[s \mid a, \iota V_\theta\right] \left(\pi_{|s} - \pi_{|u}\right). \tag{35}$$

Since $\pi_{|u}$ and $\pi_{|s}$ are constant from the point of view on an individual VC, maximizing f above is equivalent to maximizing $\mathbb{P}\left[s \mid a, \iota V_\theta\right]$. This is exactly the objective of the career-concerned VC above (as in equation (3)).

5.2 Assets in Place

In the baseline model, I assume that if the firm does not receive funding then its value is zero. This assumption determines the VC's behavior in the career-concerns equilibrium. Specifically, because both the good firm and the bad firm have value zero when the VC does not provide capital, the market's ability to update its beliefs about a VC that does not provide capital is limited. In this subsection, I relax the normalization that the firm has value zero if it does not receive funding. I extend the model to include "assets in place" in the firm—i.e. the firm value is not zero if it does not receive capital. If the firm receives capital from the VC and goes IPO, it then undertakes an additional project, the value of which is imperfectly correlated with the value of the assets in place. I show first that the career-concerned VC's behavior is qualitatively the same as it is in the baseline model. Further, this extension allows me to do comparative statics on the degree of correlation between the assets in place and the funded project. In the limit in which they are perfectly correlated, the true quality of the firm is always revealed, regardless of whether the firm receives funding. This limit provides a useful benchmark model to compare the baseline model to.

If the project is funded, V_θ is the overall value of the firm, i.e. the sum of the value of the assets in place and the value of the new project. If the project is not funded, the firm keeps its assets in place with probability q. With probability $1 - q$ it is unable to continue at all and the firm value is zero. Specifically, the firm with quality θ has value χv_θ if it is not funded, where $v_\theta << V_\theta$ is the value of the assets in place if the firm continues and χ is a an indicator random variable indicating whether the firm continues,

$$\chi = \begin{cases} 1 & \text{with prob. } q, \\ 0 & \text{with prob. } 1 - q. \end{cases} \tag{36}$$

The main result of this subsection is a characterization of the equilibrium, which is

analogous to the career-concerns equilibrium in Proposition 3.

PROPOSITION 9. (EQUILIBRIUM CHARACTERIZATION WITH A CAREER-CONCERNED VC AND ASSETS IN PLACE) *Suppose the VC is purely career concerned ($w_{\text{PM}} = 0$) and either $2q\gamma \geq 3 - \sqrt{9 - 8q}$ or*

$$\beta\big(\gamma + (1-\gamma)\mu^q\big)\text{NPV}_g + (1-\gamma)\mu^q\text{NPV}_b > 0, \tag{37}$$

where μ^q is as defined in equation (38) below. There is an equilibrium in which a VC behaves as follows. If it is positively informed it provides capital, if it is negatively informed it does not provide capital, and if it is unskilled it provides capital with probability μ^q, where

$$\mu^q = \max\left\{0\,,\,\frac{6-(3+q)\gamma - \sqrt{4+12(1-q)\gamma + (9-10q+q^2)\gamma^2}}{8(1-\gamma)}\right\}. \tag{38}$$

The IPO price p is

$$p = \frac{\beta\big(\gamma + (1-\gamma)\mu^q\big)V_g + (1-\gamma)\mu^q V_b}{\beta\big(\gamma + (1-\gamma)\mu^q\big) + (1-\gamma)\mu^q} \tag{39}$$

and the number of shares issued in the IPO is

$$n' = \frac{\beta\big(\gamma + (1-\gamma)\mu^q\big) + (1-\gamma)\mu^q}{\beta\big(\gamma + (1-\gamma)\mu^q\big)\text{NPV}_g + (1-\gamma)\mu^q\text{NPV}_b} nI. \tag{40}$$

If $2q\gamma > 3 - \sqrt{9-8q}$ and inequality (37) is violated, then a VC does not provide capital to any firm.

As in the career-concerns equilibrium, the skilled VC provides capital if it is positively informed and withholds capital if it is negatively informed and the unskilled VC randomizes. Further, the expression for μ^q in equation (38) reveals that the unskilled VC withholds capital more often than it provides capital, as in the career-concerns equilibrium. In fact, when $q = 0$, the value of the assets in place is always zero, so the equilibrium coincides with the career-concerns equilibrium. However, in the limit when $q = 1$ the assets in place are perfectly correlated with the value of the firm, so the unskilled VC randomizes fifty-fifty between providing capital and withholding capital $\mu^q = 1/2$. This because there is no asymmetric learning in this case—withholding capital does not help the unskilled VC to hide its type. Thus, the unskilled VC randomizes symmetrically in equilibrium. These facts are summarized in the next corollary.

COROLLARY 7. (THE UNSKILLED VC PROVIDES CAPITAL INFREQUENTLY) *The unskilled VC provides capital less than half the time, $\mu^q < 1/2$. Further, the unskilled VC provides capital more frequently when the co-movement between assets in place and firm*

value is high,[16]

$$\frac{\partial \mu^q}{\partial q} \geq 0. \tag{41}$$

Finally, in the limit in which assets in place v_θ are perfectly correlated with firm value V_θ, i.e. $q = 1$, the unskilled VC provides capital exactly half the time $\mu^q = 1/2$.

5.3 Imperfect Signals

In the body of the paper, I assume that the skilled VC has perfect information about the underlying quality of the firm, whereas the unskilled VC observes no information whatsoever. In this subsection, I show that my main results are robust to relaxing this information structure. I.e. the results go through if the VC observes an imperfect signal about the firm's quality, where the skilled VC observes a more precise signal than the unskilled VC does.

I extend the model to include imperfect signals as follows. The skilled VC observes a private signal $\sigma^s \in \{\sigma_b^s, \sigma_g^s\}$ about the underlying value of the firm with precision $\rho^s := \mathbb{P}\left[V_g|\sigma_g^s\right] = \mathbb{P}\left[V_b|\sigma_b^s\right] > 1/2$. Analogously, the unskilled speculator observes a private signal $\sigma^u \in \{\sigma_b^u, \sigma_b^u\}$ about the underlying value of the firm with precision $\rho^u := \mathbb{P}\left[V_g|\sigma_g^u\right] = \mathbb{P}\left[V_b|\sigma_b^u\right] > 1/2$. Assume further that $\rho^s > \rho^u$.

With imperfect signals the profit-motivation equilibrium is effectively the same as it is in the baseline model: the VC plays a pooling equilibrium. It provides capital as long as NPV_g is sufficiently high. The intuition from the baseline analysis carries over: because the VC is profit-motivated, it cares only about the IPO price and if one type of VC wants to provide capital, all types of the VC do.

The career-concerns equilibrium with imperfect signals is analogous to the career-concerns equilibrium in the baseline model, but richer. The skilled VC behaves as it does in the baseline model; it withholds capital when it has negative information and provides capital when it has positive information. The difference between this case and the baseline model is in the behavior of the unskilled VC. It also withholds capital when it has negative information, but when it has positive information it randomizes and withholds capital sometimes, despite its positive information about the underlying firm quality. This is summarized in the next proposition.

Proposition 10. (Equilibrium Characterization with an Imperfectly Informed Career-concerned VC) *Suppose the VC is purely career concerned and the VC's information is imperfect. As long as*

$$\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)\text{NPV}_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)\text{NPV}_b > 0 \tag{42}$$

[16]The inequality in equation (41) is strict for $\mu^q \neq 0$.

there is an equilibrium in which a VC behaves as follows. If it is skilled and negatively informed it withholds capital, if it is skilled and positively informed it provides capital, if it is unskilled and negatively informed it withholds capital, and if it is unskilled and positively informed it provides capital with probability $\bar{\mu} \in (0,1)$*, where* $\bar{\mu}$ *solves equation (A.97) in the Appendix. The IPO price* p *is*

$$p = \frac{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)V_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)V_b}{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big) + \gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}} \tag{43}$$

and the number of shares issued in the IPO is

$$n' = \frac{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big) + \gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}}{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)\mathrm{NPV}_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)\mathrm{NPV}_b} nI. \tag{44}$$

If inequality (42) is violated, then the VC does not provide capital to any firm.

In this equilibrium the unskilled VC provides capital less often than it withholds capital as in the baseline model (Corollary 2), i.e.

$$\begin{aligned}
\mathbb{P}\left[a = 1 \,|\, u\right] &= \mathbb{P}\left[\sigma_g^u\right]\mathbb{P}\left[a = 1 \,|\, u, \sigma_g^u\right] + \mathbb{P}\left[\sigma_b^u\right]\mathbb{P}\left[a = 1 \,|\, u, \sigma_b^u\right] && (45)\\
&= \frac{1}{2} \times \bar{\mu} + \frac{1}{2} \times 0 && (46)\\
&\leq \frac{1}{2}, && (47)
\end{aligned}$$

since $\hat{\mu} \leq 1$. I state this formally as a corollary.

Corollary 8. (The Unskilled VC Provides Capital Infrequently Even with Imperfect Information) *The unskilled VC provides capital less than half the time.*

Since my main results are driven by the fact that the uninformed VC provides capital infrequently, this corollary confirms the robustness of my results to an imperfect signal structure.

5.4 VC's Retention of Shares Post-IPO

In the baseline model, the VC sells its shares at the time of the IPO. This assumption is a reasonable approximation of reality,[17] but it is important to verify that is not the main driver of the results. Hence, in this subsection, I consider the case in which the VC does not exit at the IPO but rather retains a long-term interest in the firm. I show

[17]Real-world VCs exit shortly after the IPO, following a "lock-in period" of a few months, and the long-run value V_θ is unlikely to be realized in that time (see footnote 10 for further discussion).

that for reasonable parameters the main results are qualitatively the same as in the baseline model.

Consider the variation of the model in which if the VC provides capital c it acquires n shares in the firm, as above, but it does not sell these shares at the IPO stage, but rather retains its stake in the firm and receives a fraction of the terminal value V_θ. Thus, the expression for its long-run payoff (equation (2) in the baseline model) is now

$$\Pi^{\tau}_{\text{PM}} = \begin{cases} \dfrac{n}{n+n'} V_\theta - c & \text{if IPO succeeds,} \\ -c & \text{if IPO fails.} \end{cases} \tag{48}$$

The career-concerns portion of the payoff is unchanged, since it does not depend on the VC's monetary profit. Hence, the career concerns equilibrium is as in Proposition 3. The profit motivation-equilibrium changes, however. The main difference between the profit-motivation equilibria here and in the baseline model is the behavior of the skilled negatively informed VC. Since it is exposed to the long-run value of the firm, it does not want to invest in a bad firm and therefore withholds capital. The equilibrium is summarized in the next proposition.

Proposition 11. (Equilibrium Characterization with a Profit-motivated VC that Retains its Shares) *Suppose that firms are on average positive NPV,* $\overline{\text{NPV}} > 0$*, that the VC is purely profit motivated (*$w_{\text{CC}} = 0$*), and that the VC retains its shares after the IPO. If*

$$\frac{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b}{\beta V_g + (1-\gamma)V_b} \left(\frac{1}{2} V_g + \frac{1}{2} V_b \right) \geq c \geq \frac{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b}{\beta V_g + (1-\gamma)V_b} V_b \tag{49}$$

then the skilled positively informed VC and the unskilled VC provide capital, whereas the skilled negatively informed VC does not provide capital. The IPO price is

$$p = \frac{\beta V_g + (1-\gamma)V_b}{\beta + 1 - \gamma}, \tag{50}$$

and the number of shares issued in the IPO is

$$n' = \frac{\beta + 1 - \gamma}{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b} nI. \tag{51}$$

Unlike in the profit-motivation equilibrium in the baseline model, the investment by the profit-motivated VC has a certification effect here. Since the skilled negatively informed VC does not provide capital, the average firm that the VC invests in is good relative to the total population of firms. However, because the unskilled VC always provides capital, this certification effect is relatively weak. This contrasts with the strong certification provided by VC-backing in the career-concerns equilibrium, which

results from the fact that unskilled VCs provide capital relatively rarely ($\mu^* < 1/2$). As a result, the main intuition of the baseline comparison is robust: VC career-concerns decrease IPO discounts, market breakdowns, and post-IPO price volatility. This is summarized in the next proposition.

Proposition 12. (The Benefits of Career Concerns when the VC Retains Post-IPO) *Suppose that firms are on average positive NPV and that the VC retains its shares after the IPO. The analogous statements of Proposition 5, Proposition 6, and Proposition 7 hold. I.e. the following statements hold:*

(i) The IPO price p is higher when the VC is career concerned than when it is profit motivated.

(ii) Market breakdowns are less likely with a career-concerned VC, in the sense that there is a market breakdown with a profit-motivated VC whenever there is a market breakdown with a career-concerned VC.

(iii) Price volatility is lower in the career-concerns equilibrium than in the profit-motivated equilibrium.

6 Empirical Content

In this section, I discuss the empirical content of my model. I argue that my model explains several stylized facts about VCs.

6.1 VCs' Reputation and IPO Success

Nahata (2008) finds that reputable venture capitalists are more likely to lead their companies to successful exits, namely to take their companies to IPO. I suggest that this finding is consistent with my model. In my model, "reputation" corresponds to the probability γ that the VC is skilled—a VC has a high reputation if the market believes it is likely to be informed. The probability of a "successful exit" corresponds to the probability that $\iota = 1$. I can now compute the probability of a successful exit within my model in the career-concerns equilibrium:

$$\mathbb{P}\left[\text{ successful exit}\right] = \gamma \mathbb{P}\left[a = 1 \,|\, s\right] + (1-\gamma)\mathbb{P}\left[a = 1 \,|\, u\right], \tag{52}$$

where

$$\mathbb{P}\left[a = 1 \,|\, s\right] = \mathbb{P}\left[g\right] = 1/2 \tag{53}$$

since the skilled VC provides capital exactly when the asset is good. Further,

$$\mathbb{P}\left[a = 1 \,|\, u\right] = \mu^* \tag{54}$$

since the unskilled VC provides capital exactly with probability μ^*. Thus,

$$\mathbb{P}\left[\text{successful exit}\right] = \frac{\gamma}{2} + (1-\gamma)\mu^* \tag{55}$$

$$= \mu^* + \left(\frac{1}{2} - \mu^*\right)\gamma. \tag{56}$$

This expression is increasing in reputation γ exactly when $\mu^* < 1/2$, which is the case by Corollary 2. This says that the higher is the VC's reputation γ, the more likely is a successful exit, as Nahata (2008) finds empirically.

6.2 VC Reputation and IPO Underpricing

Barry, Muscarella, Peavy, and Vetsuypens (1990) and Megginson and Weiss (1991) compare VC-backed IPOs with non-VC-backed IPOs. They find that the post-IPO returns of VC backed firms are significantly lower than those of non-VC-backed firms; in other words, VC-backed IPOs are less underpriced. If I assume that VCs are career-concerned, then the corresponding prediction in my model is that post-IPO returns are higher in the profit-motivation equilibrium than in the career-concerns equilibrium, or

$$V_\theta - p\big|_{\text{PM}} > V_\theta - p\big|_{\text{CC}}. \tag{57}$$

By Proposition 5, the price is higher when the VC is career concerned than when it is profit motivated. Thus, the IPO discount is always *lower* when the VC is career concerned than when it is profit motivated. This finding that VC's career concerns decrease the IPO discount is consistent with the findings of the papers cited above.

Further, in my model, the IPO discount is decreasing in VC reputation γ. To see this, recall the expression for the IPO price in the career-concerns equilibrium from equation (20) and observe that

$$\frac{\partial p}{\partial \gamma} = \begin{cases} 0 & \text{if } \gamma \geq 2/3 \\ \dfrac{\beta\mu(V_g - V_b)}{\Big(\beta\big(\gamma + (1-\gamma)\mu^*\big) + (1-\gamma)\mu^*\Big)^2} & \text{if } \gamma < 2/3. \end{cases} \tag{58}$$

This is always positive, which is consistent with Gompers's (1996) finding that IPO underpricing is greater for younger VCs, given that younger VCs have had less time to develop a reputation (i.e. assuming that young VCs have a relatively low reputation γ).

6.3 VC Performance and Investor Capital

Lee and Wahal (2004) find that when a VC's profits are higher so are its investor

inflows of capital and Gompers and Lerner (1999) find that higher recent returns lead to greater capital commitments from investors to VCs. This evidence suggested that there is a positive relationship between VC performance and investor capital inflows. This is consistent with my analysis in Subsection 5.1 in which a VC's fee revenue is large after the VC takes a good firm public via an IPO.

6.4 Comparisons among VCs' Contracts

As discussed in Subsection 2.4, a VC's compensation contract typically has two components: the first component is a proportion of delegated capital or a "fixed fee" and the second component is a proportion of the VC's investment profits or a "performance fee." There is substantial heterogeneity among VCs' compensation contracts. Some VCs charge high fixed fees and low performance fees compared to other VCs that charge relatively low fixed fees and high performance fees. A VC that charges a fixed fee but no performance fee can profit only if it can expand the amount of capital it invests on the behalf of investors. In this case, the VC is purely career concerned. In contrast, a VC that charges a performance fee but no fixed fee profits from making good investments. In this case, the VC is profit motivated. My results suggest that, compared to VCs with high performance fees, VCs with high fixed fees should take firms to IPO with less underpricing, and that their IPOs should succeed more often (there should be fewer market breakdowns). Further, the firms they invest in should be less volatile following the IPO. In other words, VCs' contractual form may be a way to proxy for the extent to which VCs are career concerned, thus generating testable cross-sectional predictions. See Dasgupta and Piacentino (2015) for a discussion of how asset managers' contracts affect their behavior in secondary markets.

7 Conclusion

This paper examines the effects of the career concerns of delegated primary market investors, namely venture capitalists. I find that career concerns can improve efficiency, contrary to the findings of the literature on delegated investment in the secondary market. VCs mitigate adverse selection frictions in the IPO market, allowing good firms to raise capital. This is due to a distortion by which unskilled investors randomize between providing capital and withholding capital, akin to portfolio churning in secondary markets. However, there is a feedback effect in primary markets that is not present in secondary markets. When a VC provides seed capital, it allows a firm to undertake an investment that would not have been undertaken otherwise. Hence, outsiders learn more about the quality of a projects when VCs provide capital than when they do not.

In order to prevent outsiders from learning that they are unskilled, uninformed VCs provide capital relatively rarely. As a result, most VC investments are made by skilled VCs with positive private information about the firms they invest in. This generates a certification effect of VC-backing. This certification effect mitigates adverse selection frictions in the IPO market and thus allows more good firms to raise funds and invest, enhancing economic efficiency. In summary, this paper uncovers a new positive side of delegated investors' career concerns that is at work in the primary market.

A Proofs

Proof of Lemma 1

Suppose (in anticipation of a contradiction) that the good firm is able to raise I from informed bidders alone, then the IPO price is

$$p = V_g.$$

Substituting the price above in equation (10), I find that the IPO succeeds only if the money raised from issuing n' new shares exceeds I, or

$$\frac{n'}{n+n'} V_g \geq I \tag{A.1}$$

(since the VC owns the remaining n shares). Thus it must be that

$$n' \geq \frac{nI}{V_g - I}. \tag{A.2}$$

But, by hypothesis, all money is raised from informed bidders, so $n' < n_{\mathrm{I}}$. It follows that

$$n_{\mathrm{I}} \geq \frac{nI}{V_g - I}. \tag{A.3}$$

This contradicts Parameter Restriction 2. We thus conclude that the hypothesis is false: uninformed bidders must subscribe to the IPO in order for it to succeed.

Proof of Lemma 2

It is immediate from equation (7). □

Proof of Lemma 3

It is immediate from equation (10). □

Proof of Lemma 4

The lemma follows immediately from the fact that the payoff of a purely profit-motivated VC does not depend on its type, i.e. a VC's payoff depends only on the IPO price, which is the same for any type of VC. To illustrate this point, I show that there is no strict equilibrium in which a skilled positively informed VC funds a firm and the other types of VC do not fund firms. This argument is identical for any possible equilibrium in which VC types separate. I focus here on strict equilibria. In Proposition 2, I show that all equilibria are strict given a refinement.

VCs do not separate: a deviation. Suppose (in anticipation of a contradiction) an equilibrium in which (i) a positively informed VC provides capital, $a = 1$, (ii) a negatively informed VC does not provide capital, $a = 0$, and (iii) an uninformed VC does not provide capital $a = 0$. Then, uninformed bidders' posterior that the firm is good at the IPO is

$$\mathbb{P}\left[\theta = g | a = 1\right] = 1. \tag{A.4}$$

This is because, only a positively informed VC plays $a = 1$; so, observing $a = 1$ implies that the firm is good. Then, substituting in equation (8), I find that the IPO price is

$$p = V_g, \tag{A.5}$$

and, substituting for the price in equation (12), I find that the number of new shares issued at the IPO is

$$n' = \frac{nI}{V_g - I}. \tag{A.6}$$

Substituting into the definition of Π^s_{PM} in equation (2) gives that the skilled positively informed VC's profits are

$$\Pi^s_{\text{PM}} = \frac{n}{n+n'}p - c = \frac{n}{n+n'}V_g - c = V_g - I - c. \tag{A.7}$$

Since, by hypothesis, the skilled positively informed VC strictly prefers to provide c, the expression above is strictly positive.

Now observe that the unskilled VC strictly prefers to provide capital to a firm. The unskilled VC has a profitable deviation: it invests c in a firm of average quality and in so doing it gets payoff

$$\Pi^u_{\text{PM}} = \frac{n}{n+n'}V_g - c = V_g - I - c = \Pi^s_{\text{PM}}. \tag{A.8}$$

Thus, I have shown by contradiction that there is no equilibrium in which any VC strictly prefers to separate. □

Proof of Proposition 1

Since by Lemma 4 all types of VC pool in equilibrium, there are two candidates for equilibria: (i) all types of VC provide c and (ii) all types of VC do not. I characterize the parameters under which each type of equilibrium exists.

(i) All types of VC provide capital. Assume an equilibrium in which all types of VC provide c. This is an equilibrium as long as all types of VC are making positive profits. This is true whenever

$$\frac{n}{n+n'}p - c \geq 0 \tag{A.9}$$

or

$$p - I - c \geq 0, \tag{A.10}$$

having substituted for $n' = nI/(p-I)$ from equation (12). Since all types of VC pool in equilibrium, the posterior probability that a firm is good equals the prior probability that a firm is good, which is $1/2$. Substituting this into the expression for p in equation (8), we can rewrite equation (A.10) and obtain the following necessary and sufficient condition for funding to be a pooling equilibrium action:

$$\frac{\beta V_g + V_b}{\beta + 1} \geq I + c \tag{A.11}$$

or

$$\beta\big(\text{NPV}_g - c\big) + \text{NPV}_b - c > 0. \tag{A.12}$$

This is condition (13) in the statement of Proposition 1.

(ii) No type of VC provide capital. Here I construct an equilibrium in which no type of VC provides capital. Suppose that there is an equilibrium in which no type of VC provides capital. Providing capital is an off-equilibrium action, so I must specify out-of-equilibrium beliefs. Suppose that the market believes that a funded firm is of average quality, so $\mathbb{P}\left[g \,|\, a = 1\right] = 1/2$. Thus, the payoff from providing capital to a firm is exactly as above, and is given by $p - I - c$, as in equation (A.10). Following a derivation analogous to that of equation (A.12) above, we find that this expression is negative whenever

$$\beta\big(\text{NPV}_g - c\big) + \text{NPV}_b - c < 0. \tag{A.13}$$

Thus, whenever this inequality is satisfied, there is an equilibrium in which no type of VC provides capital. □

Proof of Corollary 1

Follows immediately from Proposition 1. When inequality (13) is not satisfied, there is a market breakdown with a profit-motivated VC. □

Proof of Lemma 5

As established in the proof of Lemma 4, if any type of VC is indifferent between playing $a = 1$ and $a = 0$, then all types of VC are indifferent. In Proposition 1, I found all equilibria in which the VC is not indifferent. Here, I characterize all equilibria in which the VC is indifferent.

The VC's indifference condition is

$$\frac{n}{n+n'}p - c = 0, \tag{A.14}$$

which says that the VC's profit from providing capital is zero. Substituting in for n' form equation (12) gives

$$p - I - c = 0. \tag{A.15}$$

Using the expression for the IPO price in equation (8) gives the following expression for p above, in terms of μ_+, μ_-, and μ:

$$p = \frac{\beta\big(\gamma\mu_+ + (1-\gamma)\mu\big)V_g + \big(\gamma\mu_- + (1-\gamma)\mu\big)V_b}{\beta\big(\gamma\mu_+ + (1-\gamma)\mu\big) + \gamma\mu_- + (1-\gamma)\mu}, \tag{A.16}$$

Now, substituting for p in equation (A.15), I find that all types of VC are indifferent if

$$\beta\big(\gamma\mu_+ + (1-\gamma)\mu\big)(\text{NPV}_g - c) + \big(\gamma\mu_- + (1-\gamma)\mu\big)(\text{NPV}_b - c) = 0. \tag{A.17}$$

Thus, for any mixing probabilities (i.e. numbers between zero and one), μ_-, μ_+, and μ that solve this equation, there is an equilibrium in which all types of VC are indifferent between $a = 0$ or $a = 1$. □

Proof of Proposition 2

I prove the statement by contradiction. I suppose that there is a weak profit-motivation equilibrium of the form stated in Lemma 5 and that $\epsilon > 0$. I show that it cannot be that both the positively informed VC and the negatively informed VC are indifferent between $a = 0$ and $a = 1$, contradicting the fact that if one type of VC is indifferent then all types of VC must be indifferent.

Now suppose (in anticipation of a contradiction) an equilibrium in which the VC is indifferent between $a = 0$ and $a = 1$. The indifference condition of the positively informed VC is

$$(1-\epsilon)\frac{n}{n+n'}p + \epsilon\,\text{NPV}_g - c = 0, \tag{A.18}$$

and the indifference condition of the negatively informed VC is

$$(1-\epsilon)\frac{n}{n+n'}p+\epsilon\,\mathrm{NPV}_b-c=0, \tag{A.19}$$

no matter how small $\epsilon>0$, equations (A.18) and (A.19) imply that

$$\mathrm{NPV}_g=\mathrm{NPV}_b, \tag{A.20}$$

a contradiction. □

Proof of Proposition 3

In this proof, I proceed by the usual conjecture-and-verify method of finding Perfect Bayesian Equilibria. I conjecture an equilibrium in which (i) the positively informed VC provides capital, (ii) the negatively informed VC does not provide capital, and (iii) the unskilled VC funds firms with probability μ. Further, whenever funding occurs, the IPO succeeds and the firm invests.

Beliefs. The market observes the VC's action a and, if the IPO succeeds, it also observes the the long-run realized value of the firm V_θ. Given this information it updates its beliefs about the VC's type. The application of Bayes's rule gives the following posterior beliefs about the VC's type:

$$\mathbb{P}\left[s\,|\,\iota V_\theta,a\right]=\begin{cases}0 & \text{if } V_\theta=V_b \text{ and } a=1,\\ \dfrac{\gamma}{\gamma+2(1-\gamma)(1-\mu)} & \text{if } a=0,\\ \dfrac{\gamma}{\gamma+(1-\gamma)\mu} & \text{if } V_\theta=V_g \text{ and } a=1.\end{cases}$$

Unskilled VC. If the unskilled VC provides capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=1)\right]=\frac{1}{2}\left[\frac{\gamma}{\gamma+(1-\gamma)\mu}\right]. \tag{A.21}$$

This is because, when the VC provides c, the IPO succeeds, and the firm value is realized. The firm can be good or bad. The firm is bad with probability 1/2, in which case the VC reveals that it is unskilled and earns nothing. With probability 1/2 the firm is good and the unskilled VC pools with the skilled VC.

If the unskilled VC does not provide capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=0)\right]=\frac{\gamma}{\gamma+2(1-\gamma)(1-\mu)}. \tag{A.22}$$

This is because, when it does not provide capital, the firm value is not realized, and the

market can only make inferences about the VC's type by observing the VC's action.

I now consider three possible cases: (i) the unskilled VC always provides capital, $\mu = 1$, (ii) the unskilled VC never provides capital, $\mu = 0$, and (iii) the unskilled VC provides capital with probability $\mu \in (0, 1)$.

(i) The unskilled VC always provides capital. $\mu^* = 1$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a = 1)\right] > \mathbb{E}\left[\Pi^u_{\text{CC}}(a = 0)\right], \tag{A.23}$$

when $\mu^* = 1$. This reduces to

$$\frac{\gamma}{2} > 1, \tag{A.24}$$

which is never satisfied. Thus, it must be that $\mu^* < 1$.

(ii) The unskilled VC never provides capital. $\mu^* = 0$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a = 1)\right] < \mathbb{E}\left[\Pi^u_{\text{CC}}(a = 0)\right], \tag{A.25}$$

when $\mu^* = 0$. This reduces to

$$\gamma > \frac{2}{3}. \tag{A.26}$$

Thus, $\mu^* = 0$ if and only if $\gamma > 2/3$.

(iii) The unskilled VC provides capital with probability $\mu \in (0, 1)$. $\mu^* \in (0, 1)$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a = 1)\right] = \mathbb{E}\left[\Pi^u_{\text{CC}}(a = 0)\right]. \tag{A.27}$$

This reduces to

$$\mu^* = \frac{2 - 3\gamma}{4(1 - \gamma)}. \tag{A.28}$$

Thus, there is an interior equilibrium with μ^* as given in equation (A.28) whenever $\gamma \in [0, 2/3)$.

Skilled VC. I must show that the skilled VC has no profitable deviation from not providing capital to a bad firm and providing capital to a good firm. The payoff of a positively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a = 1, \theta = g)\right] = \frac{\gamma}{\gamma + (1 - \gamma)\mu^*} \tag{A.29}$$

if it provides capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a = 0, \theta = g)\right] = \frac{\gamma}{\gamma + 2(1 - \gamma)(1 - \mu^*)} \tag{A.30}$$

if it does not provide capital. The positively informed VC provides capital if

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a = 1, \theta = g)\right] > \mathbb{E}\left[\Pi^s_{\text{CC}}(a = 0, \theta = g)\right]. \tag{A.31}$$

This inequality reduces to $\mu^* < 2/3$, which is the case in equilibrium as established above.

The payoff of a negatively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=b)\right] = \frac{\gamma}{\gamma + 2(1-\gamma)(1-\mu^*)} \tag{A.32}$$

if it does not provide capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=b)\right] = 0 \tag{A.33}$$

if it does provide capital. The negatively informed VC does not provide capital if $\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=g)\right] > \mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=g)\right]$. This inequality is always satisfied.

IPO Price. Substituting in equation (8), we find that the IPO price is

$$p = \frac{\beta\big(\gamma + (1-\gamma)\mu^*\big)V_g + (1-\gamma)\mu^* V_b}{\beta\big(\gamma + (1-\gamma)\mu^*\big) + (1-\gamma)\mu^*} \tag{A.34}$$

and the number of new shares issued is

$$n' = \frac{\beta\big(\gamma + (1-\gamma)\mu^*\big) + (1-\gamma)\mu^*}{\beta\big(\gamma + (1-\gamma)\mu^*\big)\text{NPV}_g + (1-\gamma)\mu^*\text{NPV}_b} nI. \tag{A.35}$$

The IPO succeeds if condition (11) is satisfied or

$$\frac{\beta\big(\gamma + (1-\gamma)\mu^*\big)\text{NPV}_g + (1-\gamma)\mu^*\text{NPV}_b}{\beta\big(\gamma + (1-\gamma)\mu^*\big) + (1-\gamma)\mu^*} > 0. \tag{A.36}$$

There are now two cases to be considered: (i) $\gamma \geq 2/3$, so $\mu^* = 0$ and (ii) $\gamma < 2/3$, so $\mu^* = (2-3\gamma)/(4(1-\gamma))$.

In case (i), inequality (A.36) is always satisfied; in fact, the inequality re-writes as

$$\text{NPV}_g \geq 0, \tag{A.37}$$

which is always satisfied by Parameter Restriction 1.

In case (ii), inequality (A.36) is satisfied whenever

$$\beta(2+\gamma)\text{NPV}_g + (2-3\gamma)\text{NPV}_b > 0. \tag{A.38}$$

This is the condition given in the statement of the proposition (Proposition 3). □

Proof of Corollary 3

Follows immediately from Proposition 3. When inequality (18) is not satisfied, there is a market breakdown with a career-concerned VC. □

Proof of Proposition 4

First observe that there is no equilibrium in which all (strategic) types of VC play $a = 0$ or $a = 1$. This is because there is always a proportion $\eta/2$ of skilled behavioral types playing the other action. As a result, in any such pooling equilibrium, the VC has incentive to deviate to the other action and pool with these behavioral types, since it will be believed to be skilled.

Now I must show that there can be no non-perverse equilibrium in which the skilled negatively informed VC provides capital and the skilled positively informed VC withholds capital.[18] I prove that this cannot be the case by contradiction.

Suppose a non-perverse equilibrium in which the skilled negatively informed VC provides capital and the skilled positively informed VC withholds capital. Thus the following two conditions must be satisfied:

1. The skilled negatively informed VC (weakly) prefers to play $a = 1$.
2. The skilled positively informed VC (weakly) prefers to play $a = 0$.

Substituting for the career-concerned VC's payoff, we can express these conditions as follows:

$$\delta \mathbb{P}\left[s \,|\, a = 1, V_b\right] + (1-\delta)\mathbb{P}\left[s \,|\, a = 1, \iota V_b\right] \geq \mathbb{P}\left[s \,|\, a = 0\right] \tag{A.39}$$

and

$$\mathbb{P}\left[s \,|\, a = 0\right] \geq \delta \mathbb{P}\left[s \,|\, a = 1, V_g\right] + (1-\delta)\mathbb{P}\left[s \,|\, a = 1, \iota V_g\right]. \tag{A.40}$$

Combining these inequalities implies that

$$\delta \mathbb{P}\left[s \,|\, a = 1, V_b\right] + (1-\delta)\mathbb{P}\left[s \,|\, a = 1, \iota V_b\right] \geq \delta \mathbb{P}\left[s \,|\, a = 1, V_g\right] + (1-\delta)\mathbb{P}\left[s \,|\, a = 1, \iota V_g\right]. \tag{A.41}$$

There are two cases to consider, $\iota = 0$ and $\iota = 1$. If $\iota = 0$, $\mathbb{P}\left[s \,|\, a = 0, \iota V_g\right] = \mathbb{P}\left[s \,|\, a = 0, \iota V_b\right]$ so we have that

$$\mathbb{P}\left[s \,|\, a = 1, V_b\right] \geq \mathbb{P}\left[s \,|\, a = 1, V_g\right], \tag{A.42}$$

implying that if $\iota = 0$ the equilibrium must be perverse. Thus, it must be that $\iota = 1$.

[18] This includes mixed strategies. Formally: there can be no equilibrium in which both (i) the skilled negatively informed VC plays $a = 1$ with positive probability and (ii) the skilled positively informed VC plays $a = 0$ with positive probability.

But in this case the inequality above reads

$$\delta\mathbb{P}\left[s \,|\, a=1, V_b\right] + (1-\delta)\mathbb{P}\left[s \,|\, a=1, V_b\right] \geq \delta\mathbb{P}\left[s \,|\, a=1, V_g\right] + (1-\delta)\mathbb{P}\left[s \,|\, a=1, V_g\right] \tag{A.43}$$

or

$$\mathbb{P}\left[s \,|\, a=1, V_b\right] \geq \mathbb{P}\left[s \,|\, a=1, V_g\right]. \tag{A.44}$$

Again, this implies the equilibrium is perverse. This contradicts the hypothesis. Thus, in all reasonable non-perverse equilibria the skilled positively informed VC plays $a=1$ and the skilled negatively informed VC plays $a=0$. □

Proof of Proposition 5

Comparing the price when a profit-motivated VC provides capital in equality (14) with the price when a career-concerned VC provides capital in equality (20), we find that

$$p_{\big|\text{CC}} - p_{\big|\text{PM}} > 0 \tag{A.45}$$

whenever $\mu^* = 1$. In fact, when $\mu^* = 1$,

$$p_{\big|\text{CC}} - p_{\big|\text{PM}} = \frac{\beta V_g + (1-\gamma)V_b}{\beta + 1 - \gamma} - \frac{\beta V_g + V_b}{\beta + 1} > 0. \tag{A.46}$$

This inequality simplifies to

$$\frac{\gamma\beta(V_g - V_b)}{(\beta + 1 - \gamma)(1+\beta)} > 0, \tag{A.47}$$

which is also always satisfied since $V_g > V_b$ by Parameter Restriction 1. Since $p_{|\text{CC}}$ is decreasing in μ by Corollary 4, and $p_{|\text{PM}}$ does not depend on μ, the difference $p_{|\text{CC}} - p_{|\text{PM}}$ is increasing in μ. In other words, inequality (A.45) is hardest to satisfy when $\mu = 1$. Thus, since it is satisfied when $\mu = 1$, it is always satisfied. □

Proof of Corollary 4

Equation (20) gives the IPO price in the career-concerns equilibrium. Then, I can compute

$$\frac{\partial p}{\partial \mu} = -\frac{\beta\gamma(1-\gamma)(V_g - V_b)}{\big(\beta\big(\gamma + (1-\gamma)\mu\big) + (1-\gamma)\mu\big)^2}, \tag{A.48}$$

which is negative since $V_g > V_b$ by Parameter Restriction 1. □

Proof of Proposition 6

If VCs are profit motivated there is a market breakdown whenever inequality (16) is satisfied, or if

$$\tau_{\text{PM}} := \beta\text{NPV}_g + \text{NPV}_b - (1+\beta)c < 0; \tag{A.49}$$

if they are career-concerned, there is a market breakdown whenever inequality (22) is satisfied, or

$$\tau_{\text{CC}} := \beta(2+\gamma)\text{NPV}_g + (2-3\gamma)\text{NPV}_b < 0. \tag{A.50}$$

In order to prove the proposition, I need to show that $\tau_{\text{CC}} < 0$ implies $\tau_{\text{PM}} < 0$. Suppose (in anticipation of a contradiction) that $\tau_{\text{CC}} < 0$ does not imply that $\tau_{\text{PM}} < 0$. This is equivalent to supposing that $\tau_{\text{CC}} < 0$ and $\tau_{\text{PM}} > 0$. Now, $\tau_{\text{CC}} < 0$ if and only if

$$\beta\text{NPV}_g + \text{NPV}_b < \frac{\gamma}{2}\big(3\text{NPV}_b - \beta\text{NPV}_g\big). \tag{A.51}$$

Since the right-hand side above is negative because $\text{NPV}_b < 0$ (Parameter Restriction 1), this implies that

$$\beta\text{NPV}_g + \text{NPV}_b < 0. \tag{A.52}$$

However, the hypothesis that $\tau_{\text{PM}} > 0$ is equivalent to

$$\beta\text{NPV}_g + \text{NPV}_b > (1+\beta)c, \tag{A.53}$$

which, since $c > 0$, implies that

$$\beta\text{NPV}_g + \text{NPV}_b > 0, \tag{A.54}$$

contradicting inequality (A.52). □

Proof of Corollary 5

This is immediate from Corollary 4 by which p is decreasing in μ. In fact, the lower is μ, the higher is p and the easier it is to satisfy the condition for the IPO to be succesful (inequality (11)). □

Proof of Proposition 7

We first compute the conditional variance. The firm value can be expressed as

$$V_\theta = V_b + \mathbb{1}_{\{\theta=g\}}\big(V_g - V_b\big). \tag{A.55}$$

Thus

$$\begin{aligned}\text{Var}\left[V_\theta \,\middle|\, \iota = 1\right] &= \left(V_g - V_b\right)^2 \text{Var}\left[\mathbb{1}_{\{\theta=g\}} \,\middle|\, \iota = 1\right] &\text{(A.56)}\\ &= \left(V_g - V_b\right)^2 \mathbb{P}\left[V_\theta = V_g \,\middle|\, \iota = 1\right] \mathbb{P}\left[V_\theta = V_b \,\middle|\, \iota = 1\right], &\text{(A.57)}\end{aligned}$$

by the formula for the variance of a Bernoulli variable.

We now apply this formula to the equilibrium probabilities in the profit-motivation equilibrium and the career-concerns equilibrium. In the profit-motivation equilibrium $\mathbb{P}\left[V_\theta = V_g \,\middle|\, \iota = 1\right] = 1/2$, so we have

$$\text{Var}\left[V_\theta \,|\, \iota = 1\right]\Big|_{\text{PM}} = \frac{1}{4}(V_g^2 - V_b^2). \tag{A.58}$$

And in the career-concerns equilibrium

$$\mathbb{P}\left[V_\theta = V_g \,\middle|\, \iota = 1\right] = \frac{\gamma + (1-\gamma)\mu^*}{\gamma + 2(1-\gamma)\mu^*}, \tag{A.59}$$

so we have

$$\text{Var}\left[V_\theta \,|\, \iota = 1\right]\Big|_{\text{CC}} = \frac{\left(\gamma + (1-\gamma)\mu^*\right)(1-\gamma)\mu^*}{\left(\gamma + 2(1-\gamma)\mu^*\right)^2}(V_g^2 - V_b^2). \tag{A.60}$$

We can now write the condition for the variance to be greater in the profit-motivation equilibrium than in the career-concerns equilibrium:

$$\text{Var}\left[V_\theta \,|\, \iota = 1\right]\Big|_{\text{CC}} < \text{Var}\left[V_\theta \,|\, \iota = 1\right]\Big|_{\text{PM}} \tag{A.61}$$

or

$$\frac{\left(\gamma + (1-\gamma)\mu^*\right)(1-\gamma)\mu^*}{\left(\gamma + 2(1-\gamma)\mu^*\right)^2} < \frac{1}{4}. \tag{A.62}$$

This reduces to

$$\frac{\gamma^2}{4\left(\gamma + 2(1-\gamma)\mu^*\right)^2} > 0 \tag{A.63}$$

which is always satisfied. □

Proof of Corollary 6

The LHS of equation (A.62) gives the variance in the career-concerns equilibrium. Then, I can compute

$$\frac{\partial}{\partial \mu}\text{Var}\left[V_\theta \,|\, \iota = 1\right]\Big|_{\text{CC}} = -\frac{\gamma\mu}{\left(\gamma + 2(1-\gamma)\mu\right)^3} < 0 \tag{A.64}$$

which is negative. □

Proof of Proposition 8

Let us consider the case in which inequalities (13) and (18) are satisfied and there is an IPO both when a VC is career concerned and when it is profit motivated (Proposition 1 and Proposition 3). In this case, the expected welfare when the VC is profit motivated is

$$\mathbb{E}\left[W_{\mathrm{PM}}\right] = \frac{1}{2}\Big(\mathrm{NPV}_g - c\Big) + \frac{1}{2}\Big(\mathrm{NPV}_b - c\Big); \tag{A.65}$$

and the expected welfare when it is career concerned is

$$\mathbb{E}\left[W_{\mathrm{CC}}\right] = \frac{1}{2}\Big(\gamma + (1-\gamma)\mu^*\Big)\Big(\mathrm{NPV}_g - c\Big) + \frac{1}{2}(1-\gamma)\mu^*\Big(\mathrm{NPV}_b - c\Big). \tag{A.66}$$

Welfare is strictly higher when the VC is career concerned if $\mathbb{E}\left[W_{\mathrm{CC}}\right] > \mathbb{E}\left[W_{\mathrm{PM}}\right]$, or, substituting, if

$$\gamma\mathrm{NPV}_g + 2\mu^*(1-\gamma)\Big(\overline{\mathrm{NPV}} - c\Big) > 2\overline{\mathrm{NPV}} - (2-\gamma)c. \tag{A.67}$$

□

Proof of Proposition 9

The proof of the proposition is analogous to that of Proposition 3 of the characterization of the career-concerns equilibrium. The only real difference is that with probably q the type of the VC is revealed even if the firm does not receive capital.

Beliefs. The market updates its beliefs given what is publicly observable. If the firm receives funding from the VC, or $a = 1$, then the market observes V_θ. If the firm does not receive funding from the VC, or $a = 0$, then the market observes the value of the assets in place v_θ if the firm continues, or $\chi = 1$. Otherwise it observes nothing about the quality of the firm. Applying Bayes rule gives the following expression for the market's beliefs:

$$\mathbb{P}\left[s \mid \iota V_\theta, a, (1-\iota)\chi v_\theta\right] = \begin{cases} 0 & \text{if } V_\theta = V_b \text{ and } a = 1, \\ 0 & \text{if } \chi = 1,\ v_\theta = v_g, \text{ and } a = 0, \\ \dfrac{\gamma}{\gamma + 2(1-\gamma)(1-\mu)} & \text{if } \chi = 0 \text{ and } a = 0, \\ \dfrac{\gamma}{\gamma + (1-\gamma)(1-\mu)} & \text{if } \chi = 1,\ v_\theta = v_b, \text{ and } a = 0, \\ \dfrac{\gamma}{\gamma + (1-\gamma)\mu} & \text{if } V_\theta = V_g \text{ and } a = 1. \end{cases}$$

Unskilled VC. If the unskilled VC provides capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=1)\right] = \frac{1}{2}\left[\frac{\gamma}{\gamma+(1-\gamma)\mu}\right]. \tag{A.68}$$

If the unskilled VC does not provide capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=0)\right] = (1-q)\frac{\gamma}{\gamma+2(1-\gamma)(1-\mu)} + \frac{1}{2}q\frac{\gamma}{\gamma+(1-\gamma)(1-\mu)}. \tag{A.69}$$

I now consider three possible cases: (i) the unskilled VC always provides capital, $\mu = 1$, (ii) the unskilled VC never provides capital, $\mu = 0$, and (iii) the unskilled VC provides capital with probability $\mu \in (0,1)$.

(i) The unskilled VC always provides capital. $\mu^q = 1$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=1)\right] > \mathbb{E}\left[\Pi^u_{\text{CC}}(a=0)\right], \tag{A.70}$$

when $\mu^q = 1$. This reduces to

$$q + \gamma > 2, \tag{A.71}$$

which is never satisfied. Thus, it must be that $\mu^q < 1$.

(ii) The unskilled VC never provides capital. $\mu^q = 0$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=1)\right] < \mathbb{E}\left[\Pi^u_{\text{CC}}(a=0)\right], \tag{A.72}$$

when $\mu^q = 0$. This reduces to

$$2 - 3\gamma + q\gamma^2 < 0. \tag{A.73}$$

Solving the quadratic equation above, this implies that $\mu^q = 0$ if and only if

$$\gamma > \gamma^q := \frac{3-\sqrt{9-8q}}{2q}. \tag{A.74}$$

(iii) The unskilled VC provides capital with probability $\mu^q \in (0,1)$. $\mu^q \in (0,1)$ is an equilibrium if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=1)\right] = \mathbb{E}\left[\Pi^u_{\text{CC}}(a=0)\right]. \tag{A.75}$$

This reduces to

$$\mu^q = \frac{6-(3+q)\gamma-\sqrt{4+12(1-q)\gamma+(9-10q+q^2)\gamma^2}}{8(1-\gamma)}. \tag{A.76}$$

Thus, there is an interior equilibrium with μ^q as given in equation (A.76) whenever $\gamma \in [0, \gamma^q)$, where γ^q is as defined in equation (A.74) above.

Skilled VC. I must show that the skilled VC has no profitable deviation from not

providing capital to a bad firm and providing capital to a good firm. The payoff of a positively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=g)\right] = \frac{\gamma}{\gamma+(1-\gamma)\mu^q} \tag{A.77}$$

if it provides capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=g)\right] = (1-q)\frac{\gamma}{\gamma+2(1-\gamma)(1-\mu^q)} \tag{A.78}$$

if it does not provide capital.

The positively informed VC provides capital if $\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=g)\right] > \mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=g)\right]$. This inequality reduces to

$$\mu^q < \frac{2(1-\gamma)+q\gamma}{(1-\gamma)(3-q)}. \tag{A.79}$$

The LHS of the inequality is increasing in q and it is equal to $2/3$ when $q=0$. Since $\mu^q < 1/2$ as established by Corollary 7, the inequality above is always satisfied.

The payoff of a negatively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=b)\right] = (1-q)\frac{\gamma}{\gamma+2(1-\gamma)(1-\mu^q)} + q\frac{\gamma}{\gamma+(1-\gamma)(1-\mu^q)} \tag{A.80}$$

if it does not provide capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=b)\right] = 0 \tag{A.81}$$

if it does provide capital. The negatively informed VC does not provide capital if $\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\theta=g)\right] > \mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\theta=g)\right]$. This inequality is always satisfied.

IPO Price. Substituting in equation (8), we find that the IPO price is

$$p = \frac{\beta\big(\gamma+(1-\gamma)\mu^q\big)V_g + (1-\gamma)\mu^q V_b}{\beta\big(\gamma+(1-\gamma)\mu^q\big)+(1-\gamma)\mu^q}. \tag{A.82}$$

The IPO succeeds if condition (11) is satisfied or

$$\frac{\beta\big(\gamma+(1-\gamma)\mu^q\big)\text{NPV}_g + (1-\gamma)\mu^q\text{NPV}_b}{\beta\big(\gamma+(1-\gamma)\mu^q\big)+(1-\gamma)\mu^q} > 0. \tag{A.83}$$

There are now two case to be considered: (i) $\gamma \geq \gamma^q$, so $\mu^q = 0$ and (ii) $\gamma < \gamma^q$, so μ^q is as in equation (A.76).

In case (i), inequality (A.83) is always satisfied; in fact, the inequality above rewrites as

$$\text{NPV}_g > 0, \tag{A.84}$$

which is always satisfied by Parameter Restriction 1. In this case, the IPO price is

$$p = V_g \tag{A.85}$$

and the number of new shares issued

$$n' = \frac{nI}{\text{NPV}_g}. \tag{A.86}$$

In case (ii), inequality (A.83) is satisfied whenever

$$\beta\big(\gamma + (1-\gamma)\mu^q\big)\text{NPV}_g + (1-\gamma)\mu^q\text{NPV}_b > 0. \tag{A.87}$$

This is the condition given in the statement of the proposition (Proposition 9). In this case, the IPO price is

$$p = \frac{\beta\big(\gamma + (1-\gamma)\mu^q\big)V_g + (1-\gamma)\mu^q V_b}{\beta\big(\gamma + (1-\gamma)\mu^q\big) + (1-\gamma)\mu^q} \tag{A.88}$$

and the number of new shares issued

$$n' = \frac{\beta\big(\gamma + (1-\gamma)\mu^q\big) + (1-\gamma)\mu^q}{\beta\big(\gamma + (1-\gamma)\mu^q\big)\text{NPV}_g + (1-\gamma)\mu^q\text{NPV}_b} nI. \tag{A.89}$$

□

Proof of Corollary 7

From equation (38) I can compute

$$\frac{\partial \mu^q}{\partial q} = \begin{cases} 0 & \text{if } \gamma \geq \frac{3-\sqrt{9-8q}}{2q} \\ \dfrac{\gamma}{8(1-\gamma)}\left[-1 + \dfrac{6+(5-q)\gamma}{\sqrt{4+12(1-q)\gamma+(9-10q+q^2)\gamma^2}}\right] & \text{if } \gamma < \frac{3-\sqrt{9-8q}}{2q}. \end{cases} \tag{A.90}$$

Thus,

$$\frac{\partial \mu^q}{\partial q} \geq 0 \tag{A.91}$$

if

$$\frac{6+(5-q)\gamma}{\sqrt{4+12(1-q)\gamma+(9-10q+q^2)\gamma^2}} \geq 1 \tag{A.92}$$

or if

$$16(2+3\gamma+\gamma^2) \geq 0, \tag{A.93}$$

which is always satisfied. So μ^q will be the largest when $q = 1$. Substituting $q = 1$ in

the equation for μ^q (equation (38)), I find that it is equal to 1/2. Thus, $\mu^q < 1/2$ for all $q < 1$. □

Proof of Proposition 10

The proof is similar to that of Proposition 3. Here I present only the points of departure from such proof.

Beliefs. The investor's posteriors are as follows:

$$\mathbb{P}\left[\mathrm{S} \mid \iota V_\theta, a, y\right] \begin{cases} = \dfrac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}} & \text{if } V_\theta = V_b \text{ and } a = 1 \\ = \dfrac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})} & \text{if } a = 0, \\ = \dfrac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}} & \text{if } V_\theta = V_g \text{ and } a = 1. \end{cases}$$

Unskilled VC. Conditional on observing a positive signal the unskilled VC mixes with probability $\bar{\mu}$ if it is indifferent between withholding capital and investing. If the unskilled VC does not provide capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=0, \sigma^u = \sigma^u_g)\right] = \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})}. \tag{A.94}$$

If the unskilled VC provides capital its payoff is

$$\mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=1, \sigma^u = \sigma^u_g)\right] = \rho^u\frac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}} + (1-\rho^u)\frac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}}. \tag{A.95}$$

He mixes if

$$f(\bar{\mu}) := \mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=1)\right] - \mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=0)\right] = 0 \tag{A.96}$$

or

$$\rho^u\frac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}} + (1-\rho^u)\frac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}} - \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})} = 0. \tag{A.97}$$

In equilibrium, $\bar{\mu}(\gamma) \in (0,1)$. In fact, $\bar{\mu}(\gamma) \in (0,1)$ by the intermediate value theorem when one considers that $\gamma \in (0,1)$ and f is continuous in μ, as well as $f(\bar{\mu}=0) > 0$ and $f(\bar{\mu}=1) < 1$.

Conditional on observing a negative signal, the unskilled VC's payoff from withholding capital is

$$\mathbb{E}\left[\Pi^u_{\mathrm{CC}}(a=0, \sigma^u = \sigma^u_b)\right] = \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})}. \tag{A.98}$$

It would deviate and provide capital if

$$g(\bar{\mu}) := \mathbb{E}\left[\Pi^u_{\text{CC}}(a=1,\sigma^u=\sigma^u_b)\right] - \mathbb{E}\left[\Pi^u_{\text{CC}}(a=0,\sigma^u=\sigma^u_b)\right] > 0 \tag{A.99}$$

or

$$\rho^u \frac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}} + (1-\rho^u)\frac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}} - \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})} > 0. \tag{A.100}$$

But this cannot be the case: since $\rho^s > \rho^u > 1/2$, $f > g$ and since $\bar{\mu}$ is such that $f(\bar{\mu}) = 0$, it follows that $g(\bar{\mu}) < 0$. This just says that if the unskilled with a positive signal is indifferent between providing and withholding capital, then the unskilled with the negative signal must strictly prefer to withhold capital.

Skilled VC. I must show that the skilled VC has no profitable deviation from not providing capital after observing a bad signal and providing capital after observing a good signal. The payoff of a positively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\sigma^s=\sigma^s_g)\right] = \rho^s\frac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}} + (1-\rho^s)\frac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}} \tag{A.101}$$

if it provides capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_g)\right] = \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})} \tag{A.102}$$

if it does not provide capital. A positively informed VC does not have a profitable deviation if

$$\hat{f}(\bar{\mu}) = \mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\sigma^s=\sigma^s_g)\right] - \mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_g)\right] > 0. \tag{A.103}$$

This inequality holds since $\bar{\mu}$ is such that $f(\bar{\mu}) = 0$ and $\hat{f}(\bar{\mu}) > f(\bar{\mu})$ because $\rho^s > \rho^u$.

The payoff of a negatively informed VC is

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\sigma^s=\sigma^s_b)\right] = \rho^s\frac{\gamma(1-\rho^s)}{\gamma(1-\rho^s)+(1-\gamma)(1-\rho^u)\bar{\mu}} + (1-\rho^s)\frac{\gamma\rho^s}{\gamma\rho^s+(1-\gamma)\rho^u\bar{\mu}}, \tag{A.104}$$

if it provides capital and

$$\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_b)\right] = \frac{\gamma}{\gamma+(1-\gamma)(2-\bar{\mu})} \tag{A.105}$$

if it does not provide capital. A negatively informed VC has a profitable deviation if

$$\hat{g}(\bar{\mu}) = \mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\sigma^s=\sigma^s_b)\right] - \mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_b)\right] > 0 \tag{A.106}$$

This inequality is violated. First recall that $g < 0$. Since $\mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_b)\right] = \mathbb{E}\left[\Pi^u_{\text{CC}}(a=0,\sigma^u=\sigma^u_b)\right]$, then I can rewrite g as

$$g(\bar{\mu}) = \mathbb{E}\left[\Pi^u_{\text{CC}}(a=1,\sigma^s=\sigma^s_b)\right] - \mathbb{E}\left[\Pi^s_{\text{CC}}(a=0,\sigma^s=\sigma^s_b)\right] < 0. \tag{A.107}$$

It follows that $\hat{g} < 0$ if

$$\mathbb{E}\left[\Pi^u_{\text{CC}}(a=1,\sigma^u=\sigma^u_b)\right] > \mathbb{E}\left[\Pi^s_{\text{CC}}(a=1,\sigma^s=\sigma^s_b)\right]. \tag{A.108}$$

This is true since $\rho^s > \rho^u > 1/2$.

IPO Price. Substituting in equation (8), we find that the IPO price is

$$p = \frac{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)V_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)V_b}{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big) + \gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}}. \tag{A.109}$$

The IPO succeeds if condition (11) is satisfied or

$$\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)\text{NPV}_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)\text{NPV}_b > 0. \tag{A.110}$$

The number of new shares issued is

$$n' = \frac{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big) + \gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}}{\beta\big(\gamma\rho^s + (1-\gamma)\rho^u\bar{\mu}\big)\text{NPV}_g + \big(\gamma(1-\rho^s) + (1-\gamma)(1-\rho^u)\bar{\mu}\big)\text{NPV}_b} nI. \tag{A.111}$$

□

Proof of Proposition 11

Consider the case in which the VC is purely profit motivated. Below, I prove that there is an equilibrium as described in the proposition. Specifically, I suppose that the positively informed skilled VC and the unskilled VC provide capital whereas the negatively informed skilled VC does not provide capital and I show that no type of VC has a profitable deviation. To do this I first compute the IPO price and number of shares issued, conditional on the supposed equilibrium behavior.

If the IPO succeeds, the IPO price is set so that inequality (7) binds or

$$p = \frac{\beta V_g + (1-\gamma)V_b}{\beta + 1 - \gamma}. \tag{A.112}$$

The IPO succeeds if the firm can raise at least I, or if

$$\frac{\beta V_g + (1-\gamma)V_b}{\beta + 1 - \gamma} > I, \tag{A.113}$$

which is implied by condition (49) in the proposition and the number of shares issued n' is given by

$$n' = \frac{(\beta + 1 - \gamma)nI}{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b}. \tag{A.114}$$

Observe that this equation is identical to the corresponding condition (equation (12)) in the baseline model, even though the VC retains its n shares in the IPO. This is because in both cases the VC issues the lowest number of shares n' to raise new outside capital I.

Unskilled VC. I now verify that the unskilled VC prefers to provide capital than not to provide capital. Now substitute n' from equation (51) into equation (48) to write the expected payoff from providing capital as

$$\mathbb{E}\left[\Pi^u_{\text{PM}}\right] = \frac{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b}{\beta V_g + (1-\gamma)V_b}\left(\frac{1}{2}V_g + \frac{1}{2}V_b\right) - c. \tag{A.115}$$

This is positive by the assumption in equation (49) of the statement of the proposition. Thus, since the VC's payoff from not providing capital is zero, the unskilled VC prefers to provide capital, consistent with the supposed equilibrium.

Positively informed VC. The no-deviation condition for the positively informed VC follows immediately from the no-deviation condition for the unskilled VC. This is because the positively informed VC's payoff is always higher, since it knows it will receive V_g instead of $\frac{1}{2}V_g + \frac{1}{2}V_b < V_g$.

Negatively informed VC. The negatively informed VC must prefer to withhold capital than to provide capital. His expected payoff from providing capital is

$$\mathbb{E}\left[\Pi^u_{\text{PM}}\right] = \frac{\beta \text{NPV}_g + (1-\gamma)\text{NPV}_b}{\beta V_g + (1-\gamma)V_b}V_b - c. \tag{A.116}$$

This is negative by the assumption in equation (49) of the statement of the proposition. Thus, since the VC's payoff from not providing capital is zero, the negatively informed VC prefers to withhold capital, consistent with the supposed equilibrium. □

Proof of Proposition 12

All of the statements in the proposition depend on the fact that the probability that the firm is good conditional on VC investment is higher in the career-concerns equilibrium than in the profit-motivation equilibrium. Given this fact, the proofs of statements (i)–(iii) are identical to the proofs of Proposition 5, Proposition 6, and Proposition 7. Thus, here I simply compute the probability that the firm is good conditional on receiving VC investment in the profit-motivation equilibrium with retention described in Proposition 11 and show that it is less than the corresponding probability with career

concerns. We have that

$$\mathbb{P}\left[g \,|\, \iota = 1\right] \Big|_{\text{PM, retention}} = \frac{1}{2-\gamma} \tag{A.117}$$

and

$$\mathbb{P}\left[g \,|\, \iota = 1\right] \Big|_{\text{CC}} = \frac{\gamma + (1-\gamma)\mu^*}{\gamma + 2(1-\gamma)\mu^*}, \tag{A.118}$$

as above. This is decreasing in μ^* so

$$\mathbb{P}\left[g \,|\, \iota = 1\right] \Big|_{\text{CC}} \geq \frac{\gamma + (1-\gamma)\mu^*}{\gamma + 2(1-\gamma)\mu^*} \Big|_{\mu^*=1} \tag{A.119}$$

$$= \frac{1}{2-\gamma} \tag{A.120}$$

$$= \mathbb{P}\left[g \,|\, \iota = 1\right] \Big|_{\text{PM, retention}} \tag{A.121}$$

as desired. □

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