Venture Capital and Public Equity

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Abstract

In recent years, the funding mix of internet and high-tech firms includes a significant continuing stake of the venture capitalist (VC) into the post-IPO phase. We explore why VC’s post-IPO stake may be efficient, and the characteristics and timing of the IPO decision. We recognize that VC’s abilities include both monitoring-governance capabilities and identification-managerial skills. While the identification-managerial skills prove valuable in the early phases of the firm, their value diminishes as the firm matures. The maturing firm will undertake an IPO to enable VC to cash-out and re-deploy her skills to newly forming startups. However, VC may limit her cash-out at the IPO by undertaking a lockup restriction for a governance-threshold stake (or more). The lockup ensures efficient governance by VC of key post-IPO decisions that remain somewhat opaque. Since the opportunity cost (re-deployment value) of VC’s skills can vary independently of the firm’s prospects, the model admits the aborting of announced IPOs when firm prospects don’t change as well as the negative correlation between the rate of start-ups and the average time-to-IPO.

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At recent initial public offerings (IPOs), we observe characteristics that are not readily understood in the context of traditional IPO models, especially for firms from sectors such as high-technology, bio-technology or the internet:

1. Future prospects of the firm are still substantially uncertain and/or assets are mainly intangible and not verifiable, both of which suggests considerable risk of asymmetric information between insiders and prospective public investors;

2. Operating decisions loom in the coming months that can significantly impact the firm’s value, which suggests possible agency and governance problems;

3. Venture capitalist (VC) retains a significant stake in the post-IPO firm, often with a lock-up provision that further constrains her post-IPO exit, which is at odds with VC’s desire to cash out and move on when feasible.

Myers (2000), in a recent influential paper, seeks to explain why firms with characteristic #1 (asymmetric information) choose to make an IPO. Consider a date after which the entrepreneur faces significant risk of expropriation by VC whose equity ownership confers concomitant governance power. In this scenario the entrepreneur will not contribute his effort to the firm even though it may be very valuable for the firm. This benefit from eliminating the expropriation threat by having VC sell her stake in the firm offsets the cost of selling at a date with asymmetric information. However, Myers’s model that explains the VC’s exit is inconsistent with observed characteristic #2 (large payoff from presence of strong governance) and #3 (considerable stake retained by the venture capitalist).

We propose a descriptively rich model that can explain all the three characteristics. We explain the IPO decision and the amount of the stake to be sold to the public by jointly taking on
asymmetric information, agency, and governance for real-options decisions.¹ This task can lead to fairly dense layers — we make judicious simplifications which we argue preserve the key features as well as the model’s ability to inform about real-world issues. Our focus on the equity decision (what mix of equity financing) ignores the possibilities of more comprehensive capital structure choice. We discuss some suggestions for extending our model along this direction below. Also, our treatment of the entrepreneur’s compensation is primitive and ignores the possibility of choice in designing incentives. In other research, we address compensation design along with proposals for improving upon traditional executive stock options.

The plan of our paper is as follows. In section 1, we lay out the intuition underlying our model. Explicit model structure is developed in Section 2. In Section 3, we solve the model for the optimal IPO decision (whether to make an IPO, and if so, how much stake to sell), which entails addressing a dismissal decision, a monitoring-governance problem, and an efficient signaling problem. In Section 4, we employ the model to isolate the separate effects of the key features of information asymmetry, agency and governance, and expropriation risk. We also relate our model to earlier models in the literature. In Section 5, we tease out empirical implications and remark on how the model’s structure and its conclusions match up to the real world. We conclude in Section 6.

1. Intuition

The focus of our paper is around the initial public offering (IPO) when the venture capitalist considers exiting the venture by selling her stake to the public investors. Is it sensible to have an IPO before the venture becomes fully transparent? If so, what is the optimal fraction for the VC to cash out at the IPO?

¹ Gompers and Lerner (1999) note the importance of these three characteristics in their recent book on venture capital financing.
We consider three players: entrepreneur (E, referred to in the third person as “he”), venture capitalist (VC, referred to in the third person as “she”), and public investors (P, referred to in the third person as “they”). The three players are assumed to maximize the present value of their own wealth. We model the contributions that the three players make to the equity value of the firm across different dates and phases of the firm as follows:

<table>
<thead>
<tr>
<th></th>
<th>Before time 1</th>
<th>Time 1</th>
<th>Phase 2</th>
<th>Time 2</th>
<th>After time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrepreneur, E</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Venture Capitalist, VC</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Public Investors, P</td>
<td>–</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>0</td>
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</table>

Notation: “++” = very significant value if participant; “+” = useful value; “0” = no value; “–” = cost.

The table is incomplete in at least two important ways: (a) the private costs to the players from staying on with the firm or from being removed from the firm are not accounted for; and (b) the spillover costs from VC’s continuance after time 1 on E’s well-being are ignored. Therefore, it would be incorrect to conclude from the above table that VC should definitely be retained till at least time 2 (or that E must be fired at time 2). Further motivation of the schematic value-contributions sketched above is elaborated next.

Operating in an environment characterized by tremendous uncertainty, entrepreneurs frequently need outside funding to develop their ideas and prototypes. At inception the entrepreneur provide ideas, concepts, prototypes and other intangible assets whose value is hard to verify and is opaque to outsiders. Much of his input is wrapped in his human capital.

Entrepreneur gets to realize his value when the project comes to fruition resulting in a firm as a going concern. At such point he captures rents for his special skills, for instance in the form of vesting stock options or founders shares.
During the early gestation period the performance of the firm remains opaque to outsiders. The firm may not produce any tangible goods or services during this phase and has few sales, if any, let alone profits. Much of the value is in the form of real options that must be identified, nurtured and exercised in response to subtle signals that require intimate knowledge, that is privy only to informed insiders of the firm. This severe asymmetry of information (between insiders and public investors who have very limited capability of monitoring and governance) renders conventional public financing infeasible.

The venture capitalist specializes in funding start-ups because of her unique evaluation skills along with her specialization in management and governance capabilities for new firms. The VC goes behind the corporate veil of the startup firm and de facto partners in the management of the firm. She participates in identifying and selecting projects and retains direct control over important investment decisions during the early phases by staged financing and later on indirectly by owning a governance stake in equity.²

At the end of phase 1 (at time 1), once the firm chooses its projects (acquires its the real options), some of the superior skills of VC become no longer needed. She then looks for ways to exit the firm and move her funds and skills to a firm that in still in its startup phase where her skills are most needed.

At this point the VC looks to sell some or part of her equity to outside investors who provide money and expects only to earn a fair rate of return on their investment. Although some information regarding the firm can be credibly revealed to the public, much of the firm's assets are still embedded in intangibles (real options) and can not be verified by outsiders. Credibly communicating the value of the firm to outside investors unfamiliar with the intimate details of the firm remains a problem.

² Gompers and Lerner (1999) provide useful and detailed discussion of the issues surrounding financing of start-ups by venture capitalists.
Furthermore, impending real options exercise decisions create an agency problem. Since the entrepreneur/manager can only capture his rents if the firm remains a going concern at the time of the venture coming to fruition, the interests of the entrepreneur/manager (agent) and the investor (principal) need not be always aligned. It is therefore necessary to put in place a governance structure which ensures that the entrepreneur acts in the interest of the investor.

We argue that the VC can mitigate problems arising from agency/governance issues and information asymmetry by retaining a post-IPO stake in the firm. The VC’s continued equity stake also forms a credible signal to the public investors about the private information and minimizes the Lemon’s problem in the valuation of the IPO. The stake should be large enough to exert governance control and discipline the entrepreneur to make the real options exercise choices that maximize firm value (rather than his personal value). Yet the stake should not be so large that the entrepreneur will hold up his effort due to the threat of expropriation. The signaling and governance benefits due to the VC retaining a post-IPO stake must be offset against the cost of foregone outside opportunities where the VC’s superior skills can be more profitably deployed. Hence we find that a partial exit by the VC can be optimal.

2. Detailed Structure

We focus on issues surrounding a potential IPO decision at time 1 for a firm started at time 0 in the past. At time 0, an entrepreneur (E) combines with a venture capitalist (VC) to start the firm. E contributes resources such as concepts and intellectual property, which value is difficult to establish and communicate to public investors. The financial investment needed to develop the

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3 For instance, if at some point the firm value maximizing choice is to abandon the venture, a manager whose rewards are tied to the firm remaining a going concern will be inclined to make the wrong decision.
business in phase 1 exceeds $E$’s financial resources and is provided by $VC$.

$VC$’s ability to identify a good $E$ earns rents. $VC$ also contributes complementary real assets (such as contacts and start-up managerial skills) that may also be in short supply. Through her involvement in the operations of the firm (including being active on the Board of Directors), $VC$ acquires capabilities to monitor the firm and its entrepreneur-manager.

**Phase 1: Start-up, First-Phase Information, and the IPO Game**

At time 0, $E$ and $VC$ engage in what we label a startup game. For our purposes, the details of this game are not important.⁴ What emerges is an investment by $VC$ for equity ownership in the firm. (Our main results are robust to a sharing of equity ownership by $E$ and $VC$. For expositional convenience, we fix $E$’s initial equity stake to zero.) $E$ secures a form of tenure with the firm that makes it very costly to dismiss him as the operational decision maker. If $E$ survives with an ongoing firm after time 2, he secures economic rents of value $R$.⁵

By time 1, some of the uncertainty surrounding the firm’s prospects is resolved (with partial or complete validation of the firm’s business concept or key prototype). The firm’s assets and prospects become less opaque for outsiders (i.e., the firm has become translucent). The marginal value of continued contributions by $VC$ significantly diminishes though the success of the business requires continued effort by the entrepreneur till at least time 2. Given outside opportunities where $VC$ can realize significant value from her participation (which must be joint with capital), she would like to cash-out to have investable funds.⁶

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⁴ For a detailed model of the start-up negotiations, see Myers (2000) and Gompers and Lerner (1999).

⁵ See Myers (2000) for motivational details related to the economic rents available to the entrepreneur who continues as decision maker after an IPO.

⁶ Another motive for an IPO at time 1, which typically results in a very small stake sold to the public, is for marketing and for engaging in mergers/acquisitions employing equity exchanges. For this motive, the main goal is to have an external valuation of the firm that is as high as
VC’s urgency of reallocation is parameterized by a conversion factor, \( \rho \), that equalizes her payoffs at time 2 from capital freed at time 1. I.e.,

\[
\rho = \frac{\text{capital freed at time 1}}{V \text{'s value at time 2 of reinvestments in alternative opportunities}}.
\]

One can think of \( \rho \) as VC’s private rate of time discounting as of time 1 that differs from that of the market. Additionally, \( \rho \) captures any mal-diversification by VC that leads to her risk premium from maintaining a stake in the risky firm to be higher than that of a well-diversified public investor.

Given \( \rho < 1 \), time 1 could be a useful juncture to sell some or all of VC’s equity to outside public investors (\( P \)).\(^7\) In other words, the firm evaluates an initial public offering (IPO) at time 1. Formally, VC announces the fraction of the firm’s equity to be offered to the public, \( p \) (including possibly zero, i.e., no IPO).\(^8\) Since she owns all the equity prior to the announcement, her remainder position \( v \) equals \( 1-p \), and she receives the entire proceeds from the public offering. If \( v = 0 \) then VC exits completely at time 1. If \( v > 0 \), VC will sell her remainder equity stake at time 2. Since the firm is not transparent at time 1 and/or governance problems remain, \( P \)’s valuation at time 1 of the firm’s equity (\( P1 \)) will differ from the intrinsic value that is known to the insiders (\( E \) and VC) and will depend on the announced \( v \), which complication is fundamental to our explorations.

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\(^7\) Though an IPO may occur at time 1 even if \( \rho = 1 \) because of the need to possibly mitigate the threat of expropriation to the manager — see Myers (2000) and discussion below.

\(^8\) In general, we should recognize the cost of filing for IPO which has a fixed component that introduces a discontinuity at \( v = 1 \).
Phase 2: Second-Phase Information, Dismissal Game, and a Liquidation Decision

During phase 2 (between time 1 and 2), assuming the firm has survived time 1, $E$ exerts effort (whose cost is assessed by $E$ at $Eff$). $VC$’s active participation in this phase is at most that of monitoring which costs $m$. In phase 2, new information about the firm’s prospects (denoted $Inf2$) becomes available to $E$ and to monitors if any. $Inf2$, and who has it, proves material for key operating decisions to be made at time 2 (at the end of phase 2).

We elaborate using the example of a time-2 decision of whether to liquidate the firm or not. If the decision-maker (who may or may not be $E$ depending on the outcome of the dismissal game — see below) chooses to liquidate, then the firm’s liquidation or sale value, $S$, becomes public knowledge. If the decision-maker chooses to continue the firm beyond time 2, then the firm’s gross going-concern value gets publicly revealed. It will be either high ($H$) or low ($L$) which is the information content of $Inf2$. The probability of $H$ as of time 1 is $q$, and thus $L$’s probability at time 1 is $1-q$.

The ex-post value to equity holders will be less by $R$ if $E$ is the decision maker. Conditional on the publicly observable decision choice, the firm’s value becomes public knowledge. However, the hypothetical values that would have arisen under a choice not actually made are not public information. Naturally these values become known to $E$ because of his intimate involvement with the firm in phase 2. The hypothetical values are also knowable by anyone who chose to become a monitor at time 1; if outsiders chooses to be a monitor, they incur a cost of $M>m$ where recall that $m$ is the monitoring cost for $VC$. The cost difference, $M-m$, recognizes $VC$’s superior knowledge of the firm (and its industry). Thus, $VC$ has a comparative advantage in being a monitor compared to an outsider.

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9 A simple way to capture $VC$’s superior knowledge of the firm relative to $P$ is to let the exact value of $S$ be known to $VC$ while $P$ only knows a distribution for $S$. In addition, note that a $VC$ may also capture synergistic benefits by being an insider, either because of spillovers to other
At time 2 (end of phase 2), the firm has a dismissal game. $E$ can be dismissed by the monitor, if any, who controls an equity position that equals or exceeds $g$ ($g$ is the minimum stake for effective governance that depends on statutory and institutional characteristics and could be different from a simple majority [50%] stake). However, such an equity-holder has to incur a private deadweight cost $D$ to execute the dismissal.\(^{10}\)

Because of their diffuse ownership, public investors are unlikely to incur the costs of organizing to vote as a block (free rider problem). Hence $P$ does not pose a credible dismissal threat to $E$. However, if $VC$ retains a governance interest, she may replace $E$ at time 2 with a professional manager who runs the firm at a net present cost that is less by $R$, which is the value of the entrepreneur’s rent from operating the firm beyond time 2. Recognizing this threat of dismissal and consequent loss of $R$, $E$ may quit the firm at time 1. Myers (2000) motivate $VC$’s exit at time 1 via an IPO to mitigate the threat of dismissal. Our results significantly go beyond Myers in this area.

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\(^{10}\) One way to understand $D$, the private deadweight cost that $VC$ must incur if she dismisses $E$, is to consider the cost of building a solid enough case to defend against a charge of wrongful dismissal by $E$. This cost arises, for instance, due to the challenge for the monitor to make verifiable the privately know information about hypothetical values at time 2. For $VC$, $D$ also includes reputation considerations for future relations with other entrepreneurs.
Solutions for the IPO Decision and the Sub-games

The optimal equity to offer to the public at time 1 depends on what all the players do at time 1 and time 2 as a function of the offered equity. As is typical in such problems, we start from the end and fold the tree backwards.

Dismissal game at time 2

By time 2, the firm’s value relevant for the real options decision is known to insiders (E and monitors). Each player in the game only seeks to maximize their own value. Consider the case when VC’s share of equity is greater than the minimum threshold that is needed to exert governance control (i.e., \(v > g\)) and that VC has expended \(m\) to be a monitor during phase 2. In this case VC can decide whether to keep or dismiss \(E\) after accounting for her cost of dismissal, \(D\). If \(E\) is retained, then \(E\) makes the decision of whether to continue the firm or to sell it for \(S\) based entirely on the value realized to him (\(R\) only if firm continues). If \(E\) is dismissed, then VC makes the liquidation decision by maximizing the value to her (which will be the equity value accruing to her fraction \(v\)).

Consider the case when the favorable outcome, \(H\), occurs and VC decides to keep \(E\) (Figure 1a). Then \(E\) will choose to continue the firm and earn \(R\). VC would get \(v(H - R)\), her pro-rated portion of the firm’s equity value. If instead, VC dismisses \(E\), then VC will choose to have the firm as a going concern that nets her \(vH - D\).\(^{11}\) Note that the cost of dismissing \(E\) is borne by VC. Similar logic applies to the case of an unfavorable outcome, \(L\) (Figure 1b). In summary, VC’s payoffs at time 2 if \(E\) is kept are as follows:

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\(^{11}\) We assume that \(H > S > L\), which non-controversially set the firm’s value in the favorable state to be worth more than liquidation and in the unfavorable state to be below liquidation (where the latter ensures some governance-plus stake at which VC will dismiss E so that we capture a meaningful governance role in the model).
Action Regarding E: | Realization from Phase 2:  
<table>
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<tbody>
<tr>
<td>Dismiss E</td>
<td>(vH - D)</td>
<td>(vS - D)</td>
<td></td>
</tr>
<tr>
<td>Keep E</td>
<td>(v(H - R))</td>
<td>(v(L - R))</td>
<td></td>
</tr>
</tbody>
</table>

Note that \(VC\) will decide to keep the entrepreneur in the H-state only if \(v(H - R) \leq vH - D\), or \(v \leq \frac{D}{R}\). Since admissible values are \(0 \leq v \leq 1\), let \(h \equiv \min(1, D/ R)\) denote the equity-fraction threshold below which E is never dismissed if H is realized in phase 2.

In the L-state, \(VC\) won’t dismiss E in order to realize liquidation unless \(vS - D \geq v(L - R)\), i.e., \(v \geq \frac{D}{S + R - L} \equiv g^*\). But there is also a statutory or institutionally determined threshold of equity-holding, \(g\), that must be reached before \(E\) can be dismissed. So the minimum equity fraction for effective governance action is \(\max(g, g^*) \equiv l\). We assume in what follows that \(l \leq h\); the situation when \(l > h\) simply means that the interval of interest is only \([0, h]\) that can be examined as one without possibility of dismissal. The case of no possibility of dismissal is discussed next.

Suppose that \(E\) cannot be dismissed, either because \(VC\) does not retain sufficient equity to exert effective control (i.e., \(v < l\)) or \(l > h\). Then \(E\) will always keep the firm as a going concern regardless of \(H\) or \(L\) since that is his dominant choice garnering him rents worth \(R\). This is the agency problem in our model. The consequent value to \(VC\) under \(H\) and \(L\) will be \(v(H - R)\) and \(v(L - R)\).

\[\text{For convenience, we assume that } E \text{ stays if } VC \text{ is indifferent between dismissing him and keeping him.}\]
IPO game at time 1

Continuing the backward solving approach, we begin by examining $E$’s problem at time 1. $E$, who moves after VC, chooses whether to commit to work in phase 2 (expend effort $Eff$). If he works, his payoffs are:

\[
qR + (1-q)R - Eff = R - Eff \quad \text{if } v < l
\]
\[
qR + (1-q)0 - Eff = qR - Eff \quad \text{if } l \leq v \leq h
\]
\[
q0 + (1-q)0 - Eff = -Eff \quad \text{if } v > h
\]

Rerecollect that \( h (= D/R) \) is the fractional ownership level for VC below which VC won’t dismiss $E$ even if $H$ occurs at time 2. If \( qR > Eff \), which we will assume to be true, $E$ will work for all $v \leq h$. If $v > h$, clearly $E$ should not work since that choice avoids a negative payoff. But if $E$ does not work in phase 2 then the firm becomes valueless in our setup. So we can focus on the cases of $v \leq h$.

The other player moving after VC at time 1 is P who establishes a fair value of the firm’s equity, $P1$, conditional on public information which includes knowledge of $v$. Since discounting for time and risk is eliminated by choice of normalization, the fair $P1$ for us is $P$’s expectation of the firm’s value at time 2, say $P2$.

VC moves first at time 1 and announces the equity fraction she will sell to the public, $p$ ( = 1 – $v$). If $p$<1. She also commits to monitor in phase 2 at a private cost to her of $m$. $VC$ realizes $m < M$ allowed us to conveniently address the comparative advantage of VC as a monitor relative to outside monitors.

\( ^{13} \) Since the decisions of $P$ and $E$ are separable at time 1 in our model, we can study them in any order.

\( ^{14} \) In principle she could choose to not incur $m$ even if she retained some stake. But recall that $m$ might be near zero (or even negative) because she realizes spillover benefits to her activities with other startups, which spillovers several venture capitalists inform us are quite important in early-IPO cases. For our purposes, introducing $m$ suffices while modeling a choice situation about it appears to offer little insight. Recall that $m < M$ allowed us to conveniently address the comparative advantage of VC as a monitor relative to outside monitors.
proceeds of \((1 - \nu)P1\) at time 1 (less \(m\) if \(\nu > 0\)) and expects to realize proceeds from sale of her remainder stake at time 2 less dismissal costs if any. Let \(\overline{P2a}\) denote \(VC\)’s expectation of the public value of equity at time 2 if she retains a stake below \(l\), and \(\overline{P2b}\) denote \(VC\)’s expectation when her retained stake is between \(l\) and \(h\). \(VC\)’s value function at time 1 is then:

\[
F = \begin{cases} 
  P1\{0\}, & \text{if } \nu = 0 \\
  (1 - \nu)P1\{\nu\} - m + \rho \cdot \nu \cdot \overline{P2a}, & \text{if } 0 < \nu < l \\
  (1 - \nu)P1\{\nu\} - m + \rho \cdot \nu \cdot \overline{P2b} - \rho (1 - q)D, & \text{if } l \leq \nu \leq h \\
  0 & \text{if } \nu > h 
\end{cases}
\]

The dependence of \(P1\) on the fraction retained by \(VC\) is explicitly noted via the braces attached to \(P1\). The optimal fraction that \(VC\) should retain in firm is then: \(v^* = \arg\max_{[0,1]}(F)\).

It is straightforward to compute \(\overline{P2a}\) and \(\overline{P2b}\):

\[
\overline{P2a} = q(H - R) + (1 - q)(L - R) \\
\overline{P2b} = q(H - R) + (1 - q)S
\]

The value of \(P1\{v\}\) is much more challenging. It depends critically upon the information specification of what \(P\) knows relative to \(VC\). We consider below three cases in order of increasing generality/verisimilitude:

a. Symmetric information between \(P\) and \(VC\).

b. Asymmetric information with \(P\) knowing less than \(VC\) on one dimension.

c. Asymmetric information with \(P\) knowing less than \(VC\) along two or more dimensions.

a. Symmetric information between \(P\) and \(VC\)

When \(P\) and \(VC\) know all the parameters,

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15 Replace the segment of \(0 < \nu < l\) by \(0 < \nu \leq h\) if \(l > h\) along with recognizing that there is no admissible value corresponding to \(l \leq \nu \leq h\).
Given $\rho < 1$, VC’s optimal choice is straightforwardly seen to be either $v=0$ (exits completely) or $v=l$ (retains a minimum effective governance stake) — see illustrative figure 2.

This case slightly generalizes Myers (2000) in that we find that VC may not exit completely if there is a significant value from his comparative advantage of governance (because of monitoring, rather than screening ideas).

**b. Asymmetric Information in 1 Dimension**

To illustrate, we will explicitly discuss asymmetric information about $q$ and then $S$, which two cases are somewhat different. Consider the case where from $P$’s perspective, a parameter $X$ can be either $X_d$ (“down value”) or $X_u$ (“up value”). Let $w$ be the time-1 likelihood that a firm has parameter value of $X_d$ (so $w=0$ or $w=1$ revert to the symmetric information solution above). VC knows the type of her firm, i.e, whether $X_d$ or $X_u$ applies.

If full ex-post settling up is possible between VC and $P$, then the asymmetry at time 1 has no significant consequences (assuming low costs in writing and enforcing suitable contracts). In practice there are several hurdles to achieving full ex-post settling up. For example, a salvage value, $S$, may only be verifiable at time 2 for contracting purposes if the firm gets liquidated. But the value at time 1 is impacted as long as there is a likelihood of the state where $S$ come into play is nonzero. For asymmetries about information relating to private parameters, such as VC’s rate of time preference $\rho$, it may be well-nigh impossible to write any contracts with ex-post settling up.

We explore the case where there are no other devices to facilitate contracts between VC and $P$. The only instrument available is choice of VC’s equity stake, $v$. We check for whether pooling equilibrium or separating equilibrium dominates by comparing the payoffs under the two equilibria for the high- and low-value types across all admissible $v$-values. A separating
equilibrium rules (else a pooling equilibrium rules) if there exists a \( v \)-choice for the high-value type such that: (i) its separating pay-off at that choice is more than the high-value type’s maximum under pooling equilibrium, and (ii) the low-value type’s pooling pay-off at this \( v \) is less than the its maximum payoff under separating equilibrium. If there are several such \( v \) choices, the high-value type selects the one with the highest separating payoff from such \( v \) choices. The low-value type simply selects the \( v \) that maximizes its separating payoff from all admissible \( v \)’s.

We start with asymmetry about \( q \). Figure 3 shows the VC’s valuation function, \( F \), for separating and pooling equilibriums given illustrative parameter values — panels (a) and (b) correspond to two different \( r \)’s. Note that the \( F \)’s under symmetric information reveal the expected corner solutions at zero or the minimum governance stake, \( l \).

Consider the \( F \)’s under pooling. The valuation function is not a simple average of the \( F \)’s from the symmetric information cases. This arises because only part of the value depends on the sale of the stake \( p \) when asymmetric information prevails; another part obtains at time 2 when the true value becomes revealed.\(^{16}\) Since VC knows the true \( q \) value at time 1, her total valuation varies by her \( q \)-type. In our simple model, with only uncertainty about \( q \), the possible optima under pooling equilibrium remain the same as before, i.e., 0 and \( l \). Of course, the payoffs become different. In figure 3a, the parameter values are such that pooling equilibrium (of low \( q \)-type) dominates with VC exiting fully. In figure 3b, the pooling dominates with VC retaining the minimum governance stake, \( l \).

Figure 4 shows the case of separating equilibrium. The region of \( v \)-choices that separate the high type from the low type for specific values is the thatched area in the figure. The VC’s optimal \( v \)-decision if she has the high \( q \)-type leads to a \( v^* \) that is neither 0 nor \( l \)!! In general, the optimal retention stake can be any value between 0 and \( h \). This situation likely applied to the

\(^{16}\) Quite generally, when the future revelation of types is associated with values to be then realized, the cost from information asymmetry today is mitigated.
many recent IPOs that sold less than 20% of the firm’s equity to the public (— presumably the overhang of $E$’s expropriation risk by VC was relatively small, i.e., $h$ was near 100%).

If $S$ can take more than two possible values from $P$’s perspective, then a new possible scenario is possible: partial pooling, where some groups of values are distinguished by suitable optimum $v$ but full separation may not be possible. Here again, a range of optimal $v$-choices emerges.

c. Asymmetric Information along 2 or more dimensions

Consider the case where, from $P$’s perspective, $S$ and $r$ (mutually uncorrelated for simplicity) can take either down-values ($S_d$ and $r_d$) or high-values ($S_h$ and $r_h$) with all combinations having equal likelihood. However, VC knows whether $S_d$ or $S_h$ and $r_d$ or $r_u$ applies. In this setup, capital structure choice that goes beyond equity contracts could prove very useful since additional costly signals can help address the higher dimensionality of the asymmetric information. We are pursuing this issue separately. Note that such capital structure choice can prove helpful in providing a more fully separating equilibrium even in the case of 1 dimension of asymmetric information.

4. Special Cases and Extensions

It is interesting to explore how the optimum fraction retained by VC at time 1, $v^*$, varies with the following:

1. Expropriation risk facing the entrepreneur-manager calibrated by the deadweight cost, $D$, of firing the entrepreneur-manager — in particular the limiting cases of $D = \infty$ corresponding to zero threat and $D = 0$ leading directly to the case of Myers (2000).

2. Governance problem (illustrated by the liquidation problem in our setup) calibrated by the probability, $1-q$, of the state at $t=2$ when a decision conflict arises — in particular the limiting cases of $q=1$ and $q=0$. 
3. Opportunity costs facing VC calibrated by the ratio of the public investors’ return possibilities outside the firm to that for VC, ρ.

Note that the impact of the extent of asymmetric information has already been discussed in the previous section.

4. Empirical Validity and Implications

5. Conclusions

References


Figure 1a
Time 2 Game Tree
(High State: H)
Figure 1b
Time 2 Game Tree
(Low State: L)

<table>
<thead>
<tr>
<th>Value to V</th>
<th>Value to E</th>
</tr>
</thead>
<tbody>
<tr>
<td>v L - D</td>
<td>0</td>
</tr>
<tr>
<td>v S - D</td>
<td>0</td>
</tr>
<tr>
<td>v (L-R)</td>
<td>R</td>
</tr>
<tr>
<td>v S</td>
<td>0</td>
</tr>
</tbody>
</table>
Fig 2a: Symmetric information about q
(q = 0.75, \(\rho = 0.15\), v = 0)

Fig 2b: Symmetric information about q
(qh = 0.375, \(\rho = 0.15\), v = l)
Fig 3a: Asymmetric information about q
(qh = 0.75, ql = 0.35, ρ = 0.01, v* = 0)
Pooling equilibrium with full exit

Fig 3b: Asymmetric information about q
(qh = 0.35, ql = 0.15, w = 0.55, ρ = 0.5, v* = 1)
Pooling Equilibrium with Minimum Governance Stake
Fig 4: Asymmetric information about q
(qh = 0.75, ql = 0.35, r = 0.15)

High player separates

Low player separates

Separating Equilibrium

Fraction retained by VC

Value to VC

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Max_sep_lo
Max_pool_hi
sep_low
sep_hi
pool_low
pool_hi