# Posturing and Hold Up in Innovation[*]

Naveen Khanna and Richmond D. Mathews[†]

Eli Broad School of Business, Michigan State University
and Robert H. Smith School of Business, University of Maryland

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[†]Khanna is at the Eli Broad School of Business, Michigan State University, East Lansing, MI, 48824. Mathews is at the Robert H. Smith School of Business, University of Maryland, 4426 Van Munching Hall, College Park, MD 20742. Email: khanna@bus.msu.edu and rmathews@rhsmith.umd.edu.

# Posturing and Hold Up in Innovation

**Abstract**

We show that the need to "posture" can help solve the hold-up problem inherent in many multi-stage relationships, such as those between entrepreneurs and venture capitalists (VCs). Posturing arises when an informed party needs to send a strong signal to induce skeptical third parties like employees, suppliers, customers or competitors, to develop relationships with the firm or take other actions that increase firm value. In the venture capital context, this can be credibly achieved if the VC publicly invests at high prices in later rounds. This shifts ex-post bargaining power towards the entrepreneur, inducing him to exert greater effort ex-ante.

When complete contracts are difficult or impossible to write, multi-stage relationships can be vulnerable to hold up. In particular, a contracting party that expects to face aggressive renegotiation by another party ex post will be less likely to undertake relationship-specific effort ex-ante. However, if the party with the power to engage in hold up also possesses private information, the terms of the later-stage renegotiations may serve a dual role. They may not only distribute surplus between the contracting parties, but also signal information about the firm to skeptical third parties such as customers, suppliers, employees, and competitors, whose decisions or actions are not under the firm's control but can critically impact the firm's value.[1] The informed party can attempt to induce desired actions by sending a strong and credible signal about the firm's prospects, which makes it mutually beneficial for the third parties to take those actions. We show that the need to send such a signal acts as a commitment device by shifting the contracting parties' relative bargaining positions in a way that tempers hold up and induces greater effort ex-ante.

In situations where this dual role is important, the need to signal changes the nature of the contracts and the efficiency of the multi-stage relationship in important ways. For example, an informed party who would otherwise impose onerous terms in a re-negotiation would have an incentive to relax those terms to credibly signal that their information is good, i.e., to show that even when entering into a deal with relatively generous terms they expect to realize greater surplus since the resulting third party actions are expected to increase firm value and justify those terms. Thus, the need to signal creates a feedback loop between contracting terms and third party actions that helps protect ex ante effort incentives.

Existing literature on incomplete contracts generally relies on the ex ante allocation of residual control rights to help resolve the hold up problem (e.g., Grossman and Hart, 1986,

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[1]In that sense, many such third parties can be viewed as "free agents" who choose to develop firm-specific relationships only if it is in their own interest to do so. Such third parties may understand how their own decisions or actions are related to the firm's product or service, but may have relatively less information about the overall potential value of this relationship, e.g., due to uncertainty about overall market size or the firm's expected market share.

Hart and Moore, 1990, Aghion and Tirole, 1994). Our results show that when the dual role of renegotiations is taken into account, the need to resort to potentially costly or ineffective control rights allocations may be reduced or even eliminated. This will apply particularly well to situations where third party actions are important, third parties are not directly controlled by the firm, and where they are skeptical about firm prospects and therefore harder to persuade.

This general idea could be applied to multi-stage relationships in many different settings, such as financing relationships, joint ventures, alliances, customer-supplier relationships, etc. To fix ideas, we consider a specific setting with an entrepreneur who has an idea for an innovation but is capital constrained. While a venture capitalist (VC) is willing to fund the innovation, it is prepared to do so only in stages. It first needs to induce the entrepreneur to provide the optimal amount of effort in developing the idea and then, after the idea is developed, reassess the project's prospects on the basis of its private information before deciding to provide additional financing. Since at the later stage the entrepreneur's contribution is already sunk, his further involvement in the project is less important (Hellmann and Puri, 2002). However, additional financing and the support of the investor is likely to be critical at this point in both putting together a professional management team and providing the necessary resources to grow the firm and develop its market. This gives the VC an upper hand in setting the terms for this round of financing. By setting onerous terms, the investor can expropriate the entrepreneur's share in firm value that was negotiated earlier when his participation was critical. Realizing the possibility of such renegotiation through the later funding round, the entrepreneur would be reluctant to put effort into developing the innovation and profitable opportunities could be lost. Note that an ex ante allocation of control rights as in Grossman and Hart (1986) or Aghion and Tirole (1994) cannot resolve this problem, since the VC could negotiate those control rights away at the renegotiation stage.

The potential for such late-stage expropriation of entrepreneurs is well founded in the

literature. For example, later VC financing rounds generally involve new contract negotiations (Gompers, 1995), which makes the possibility of ex-post opportunism quite significant, as suggested by Gilson and Black (1998):

> What can the entrepreneur do if the venture capitalist opportunistically offers to provide the second-stage financing necessary for the entrepreneur to continue at an unfair price? The entrepreneur could seek financing from other sources, but....who would incur the costs of making a bid when potential bidders know that a bid will succeed only when a better informed party – the original investor – believes the price is too high?"[2]

Similarly, Gilson (2003) notes that while stage financing may reduce agency costs related to entrepreneurial actions, it clearly shifts the potential for opportunistic action to the VC.[3]

However, since startup firms usually develop new products and/or new markets, their prospects are particularly dependent on how they are perceived by third parties. Since information about a startup's prospects is generally limited to those close to the firm (and, indeed, it is precisely this type of information that VCs need to have in order to make good investment decisions),[4] the terms of later stage financing may be critical to relaying

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[2]Similar possibilities have been noted in relationship banking, e.g., Sharpe (1990) and Rajan (1992).

[3]See also Admati and Pfleiderer (1994), Fluck, Garrison, and Myers (2005), Atanasov, Ivanov, and Litvak (2012), and Broughman and Fried (2012), for discussions of the potential for ex post opportunism by VCs. An important legal precedent in this area is Kalashian v. Advent, in which the VC invested in a later round at a very low valuation and subsequently sold the firm for a much larger amount, prompting the founders to sue for breach of fiduciary duty with respect to the price paid in the financing round. The case was ultimately settled, but established the potential for liability for VCs who were too aggressive in pressing their bargaining advantage at later stage financings. See Cowley and Pike (2003) and Surpure (2008) for examples of practitioner advice regarding potential liability in these situations. Note that while legal recourse may somewhat constrain the scope for hold up, it is likely not sufficient to eliminate it, or to explain the steeply increasing price paths often observed in later rounds. Our model describes a self-enforcing mechanism that can do both.

[4]The idea that information on fundamentals could be private information of the VC is consistent with

the information to third parties in a credible way. Thus, the more the investor pays for an additional stake in the firm, the stronger the signal to the market and the more likely is the investor to induce desired actions by third parties.[5] This we refer to as "posturing."[6]

In fact, we show that when posturing is required, the pre-money value at which the VC is compelled to invest in the second stage is sometimes even higher than its private information can justify, which is in contrast to the usual result that a VC with substantial bargaining power should be able to demand significant underpricing. The VC is compelled to buy at such inflated prices when the feedback loop it creates by inducing desirable third party actions increases the value of its initial stake in the firm by more than the expected cost of overpayment. While the third parties are not fooled in equilibrium when the VC postures, the compulsion to inflate the price further restricts the VC's ability to exploit its bargaining power against the entrepreneur. This allows the entrepreneur to capture a larger proportion of the rents ex post despite the shift in bargaining power toward the VC. As a result, ex ante contracting is more efficient and elicits greater effort from the entrepreneur at the innovation stage, resulting in higher firm value.

Our result that the need to posture often leads to inflated pricing in the later rounds is consistent with empirical observations that VCs sometimes invest at relatively high valuations. Gompers and Lerner (2000, 2001) and Sahlman and Stevenson (1987) discuss the fact that VC valuations tend to look high (resulting in apparently low returns) in particular industries at certain times, and relate this to the amount of money being invested by limited partners at those times. In addition, practitioners and the popular press often note episodes when VC valuations seem unsustainably high, such as during the late 1990s internet boom,

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empirical evidence about the role of VCs in advising and managing portfolio firms – see Hellmann and Puri (2000, 2002), and Lerner (1995).

[5]Pricing high is equivalent to signaling a high post-money value, which is equivalent to signaling a high pre-money value, the term generally favored by practitioners.

[6]We use the term posturing to distinguish from standard signaling since the signal in our model includes a pricing element that is not always present in standard models.

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or the recent boom in social media startups.[7] Our results provide a new explanation for why prices may look inflated at certain times, particularly when third party skepticism or competitor aggressiveness makes it more difficult to create the conditions necessary for a successful exit.[8] In other words, what these commentators or researchers interpret as excessively high (potentially irrational) prices may in fact be rational inflated pricing due to the need to posture.

Our model also provides a number of testable comparative statics with respect to pricing across different financing rounds. First, when compared with situations where hold up occurs, a steeper upward price path across rounds is expected when posturing occurs. Posturing is also expected to be associated with a higher probability of initial funding and greater ex post success rates. In addition, as third parties become more skeptical about firm prospects (or when competitors are harder to scare away), the VC invests at a higher price, i.e., demands a lower second stage stake for the same amount of investment. With increasing skepticism the range of states over which second period funding is valuable decreases. Thus, less equilibrium effort is desired, which is accomplished by increasing the VC's first round stake. This increase in the VC's first round stake amplifies the increase in the second round price, because a higher initial stake makes it harder to signal. Finally, an increase in the potential severity of the hold up problem, proxied by an increased difference in the profitability of a late versus early exit, also implies a steeper pricing path when posturing occurs relative to situations where hold up occurs.

While there may exist other explanations for inflated later stage prices, our model pro-

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[7]See, e.g., Malik (2012), Carlson (2012), and Stone (2012) for discussions of recent high VC valuations of social media and other internet firms.

[8]Note that while prices may exceed fundamentals in our model, third parties are never fooled, i.e., their inference based on the prices is, on average, correct. Thus, our model cannot explain episodes of true overvaluation, where investors and third parties misperceive the value of firms on average. However, it can help explain why investment prices appear to be high in some situations, which can create or enhance the *appearance* of overpricing to a naive observer.

vides directly testable implications for when such prices are likely to be observed. As noted above, posturing is more likely to occur in industries where third party actions are important, third parties are not directly controlled by the firm, and where they are skeptical about firm prospects and therefore harder to persuade. Some industry characteristics that could predict posturing are the importance of human capital and difficulty of retaining skilled employees (e.g., employees of software/tech companies), the need to attract a large network of independent contractors to use the firm's innovation or create complementary products (e.g., app developers or users for a mobile ecosystem or social media platform), and more generally any industry where employees, customers, or suppliers have good alternative options (e.g. fast growing industries with multiple competing firms). Similarly, posturing to deter competition is more likely where multiple technologies or brands vie for market leadership, and earlier revelation of a competitive advantage could forestall lengthy price wars or potential entry by new entrants (i.e., newer markets where the important competitive edge held by some firms is not obvious).[9] Other arguments for high prices, such as that VCs irrationally overprice their investments, or that high prices are used to encourage continued effort by entrepreneurs at later stages, do not provide these predictions. Furthermore, the idea that high prices result from excessive competition among VCs is not likely to explain why an *incumbent* VC would pay high prices, as the VC's private information about the firm's prospects should prevent it from falling prey to the winner's curse.

# 1. Motivating Examples

As an example of a market where posturing seems to affect VC valuations, consider the situation currently playing out in the ride-sharing space. Since 2011, three players have

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[9]Note that while posturing occurs at later stages of a particular innovation's development in our model (after the entrepreneur has exerted the effort needed to complete the innovation), this can still be at an early phase of an industry or market's life cycle (for example, while in 2014 Uber had an established platform and was receiving later stage private equity funding, the ride sharing market was still relatively nascent).

taken the lead to develop this space: Uber, Lyft, and Sidecar. Until the beginning of 2013, they were running head-to-head. In May 2013, the VC firm Andreessen-Horowitz shook up the market by buying about 20% of Lyft for $60M, placing its value at $275M. This investment and its terms were widely reported in the media, and the valuation was considered surprisingly high by many, including management and investors at competing firm Sidecar. This had the immediate effect of freezing Sidecar's access to the capital markets, which weakened its competitive position. According to Jahan Khanna, one of the founders of Sidecar, a typical response from potential investors looked something like this:

> While [we] were very impressed with you and the growth trajectory you are on, we are going to pass on the opportunity. Our concern is that the amount of capital it will take to compete in this space is quickly becoming greater than what we'd have appetite for based on the progress to date. In a perfect world, we wouldn't have irrational players out there messing things up! But unfortunately, the idea of going up against two very well-funded, shoot for the moon type of competition is very hard and costly to overcome, and frankly gives us too much pause to proceed here.

The reference to "irrational players" is a strong indication that the valuation was higher than seemed rational to this particular investor.

In response, in August 2013, Uber sold $350M worth of shares at a valuation of $3.5B (Swisher, 2013). Apparently, the aggressive valuation accorded to Uber by its investors signaled that Uber was now considered the front runner in this space. This severely limited Lyft's ability to raise additional funds, and even though Lyft raised an additional $250m, it was at a pre-money valuation of only around $700M (De La Merced, 2014). Fortune noted "The company [Lyft] did not disclose valuation, but CEO Logan acknowledged that earlier reports of a $700M pre-money mark were in the right general ballpark" (Primack, 2014). Understandably, Lyft was reluctant to reveal the low pre-money value reflected in this deal as it would signal weakness even though it was not technically a down round.

Uber, though, soon removed any doubt in the market as to who was being anointed to lead the space. In June 2014, Uber issued an additional $1.2B of stock at an astonishing pre-money value of $17B (Saitto and Stone, 2014), even though it apparently did not need these funds at this time. The reasoning was summed up by Yarow (2014): "[Uber CEO Travis Kalanick] wants to snuff out Lyft because it's the biggest threat to Uber's plans to take over the world." Apparently, the market believed there was a degree of posturing by Uber's investors to make the signal a very strong one. According to Saitto and Stone (2014), "some VC and PE investors bailed out [of the offering] after the valuation soared beyond $10B."

Uber reportedly used some of its newfound capital to provide monetary incentives to drivers and passengers to switch to Uber from Lyft (Soper, 2014). Apparently a strong financing round by Uber, and a weak one by Lyft, left Lyft vulnerable to defections by its own employees and customers, further worsening its prospects.

In this anecdote we see two different effects that are in line with the basic premise underlying our model. First, appropriately large investments at high prices can discourage competitors and/or their investors and create a self-fulfilling competitive advantage. Second, a financing round with a low valuation can have a negative effect on a firm's own prospects as employees, customers, or suppliers become wary. Indeed, Shontel (2013) reports that down-rounds and low price levels can be very demoralizing for employees because it reduces the perceived probability that the firm will survive in a competitive market. Conversely, therefore, an up-round with a high valuation can help avoid such problems and make attracting and retaining employees, customers, and suppliers much easier.

When social media startup LivingSocial completed a financing round at a disappointing valuation in February of 2013, reporting of the terms of the deal prompted the CEO to send out a memo to reassure employees, apparently to prevent departures and loss of morale. In the memo, the CEO specifically encouraged employees not to focus on the low valuation and suggested that many people are "overly enamored" with market value signals (Lawler, 2013).

Similar events occur when public company stock prices fall. A report titled "As Zynga stock price plummets, company hemorrhaging top talent" states that "since its December 2011 IPO, Zynga has lost 70% of its value. Worse still, some of its top executives and managerial talent are jumping ship" (Farivar, 2012). Groupon, another high flying startup, started losing talent as its stock fell by half or more in 2012 (Agrawal, 2012).

Another example of the positive impact of a high valuation is Facebook. A Russian Investment firm, Digital Sky Technologies (DST), invested an initial $200M in the firm at a valuation of $10B in May of 2009. In 2011 there was an additional financing round in which DST invested another $50M, along with a $450M investment by Goldman Sachs, at a $50B valuation, implying a 5-fold increase (Craig and Sorkin, 2011, Olson, 2011). It is suggested by Olson (2011) that Goldman's investment would not have occurred without the continuing involvement of DST. Johnson (2012) argues that DST's strategy "seems to boil down to a series of straightforward steps: first find a category leader like Facebook, Zynga or Groupon; then use heavy investment to make sure that they outpace their competition and stretch their lead even further; then continue pushing them, with more money if necessary, towards an IPO."

## 2. Related Literature

Much of the previous literature on incomplete contracts assumes that all involved parties have non-contractible effort or investments that help make the firm successful. While in our paper the entrepreneur's effort choice problem is similar to existing models, for the VC we instead focus on the decision to provide additional later-stage financing and thereby relay important private information to third parties. Thus, we are implicitly assuming that the entrepreneur's non-contractible effort is the most critical input for the success of the innovation effort at the early stages. With this assumption, existing theories would imply that the entrepreneur's ownership and bargaining power need to be protected. We argue

that it may often be poorly protected because of the VC's high ex post bargaining power, and show that the need to posture can alleviate this problem.[10]

The feedback effect in which prices impact the behavior of third parties plays a critical role in our paper, as it does in Subrahmanyam and Titman (2001), Goldstein and Guembel (2008), Khanna and Mathews (2012), and others, which argue that a firm's stock price affects how the firm is perceived by its customers, suppliers, employees, competitors, lenders, and other stakeholders.[11] In turn these perceptions influence purchase, supply, market entry and investment decisions connected with the firm or its market, which feeds back into the firm's cashflow. The unique element of the feedback effect in our paper is that the prices are not set in an arm's length financial market, but instead in a negotiation between the firm and its VC. We believe that price signals revealed in VC financing rounds are especially consequential as they are the most likely source of information to third parties about the future prospects of privately held startups.

Like here, Admati and Pfleiderer (1994) argue that despite its potential advantages, stage financing might create inefficiencies because of the venture capitalist's increased bargaining power at later stages. In their model, this problem is solved by having the VC commit ex ante to invest via a "fixed-fraction" contract, whereby it receives a fixed fraction of the payoff

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[10]Indeed, even if the VC had some important effort to put into the innovation stage, their natural bargaining power may be excessive relative to the entrepreneur's, and thus shifting incentives back toward the entrepreneur (through the need to signal) could be efficient, so our main results should not be affected by the inclusion of such a role. Furthermore, if the VC had some important effort to provide *after* the innovation stage and needed to be incentivized, even a purchase at a price high enough to convince third parties could correspond to the purchase of a large stake that keeps a lot of "skin in the game" for the VC if the investment is large enough.

[11]Also see Leland (1992), Khanna, Slezak, and Bradley (1994), Dow and Gorton (1997), Khanna and Sonti (2004), Attari, Banerjee, and Noe (2006), Ozdenoren and Yuan (2008), and Goldstein, Ozdenoren, and Yuan (2013) for theoretical studies involving feedback effects. Baker, Stein, and Wurgler (2003), Durnev, Morck, and Yeung (2004), Sunder (2004), Luo (2005), Chen, Goldstein, and Jiang (2007), Bakke and Whited (2010), and Edmans, Goldstein, and Jiang (2012) provide related empirical evidence.

and also funds the exact same fraction of investment at each stage. They rely on the fact that courts will be able to enforce this contract because of its simplicity (the fixed fraction does not vary with the state). They show that this simplicity together with the ability to place an ex ante bond by the VC makes their contract effectively renegotiation proof. However, observationally, VCs do not appear to invest in equal proportions in each round of financing. This could be because of the unpredictable nature of a startup's capital requirements and the difficulty of ensuring ex ante that sufficient outside investors can be attracted in the future, or that the VC will have sufficient funds to maintain its proportional investment. As a result, stage financing contracts are likely to be more complex and enforceability through courts more difficult and costly. Our contract, on the other hand, has the attraction that commitment arises naturally through the need for posturing, and there is no need to rely on enforcement through the courts.

Two existing empirical papers address the question of whether and to what extent VCs seem to take advantage of their bargaining power vis a vis entrepreneurs in later rounds. Atanasov, Ivanov, and Litvak (2012), study this by looking at incidences of lawsuits against VCs. Broughman and Fried (2012) look at the pricing of late stage rounds for a sample of Silicon Valley startups that exit via M&A. The latter paper finds evidence that VCs do not tend to take advantage of entrepreneurs even in situations where it seems most likely they would be able to do so. In fact, they find that the pricing is relatively high in these situations. While the two papers both conclude that there are forces limiting the ability or desire of VCs to take advantage of entrepreneurs, they do not explicitly test whether third party perceptions are a potential explanation. However, Broughman and Fried (2012) do mention the possibility that VCs may want to "window dress" to facilitate future fund raising and to avoid demoralizing employees with low valuations. While we would argue that our posturing mechanism is consistent with their results, their existing tests do not provide any way to differentiate between our explanation and other possible factors limiting ex post opportunism. We believe our results should motivate future broad-based empirical studies

concerned with the effect of posturing on VC round pricing in particular, and for multi-stage hold up problems in general.

Outside the VC setting, Aghion and Tirole (1994) provide a seminal analysis of the financing and control of innovative activities in an incomplete contracting framework. In their setting, a strategic investor both funds research and is the final user of the innovation. They show that the optimal allocation of property rights gives ownership to the party whose effort is more critical. Fulghieri and Sevilir (2009a) consider the optimality of different organizational and financial arrangements for an investor and research unit when there is a competing pair of firms.[12] In both of these papers, initial ownership stakes are irrelevant, as there is complete renegotiation ex post. In our setting, by contrast, the initial stake plays two important roles. First, it sets the entrepreneur's walk-away payoff in the event the project has an early exit, and thus can be calibrated to ensure optimal effort. Second, a larger stake for the VC makes it more difficult to posture (since its benefit from good third party decisions rises), leading to higher late stage prices. The staged financing model of Inderst, Mueller, and Munnich (2007) shares the former feature. Like in our model, they assume viable startups can generate a positive return even if not refinanced, so the initial stake sets a threat point for the renegotiation. Their model also admits the possibility of reduced entrepreneurial effort due to high ex post VC bargaining power. However, in their setting the solution to this lack of incentives is to force the startups to compete for scarce funds at the second stage.

Neher (1999) shows that staged financing can be efficient when the entrepreneur has the power to bargain away the VC's claim once the investment is sunk. Repullo and Suarez (1999), Schmidt (2003), and Bergemann and Hege (1997) focus on the effect of security design on the entrepreneur's and/or VC's effort incentives. Marx (1998) studies how security design

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[12]Fulghieri and Sevilir (2009b) also study the problem of commitment when a VC may extract surplus ex post and weaken ex ante incentives, but the mechanism they consider is very different, namely a decrease in the size of the VC's portfolio of investments.

affects liquidation decisions, while Cornelli and Yosha (2003) show that convertible securities can reduce "window dressing" by entrepreneurs. Axelson (2007) studies security design in a one period model when, like here, the investor has private information rather than the issuer. None of these papers consider how the contracts or pricing might be viewed by third parties.

Liu (2012) studies a setting in which takeover bids convey information to third party investors about the bidder's valuation, which can then affect future financing terms. The mechanism is very different from ours. For example, in our setting, overpricing only occurs when the VC has an existing stake in the firm, as the gain on its position gives it the necessary incentives to posture at higher prices. In Liu (2012), overbidding can occur without existing stakes because bidders may receive a benefit of overpricing in a subsequent security issue.

Our analysis also shares some elements with models of signaling to two audiences, in particular Gertner, Gibbons, and Scharfstein (1988), in which financial structure signals information about market demand (and hence firm value) to both financial markets and product market competitors. Our analysis differs in that we study a two-stage financial market interaction and show that the need to signal to third parties disciplines the second financing stage, so that the overall financial market equilibrium is more efficient. Our paper is also related to papers that relate overbidding behavior in takeovers to initial stake ownership. For example, Burkart (1995) and Singh (1998) show that bidders with toeholds are likely to overbid in equilibrium. Mathews (2007) shows that this fact can be exploited by a potential target and potential bidder to extract surplus from other bidders ex ante. In these papers the overbidding incentive comes from a desire to increase the sale price of their initial stake if they are a losing bidder, and is not related to the need to signal to outsiders.

# 3. The Model - Basic Framework

Consider a start-up firm owned by a wealth constrained entrepreneur ($E$) that needs financing over two stages. An initial investment of $I_1$ is needed at time zero to perform research and development for a new product. Conditional on development of a viable product, the owners of the firm can choose a safe "early exit" at time 2, or can take a risky bet on a "late exit" strategy that pays off at time 3.[13] The late exit strategy requires an additional investment of $I_2$ at time 2. We assume any capital above $I_1$ at time zero would be wasted by the entrepreneur, so stage financing is strictly optimal. Ex ante, there is a competitive venture capital market with multiple identical potential financiers.

Following the investment of $I_1$ at time zero, the development of a viable product depends on effort undertaken by $E$ at time 1. For convenience we assume $E$'s chosen effort level $e$ corresponds to the probability of the product becoming viable. Choosing an effort level $e$ costs the entrepreneur $c(e)$, where $c'(\cdot) > 0$ and $c''(\cdot) > 0$.

At time 2, if the product turns out to be non-viable the initial investment of $I_1$ is recovered via liquidation, but there is no additional value in the firm.[14] If the product turns out to be viable, then the firm is worth $\pi_1 > I_1$ in an early exit at time 2. If, instead, the firm remains independent and raises an additional investment of $I_2$ from its current venture capitalist (hereafter the "VC"), then firm value, realized at time 3, will be either $\pi_2$, where $\pi_2 > \pi_1$, or zero (i.e., choosing to pursue the risky late exit option results in either greater success or complete failure).[15]

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[13]The early exit opportunity could represent, for example, an early M&A exit where a young firm with a nascent product sells out to an existing firm in a related market, whereas the late exit strategy could represent an attempt to develop the firm's product and market more fully to achieve a more profitable IPO or late M&A exit. The structure and timing of payoffs is all that matters for the results.

[14]See the text following Proposition 1 for further discussion of the implications of this assumption.

[15]The assumption that the firm has to raise the second stage funding from its initial VC is motivated by the informational advantage that this VC acquires as a result of its close relationship with the firm. I.e., as

The ability to successfully exit late and realize $\pi_2$ at time 3 depends on the final state of nature. The state of nature is $\Theta \in \{G, B\}$, and the random variable $s$, which is continuously distributed over $[0, 1]$, gives the probability that the state is good. A publicly observable signal of $s$ is realized at time 2 (we use $s$ to denote both the random variable and the signal). The good state of nature represents an outcome where the firm and its product are of sufficiently high quality to complete a successful late exit.

Figure 1 illustrates the timeline of the game. Branches with dashed lines indicate random events chosen by nature, while those with solid lines are decisions by players in the game. Bold italics indicate final firm payoffs in different outcomes. To summarize, first an initial investment of $I_1$ is made at time zero. Next, $E$ chooses his effort level $e$ at time 1 and then nature determines whether the product is viable. If not viable, liquidation occurs at time 2. If viable, at time 2 the signal $s$ is observed and a late or early exit is chosen. If a late exit is chosen, $I_2$ must be invested at that time. Following an investment of $I_2$, the late exit is successful with probability $s$ at time 3.

# 4. Benchmark Models

In this section we consider two benchmark models built on the basic framework above. Understanding these models helps to illustrate the unique features of the contracting environment in our main Posturing model, which we specify and solve in Section 5.

## 4.1. Complete Contracting Model

We first consider a version of the model in which the time 2 signal of the random variable $s$ is contractible (i.e., it can be verified in a court of law). Since the VC market is assumed to be ex ante competitive, $E$ has all of the bargaining power at time zero and makes a

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discussed in the introduction, the firm would face a lemons problem if it were to approach another VC for second round funding.
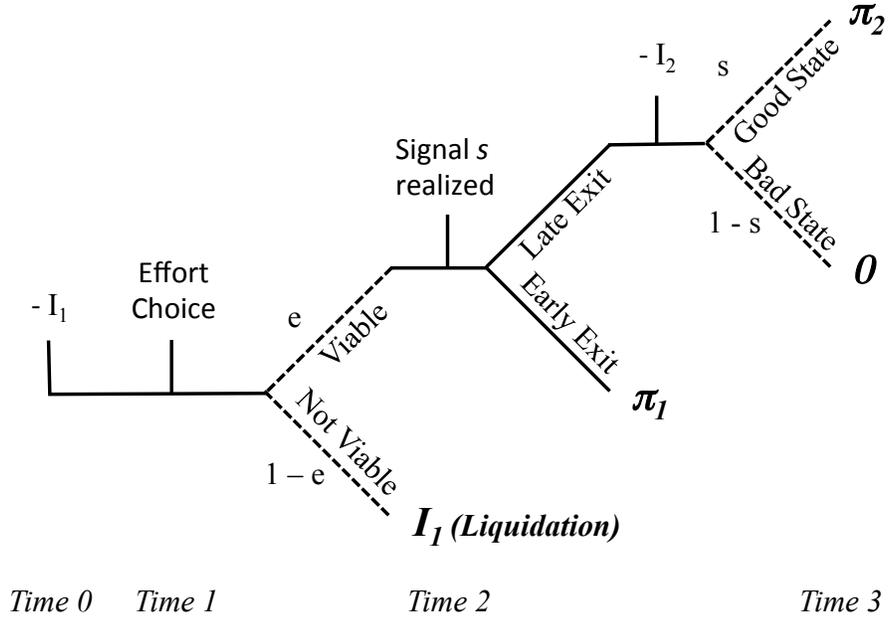
Figure 1: Timeline of the Base Model

take-it-or-leave it offer to a chosen VC for a funding contract. $E$ will optimally design a contract that maximizes overall surplus if possible. Such a contract can potentially include a non-negative side payment (hereafter $\tau$) from the VC to $E$ at time zero. Since $E$ has all of the bargaining power, the transfer $\tau$ will be set so as to satisfy a zero expected profit constraint for the VC.

Given this, $E$ will seek to ensure that an early exit is chosen at time 2 if the product is viable but $s$ is not sufficiently high, and the firm receives additional funding of $I_2$ and attempts a late exit if the product is viable and $s$ is sufficiently high. The signal $s$ is sufficiently high to support a late exit attempt if such an attempt is positive NPV in expectation, i.e., if $s \geq \underline{s}$ where:

$$\underline{s}\pi_2 - I_2 = \pi_1 \implies \underline{s} = \frac{I_2 + \pi_1}{\pi_2}. \tag{1}$$

In addition, the contract should ensure that $E$ will exert the first best level of effort, which solves

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$$\text{Max}_e \; e \left( Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - I_2) + Pr[s < \underline{s}]\pi_1 \right) + (1-e)I_1 - I_1 - c(e), \qquad (2)$$

$$s.t. \; e \in [0,1],$$

and has first order condition

$$c'(e) = Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - I_2) + Pr[s < \underline{s}]\pi_1 - I_1, \qquad (3)$$

where the second order condition is clearly satisfied given $c''(\cdot) > 0$.

Consider a contract that specifies an early exit given viability when $s < \underline{s}$, and a capital injection of $I_2$ from the VC for a late exit attempt given viability and $s \geq \underline{s}$. To fully specify the contract it simply remains to allocate the possible payoffs, $I_1$, $\pi_1$, and $\pi_2$. To be optimal and feasible the allocation must satisfy the VC's participation constraint, and calibrate E's effort to match the first best. Giving the VC a liquidation preference when the product is not viable will encourage effort by $E$, so we assume without loss of generality that the VC recovers the full payoff $I_1$ upon liquidation.[16]

We also assume that the contract allocates to the VC a proportion $\alpha_1$ of the early exit payoff $\pi_1$. To be consistent with how VC contracts are implemented in practice, we assume that the VC's total stake in the potential late exit payoff $\pi_2$ is

$$\alpha_1(1 - \alpha_2) + \alpha_2 \equiv \alpha, \qquad (4)$$

where $\alpha_1$ is the equity "purchased" by the VC at time zero, and $\alpha_2$ is the additional equity "purchased" at time 2 when the VC makes the later round investment of $I_2$, which dilutes $\alpha_1$. This, along with the VC's recovery of $I_1$ upon liquidation if the project is not viable, corresponds closely to real-life VC contracts, which in early rounds often consist of a redeemable convertible preferred security giving a high fixed payoff to the VC in the event of

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[16]This assumption is without loss of generality as it never constrains the parties away from achieving the maximum attainable efficiency. This is because it turns out that encouraging effort provision by the entrepreneur is always the binding constraint on efficiency when the first best cannot be achieved.

failure, and conversion into a standard equity claim in case of success (see, e.g., Sahlman (1990) and Kaplan and Stromberg (2003)). Note that the assumption of this contracting structure is without loss of generality since any arbitrary sharing rule conditioned on the different possible surplus realizations can be expressed in this form.

For simplicity, we assume here that the contract specifies a single $\alpha_2$ for all $s \geq \underline{s}$ ($\alpha_2$ could also be contingent on the specific realization of $s$, but the efficiency of the contract would not be affected). Given this, $E$'s effort choice problem will be

$$\underset{e}{\text{Max}}\ e(Pr[s < \underline{s}](1 - \alpha_1)\pi_1 + Pr[s \geq \underline{s}](1 - \alpha)E[s|s \geq \underline{s}]\pi_2) - c(e) \qquad (5)$$

$$s.t.\ e \in [0, 1].$$

The first-order condition is then

$$c'(e) = Pr[s < \underline{s}](1 - \alpha_1)\pi_1 + Pr[s \geq \underline{s}](1 - \alpha)E[s|s \geq \underline{s}]\pi_2, \qquad (6)$$

and the second order condition is clearly satisfied given $c''(\cdot) > 0$.

We have the following result (all proofs can be found in Appendix 2).

**Proposition 1** *As long as it is profitable for $E$ to seek funding at time zero, there exists a continuum of pairs $(\alpha_1, \alpha_2)$ that yield an optimal contract, where each such pair sets the right hand side of (6) equal to the right hand side of (3). Under such a contract, the first best is achieved and the VC's participation constraint is satisfied with a transfer from the VC to $E$ of $\tau = 0$.*

Because the parties can contract on whether the public signal is high enough to make a late exit positive NPV, they are able to achieve the first best. Note that $\tau$ is equal to zero in equilibrium when full efficiency is achieved (in all of our models) because of our assumption that the firm simply returns the initial investment of $I_1$ when the product is not viable. Changing this assumption such that the payoff in that state exceeds $I_1$ would simply shift the optimal $\tau$ upward without qualitatively changing any of the other results. However,

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assuming a smaller payoff than $I_1$ in this state would imply $\tau < 0$ (i.e., $E$ pays the VC up front), which is not possible because of the entrepreneur's wealth constraint. This would induce additional inefficiency in the equilibrium. We do not analyze this case here so that we can more easily focus on the contrast between the different equilibria we study.

## 4.2. Hold Up Model

Here we consider a variation of the above model in which the public signal $s$ is no longer verifiable so contracts cannot be written based on its realization. To illustrate the maximum potential for inefficiency from this contractual incompleteness, we assume that at time 2, the VC has all of the bargaining power and can make a take it or leave it offer to $E$ for providing additional funding of $I_2$ (though $E$ still has the bargaining power at time zero). The shift in bargaining power from $E$ to the VC over time reflects the fact that the VC's continued participation is crucial to raising additional later stage funds, while the entrepreneur's contribution to firm value is lessened after his effort is exerted.[17] Without loss of generality, we keep the same contracting framework as above, with a time zero contract that specifies full recovery of the liquidation value for the VC when the product is not viable (which will help maximize $E$'s effort), and an equity stake of $\alpha_1$ conditional on viability. If the VC finds it optimal to attempt a late exit, the time 2 renegotiation then determines the second round stake of $\alpha_2$, leading to the VC's final overall share of the late exit payoff, $\alpha_1(1 - \alpha_2) + \alpha_2$.

In this framework, because of the non-contractibility of $s$, if the initial contract tried to specify an $\alpha_2$ it would be meaningless as it would not constrain the VC in its renegotiation offer. The initial contract therefore serves to: (1) allocate the liquidation payoff and the early exit payoff in case one of those outcomes occurs, and (2) set the stage for the renegotiation if a late exit turns out to be optimal by establishing the parties' walkaway payoffs, $(1 - \alpha_1)\pi_1$

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[17]The complete shift in bargaining power makes the results as clear as possible, but such an extreme shift is not necessary for our results. As long as the VC gains sufficient advantage, the hold up problem remains relevant as do our comparisons to the Posturing model below.

for E and $\alpha_1\pi_1$ for the VC.

The concern with hold up is that it might result in too little entrepreneurial effort since $E$'s share of $\pi_2$ is constrained by the time 2 renegotiation. Indeed, in the renegotiation game the VC will take advantage of its bargaining power and offer $E$ an $\alpha_2$ that makes him indifferent between accepting the offer and taking his walkaway payoff. Specifically, whenever the product is viable and $s \geq \underline{s}$, the VC's optimal strategy is to offer to purchase a second stage stake that solves

$$(1 - \alpha_1(1 - \alpha_2) - \alpha_2)s\pi_2 = (1 - \alpha_1)\pi_1. \tag{7}$$

Solving for the second round stake, $\alpha_2$, gives

$$\alpha_2 = 1 - \frac{\pi_1}{s\pi_2} \equiv \alpha_2^H. \tag{8}$$

Since $\alpha_2^H$ does not depend on $\alpha_1$, it is clear that if this renegotiation reduces $E$'s effort below the first best for a given $\alpha_1$, a reduction in $\alpha_1$ (and thus a higher payoff to $E$ if an early exit is actually implemented) is the only way to increase $E$'s effort. The hold up problem will reduce efficiency when this is no longer feasible, i.e., when the first round stake for the VC needed to induce the optimal level of effort by $E$ is negative. We assume a negative $\alpha_1$ is infeasible because it violates limited liability.[18] The best that can be done when $\alpha_1$ is constrained to be positive is to ensure $E$ a payoff of $\pi_1$ if the project is viable and no payoff if it is not. However, this will not necessarily be enough in the presence of hold up, and efficiency will decrease whenever $\pi_1$ is less than the right hand side of (3), the first order

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[18]Essentially, a contract with a negative $\alpha_1$ would correspond to an extra payment out of the VC's own pocket to the entrepreneur in the event of an early exit, which is not a contract we see in reality and violates the usual limited liability feature of securities bought by VCs. While the contracts we see in reality may require additional investment funds from the VC (i.e., milestone payments), such payments occur under continuation, not upon an exit event. Also, such payments do not directly compensate the entrepreneur. In addition, it may be difficult to enforce such a contract in reality (i.e., it may be difficult to specify in exactly what circumstances the payment is triggered, since real life outcomes are not as stark as those in the model).

condition for first best effort, i.e., whenever

$$\pi_1 < Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - I_2) + Pr[s < \underline{s}]\pi_1 - I_1 \tag{9}$$

$$\implies \pi_1 < E[s|s \geq \underline{s}]\pi_2 - I_2 - \frac{I_1}{Pr[s \geq \underline{s}]}.$$

When this inequality holds, the first best cannot be achieved and efficiency is lower than in the Complete Contracting model. However, when this inequality does *not* hold, efficient effort can be elicited with a positive $\alpha_1$, so the Hold Up model simply pins down the equilibrium equity stakes and achieves the same level of efficiency as the Compete Contracting model. In particular, since $\alpha_2^H$ is determined by the renegotiation game, $\alpha_1$ will be chosen to elicit optimal effort. $E$'s effort choice problem, given that he is held to a payoff of $(1 - \alpha_1)\pi_1$ whenever the product is viable and nothing otherwise, is

$$\underset{e}{\text{Max}} \; e(1 - \alpha_1)\pi_1 - c(e) \tag{10}$$

$$s.t. \; e \in [0, 1].$$

with first-order condition

$$c'(e) = (1 - \alpha_1)\pi_1, \tag{11}$$

and the second order condition is again clearly satisfied given $c''(\cdot) > 0$.

The optimal $\alpha_1$ then sets the right hand side of (3) equal to the right hand side of (11) as follows

$$Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - I_2) + Pr[s < \underline{s}]\pi_1 - I_1 = (1 - \alpha_1^H)\pi_1 \tag{12}$$

$$\implies \alpha_1^H = \frac{I_1 + Pr[s \geq \underline{s}](I_2 + \pi_1 - E[s|s \geq \underline{s}]\pi_2)}{\pi_1} \tag{13}$$

We have the following result.

**Proposition 2** *(a) When $\pi_1 < E[s|s \geq \underline{s}]\pi_2 - I_2 - \frac{I_1}{Pr[s \geq \underline{s}]}$, full efficiency cannot be achieved in the Hold Up model because there will be too little entrepreneurial effort. In this case,*

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*whenever it is profitable for E to seek funding at time zero, he offers to the VC (and the VC accepts) a stake of $\alpha_1 = 0$ in the initial contract, and the up front transfer from the VC to E, $\tau$, is positive. At time 2, the VC offers to purchase from E (and E accepts) a stake of $\alpha_2 = \alpha_2^H$ if the product is viable and $s \geq \underline{s}$.*

*(b) When $\pi_1 \geq E[s|s \geq \underline{s}]\pi_2 - I_2 - \frac{I_1}{Pr[s \geq \underline{s}]}$, full efficiency is achieved in the Hold Up model. In this case, whenever it is profitable for E to seek funding at time zero he offers to the VC (and the VC accepts) a stake of $\alpha_1 = \alpha_1^H$ in the initial contract, and the up front transfer from the VC to E is $\tau = 0$. At time 2, the VC offers to purchase from E (and E accepts) a stake of $\alpha_2 = \alpha_2^H$ if the product is viable and $s \geq \underline{s}$.*

Thus, we see that hold up causes inefficiency when the early exit payoff is relatively low, as the entrepreneur's share of this payoff is the source of his incentives given the onerous renegotiation game. In these cases, the VC takes the full liquidation payoff if the project ends up non-viable but gives up any claim on a payoff from an early exit, to incentivize $E$ as far as possible. Thus, the VC's upside comes solely from the late exit possibility, where it is able to exploit its renegotiation power.

# 5. Posturing Model

We now turn to our full Posturing model. Here, we assume that there is no longer a public signal of $s$, but the VC *privately* observes $s$ just before time 2. Furthermore, we assume that third parties critical to the firm's success can observe only the terms of the financing contracts between the Entrepreneur and VC, and form beliefs about $s$ on that basis just after time 2. If they are convinced that $s$ is sufficiently high (defined below) *and* the state ultimately turns out to be good, $G$, then the firm can have a successful late exit at time 3 and return $\pi_2$. If *either* the third parties are not convinced *or* the state turns out to be bad, $B$, then a late exit attempt will ultimately fail and the payoff is zero. These assumptions alter the timeline of the model by adding a decision node for the third parties to Figure 1
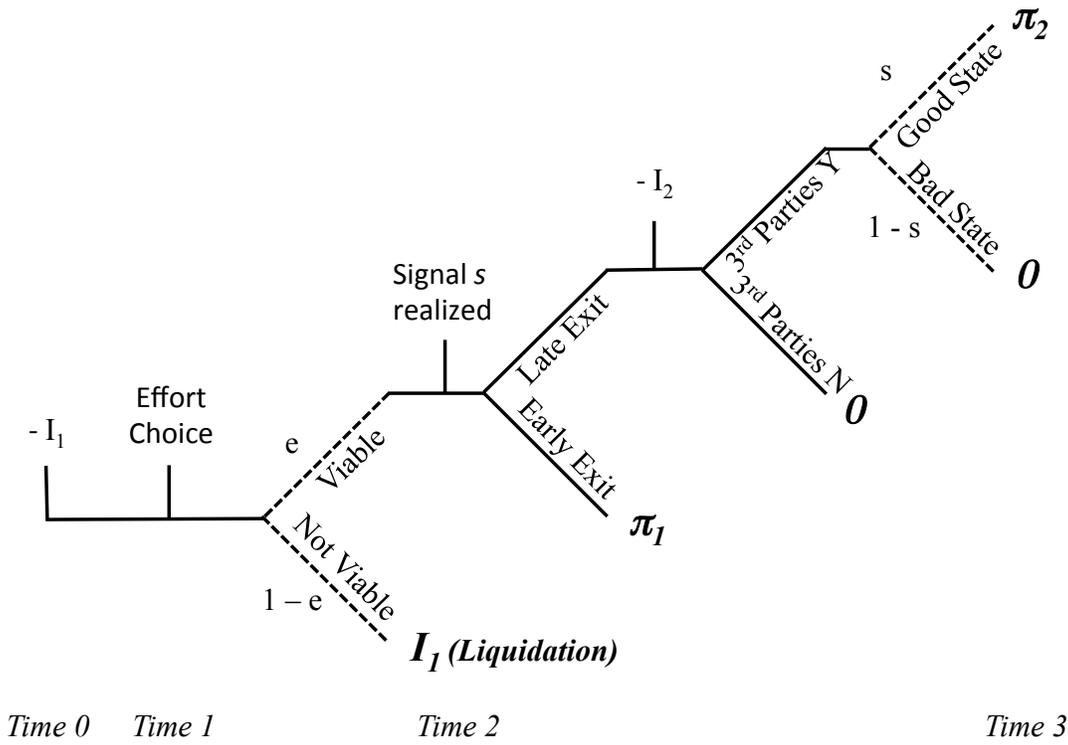
(see Figure 2).



Figure 2: Timeline of the Posturing Model

We assume that third party beliefs about $s$ are sufficiently strong to support a late exit attempt if they infer that the probability of the good state is at least $q$, where $q > E[s]$. We purposefully choose this reduced form characterization of third party beliefs and actions because we believe the basic model will apply to a wide range of scenarios (as discussed in the Introduction) in which different types of third parties may take actions that affect firm value after forming beliefs about the firm's quality.[19]

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[19]Many third parties discussed in the introduction, such as current or future employees, customers and investors, are clearly more likely to take actions that increase firm value when they believe the firm or its market are of high quality. Using posturing to discourage a (potential) competitor is more subtle, as signaling a high value could, in some circumstances, encourage competitor entry (e.g., because it indicates a large market size). However, we believe our model will apply in any situation where the strength of the firm-specific component of the signal (i.e, the quality of the firm's products and its ability to dominate the

For convenience, we define $\hat{s}$ as the signal that satisfies $E[s|s \geq \hat{s}] = q$, i.e., it is the minimum $s$ such that if third parties infer only that $s \geq \hat{s}$, their beliefs will be sufficiently strong to support a late exit attempt. Throughout we assume that $\hat{s} \geq \underline{s}$, where $\underline{s}$ is the cutoff level of $s$ at which risking a late exit is positive NPV. Thus $\hat{s}$ acts as a measure of third party "skepticism."

These assumptions put the onus on the VC to convince the third parties by signaling that $s$ is sufficiently high. We assume that the only way to credibly signal $s$ is through the terms of the time 2 funding contract. Whereas $E$ makes a take it or leave it offer to a chosen VC at time zero, we continue to assume that the VC makes a take-it-or-leave-it offer to the entrepreneur at time 2 for a new contract to provide funding of $I_2$. Notice that, as in the Hold Up model, we thus maintain the assumption of a shift in bargaining power from $E$ to the VC over time. Later we also consider what would happen if the bargaining power remained with $E$ at time 2.

We derive a pure strategy Perfect Bayesian equilibrium (PBE) using backward induction. We begin with the time 2 bargaining game between $E$ and the VC. We maintain the same assumptions as in the Hold Up model about the form of the contracts.

## 5.1. The Second Stage Negotiation

Consider the problem at time 2 conditional on the discovery of a viable product (as before, if the product is not viable, the project is liquidated and the final payoff $I_1$ is distributed to the VC). The VC has privately observed $s$ and can make a take-it-or-leave-it offer to provide funding of $I_2$ in exchange for an additional equity stake $\alpha_2$, leading to a final share of firm value for the VC equal to $\alpha \equiv \alpha_1(1 - \alpha_2) + \alpha_2$. After the time 2 funding contract is finalized, third parties observe the contact and form their beliefs about $s$.

As the financing terms (in particular $\alpha_1$, $\alpha_2$, $I_1$, and $I_2$) are the only conditioning infor-

market) outweighs the market-wide component (i.e., this is a very large/profitable market). See Appendix 1 for such an example.

mation available to the third parties, the VC will take into account how the contract terms affect their beliefs. In particular, whenever the VC prefers to fund the firm instead of letting it be sold in an early exit, it would like to generate sufficient "excitement" about the firm through a high issue price to induce desirable third party actions. In other words, the VC will take into account the feedback loop created by third party beliefs, in that their resulting actions increase firm value and ex post justify the VC's time 2 purchase of shares at a high price. However, anytime the VC believes the third party beliefs will not be sufficiently strong, or that providing additional funding is negative NPV, its optimal strategy is to simply let $E$ sell the firm for $\pi_1$ in an early exit.

From here on we focus on the most efficient time 2 signaling equilibrium, i.e., the one in which the NPV of the firm is maximized. While other PBEs exist, they are all less efficient and also less profitable for the VC. In addition, we show in Appendix 3 that the most efficient equilibrium is the only equilibrium that survives a continuous-type version of the Divinity refinement of Banks and Sobel (1987).

In the most efficient equilibrium, conditional on a viable product the VC's signal can be in one of two "pools." If its signal is in one pool the VC chooses not to make an offer (which triggers an early exit), while if its signal is in the other pool it purchases an additional stake, defined as $\alpha_2^P$, following which the third party beliefs are sufficiently strong to support a late exit. Clearly, if a VC with a given signal finds it optimal to buy a stake of $\alpha_2^P$ in order to convince third parties, then it will also find it optimal to buy the same stake with a higher signal (the purchase will be more profitable the higher is $s$). Thus, the equilibrium must have a "threshold" structure with a cutoff signal, say $s^*$, such that the VC purchases a stake $\alpha_2^P$ if its signal is above $s^*$, while if its signal is below $s^*$ it foregoes the possibility of a late exit.[20] The most efficient equilibrium has $s^* = \hat{s}$ as that ensures third party participation for the maximum number of positive NPV late exit attempts.

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[20]E's acceptance of the offer is, obviously, also required, but, as will be shown below, E's participation constraint will not bind, i.e., E will always accept whenever the third parties' beliefs are sufficiently strong.

Given a threshold $\hat{s}$, the proposed stake $\alpha_2^P$ must be such that a VC of type $\hat{s}$ is just indifferent to purchasing the additional stake, so that all higher types strictly prefer this purchase (if it convinces the third parties), while all lower types strictly prefer an early exit. This is what is required to convince the third parties that $s \geq \hat{s}$. The indifference condition that defines $\alpha_2^P$ as a function of $\hat{s}$ can therefore be expressed as

$$(\alpha_1(1 - \alpha_2^P) + \alpha_2^P)\hat{s}\pi_2 - I_2 = \alpha_1\pi_1 \tag{14}$$

$$\implies \alpha_2^P = \frac{I_2 - \alpha_1(\hat{s}\pi_2 - \pi_1)}{(1 - \alpha_1)\hat{s}\pi_2}. \tag{15}$$

This equity stake is easily shown to be increasing in $I_2$ and $\pi_1$, and decreasing in $\hat{s}$, $\alpha_1$, and $\pi_2$. It is also straightforward to show that $\alpha_2^P < \alpha_2^H$ always holds.[21]

We have the following result.

**Proposition 3** *Conditional on a viable product, the most efficient signaling equilibrium has a critical signal, $\hat{s}$, such that in equilibrium the VC chooses not to buy an additional stake for all $s < \hat{s}$, and demands a stake of $\alpha_2^P \leq \alpha_2^H$ in exchange for funding of $I_2$ for all $s \geq \hat{s}$. Furthermore, third parties believe that $s \geq \hat{s}$ (and E accepts) anytime a stake of $\alpha_2^P$ is proposed; otherwise an early exit is chosen. Expected firm value (from the VC's perspective) is $\pi_1$ for all $s < \hat{s}$ and $s\pi_2$ for all $s \geq \hat{s}$.*

Since the VC is indifferent to this stake purchase at $s = \hat{s}$, it must be leaving significant money on the table at higher signals, which implies that the entrepreneur is receiving a significant share of the surplus despite his lack of formal bargaining power. In particular, he does better in expectation than his walkaway payoff of $(1 - \alpha_1)\pi_1$, which is his continuation payoff for all $s$ in the Hold Up model. The price of the second stage investment can be expressed as $\frac{I_2}{\alpha_2}$, so the fact that $E$ has a higher continuation payoff implies that the VC is

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[21]To see this, first note that (15) is decreasing in $\alpha_1$ and equals $\frac{I_2}{\hat{s}\pi_2}$ at $\alpha_1 = 0$. From (8), $\alpha_2^H$ can be expressed as $\frac{s\pi_2 - \pi_1}{s\pi_2}$. Replacing $s$ with $\underline{s}$ would yield $\frac{s\pi_2 - \pi_1}{\underline{s}\pi_2}$ which is clearly greater than $\frac{I_2}{\hat{s}\pi_2}$ (the numerator is the same and the denominator is smaller). The inequality follows since $\frac{s\pi_2 - \pi_1}{s\pi_2}$ is increasing in $s$.

buying at higher prices at this stage compared to the Hold Up model (through a lower $\alpha_2$ for a given $I_2$). This is the sense in which the VC uses higher pricing to generate excitement and convince the third parties, which significantly benefits the entrepreneur. Essentially, the need to posture causes the VC to bargain less forcefully, leading to a higher pre-money value and a higher continuation payoff to $E$.

It is interesting to note the difference between our signaling equilibrium and traditional models such as Leland and Pyle (1977, "LP"), where the owner signals a high value by retaining a large portion of the firm. The reason for the difference is that in our setting the signaler is a buyer of equity, while in LP the signaler is a seller of equity. Thus, while in LP lower types will not mimic high types because retaining a large amount of low value equity is expensive despite getting a higher price for the sold equity, here the lower types will not mimic because paying too high of a price for new equity is negative NPV given low fundamentals despite the positive signal that convinces the third parties.

It is also important to note that the need for posturing often eliminates any benefit to the VC from having the formal bargaining power at time 2. To see this, consider how the model would change if $E$ were to continue to hold the bargaining power at this stage. In this case, holding the threshold signal $s^*$ constant at $\hat{s}$, $E$ would offer an equity stake intended to cause the VC to accept only if $s \geq \hat{s}$ (i.e., a screening contract), and otherwise let the firm be sold. But the condition that determines the equity stake that would accomplish this is exactly (15), so the stake would be the same. Thus, whenever $E$ would optimally choose to have all VC types with $s \geq \hat{s}$ participate, the need to posture essentially puts the bargaining power back in $E$'s hands. To put it another way, the formal allocation of bargaining power at this stage is then irrelevant because of the need to posture.[22]

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[22]It is not always the case that $E$ would want to choose the same $s^*$ as in the equilibrium we focus on, where $s^* = \hat{s}$. He would sometimes choose a higher $s^*$ when $\hat{s}$ is low in order to capture a greater part of the VC's private information rent. In such cases, the shift in bargaining power to the VC does benefit the VC somewhat. However, our statement that the allocation of bargaining power is irrelevant will hold whenever $\hat{s}$ is sufficiently high.

In contrast, however, the allocation of bargaining power always affects the Hold Up equilibrium. If the bargaining power remained entirely with $E$ at stage 2 in the Hold Up model, then he would optimally offer a stake that held the VC to its walkaway payoff. This would leave $E$ with a much higher continuation payoff and make it easier to induce optimal effort in the Hold Up model than in the Posturing model. Thus, what is needed for our comparisons between the two models to hold is that the VC gain sufficient bargaining advantage so that it leaves $E$ a lower continuation payoff in the Hold Up model than in the Posturing model.

## 5.2.  The First Stage Negotiation

As above, the optimal time zero contract offered by $E$ will set $\alpha_1$ to elicit first best effort if possible. Intuitively, $\alpha_1$ should be larger in the Posturing model than in the Hold Up model since $\alpha_2$ is smaller. Indeed, whereas in the Hold Up model the optimal $\alpha_1$ is often zero, in the Posturing model a positive $\alpha_1$ is often required to ensure that there is not over-provision of effort, since $E$ now captures much more of the surplus from the late exit strategy.

Formally, E's effort choice problem is identical to (5) but with $\underline{s}$ replaced by $\hat{s}$. Setting the right hand side of (6) equal to the right hand side of (3), replacing $\underline{s}$ with $\hat{s}$ and $\alpha$ with $\alpha_1(1 - \alpha_2^P) + \alpha_2^P$, and solving for the optimal $\alpha_1$ gives

$$\alpha_1 = \frac{\hat{s}I_1 + Pr[s \geq \hat{s}]I_2(\hat{s} - E[s|s \geq \hat{s}])}{\pi_1(\hat{s}Pr[s < \hat{s}] + E[s|s \geq \hat{s}]Pr[s \geq \hat{s}])} \equiv \alpha_1^P. \tag{16}$$

We have the following result.

**Proposition 4** *In the unique equilibrium of the time zero bargaining game, whenever $\alpha_1^P \geq 0$ and it is profitable for $E$ to seek funding at time zero, $E$ offers a contract to the VC which gives it an equity stake of size $\alpha_1 = \alpha_1^P \geq \alpha_1^H$ in return for funding of $I_1$, and the first best is achieved. In this case the monetary transfer from the VC to $E$ is $\tau = 0$. When $\alpha_1^P < 0$ and it is positive NPV for $E$ to seek funding, $E$ offers a contract to the VC which gives it an*

*equity stake of size $\alpha_1 = 0$ in return for funding of $I_1$, and there is less than first best effort by E. In this case, the monetary transfer $\tau$ from the $VC$ to E is positive.*

Since the VC takes less advantage of its bargaining power in the Posturing model, it extracts less surplus from the entrepreneur ex post, which implies that its initial stake, $\alpha_1^P$, can be larger and still provide $E$ with sufficient incentives to provide optimal effort.

# 6. Efficiency Implications

An important consequence of the implicit shift in bargaining power back toward $E$ is that the Posturing equilibrium will often be more efficient. In fact, we have the following efficiency result.

**Proposition 5** *Whenever the equilibrium in the Hold Up model is inefficient, i.e., $\pi_1 < E[s|s \geq \underline{s}]\pi_2 - I_2 - \frac{I_1}{Pr[s \geq \underline{s}]}$, efficiency is greater in the Posturing model than in the Hold Up model as long as $\hat{s}$ is not too large. Whenever the equilibrium in the Hold Up model is efficient, i.e., $\pi_1 \geq E[s|s \geq \underline{s}]\pi_2 - I_2 - \frac{I_1}{Pr[s \geq \underline{s}]}$, the Posturing model is weakly less efficient.*

This result shows that the need to posture can actually increase firm value by eliciting greater effort from $E$ and thus enabling a more efficient ex ante contract. This will be more likely the more severe is the hold up problem. This occurs because the need for posturing allows the VC to commit not to expropriate $E$'s rents in the continuation stage. Thus, $E$ realizes that even though bargaining power passes to the VC in later rounds, the VC is limited in exploiting it. Posturing therefore makes it more likely that the entrepreneur is willing to enter into a staged financing contract in these circumstances. On the other hand, when the Hold Up problem is not as severe, or the Hold Up model is fully efficient, the need to convince third parties can make the Posturing equilibrium less efficient because some profitable late exit attempts are lost.

In Figure 3 below we illustrate the efficiency results through a numerical example where the entrepreneur's effort cost function takes the form $c(e) = be^2$ and $s$ is distributed uniformly

on $[0,1]$. We first consider the case where the Posturing model is as efficient as possible, i.e., $\hat{s} = \underline{s}$, as this keeps the range of signals $s$ with late exit attempts constant across the two models. We set the model's base parameters to the following values: $I_1 = 2$, $I_2 = 5$, $\pi_1 = 15$, $\pi_2 = 45$, and $b = 12$, which corresponds to the mid-point of the x-axis on the graph. We then vary $\pi_1$ up and down, allowing $\pi_2$ to adjust such that the first best firm value (i.e., the firm value achievable in the Complete Contracting model) is held constant across the range of $\pi_1$'s (represented by the dotted line at the top of the figure).[23] This gives us a measure of the severity of the potential hold up problem - the lower is $\pi_1$ holding first best firm value constant, the greater is the hold up problem since $\pi_1$ is the source of incentives for $E$ in the Hold Up model. As expected, the more severe is the potential for holdup, the more relatively efficient is the Posturing model. Note that for the right hand side of the graph ($\pi_1 > 15$), the Posturing model is fully efficient ($\alpha_1^P > 0$), while to the left hand side of the graph ($\pi_1 < 15$), both models are inefficient ($\alpha_1$ runs into the positivity constraint in both models). However, as is clearly shown, the inefficiency in the Posturing model is very small relative to the inefficiency in the Hold Up model.

In Figure 4 we perform the same exercise with the same base parameters, but for the case $\hat{s} = \underline{s} + 0.25 * (1 - \underline{s})$, so that the bottom 25% of profitable late exit attempts are lost in the Posturing model due to third party skepticism. This decreases the efficiency of the Posturing equilibrium without affecting the Hold Up equilibrium. The loss of efficiency in the Posturing model is more severe for lower $\pi_1$ because these are the cases with lower $\underline{s}$ and therefore a larger range of profitable late exit attempts are lost. Note that the Posturing model's *relative* efficiency is still greater when the hold up problem is more severe.

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[23]In this example, first best value at $\pi_1 = 15$ (the midpoint) is equal to 8.3, and here $\pi_2 = 45$. For $\pi_1 = 12$ for instance, the $\pi_2$ which keeps the first best value at 8.3 is 47.8. Keeping first best value fixed at 8.3 highlights the inefficiency created by the hold up problem vis a vis the posturing model.
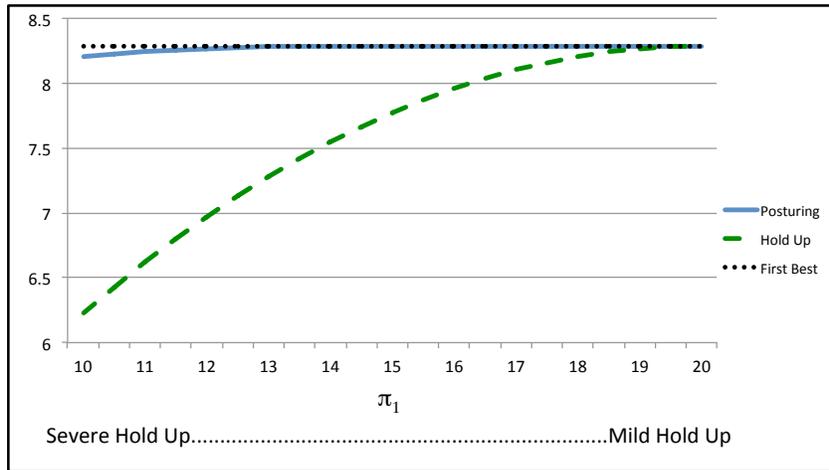
Figure 3: Ex Ante Firm Value as a Function of Hold Up Severity with $\hat{s} = \underline{s}$
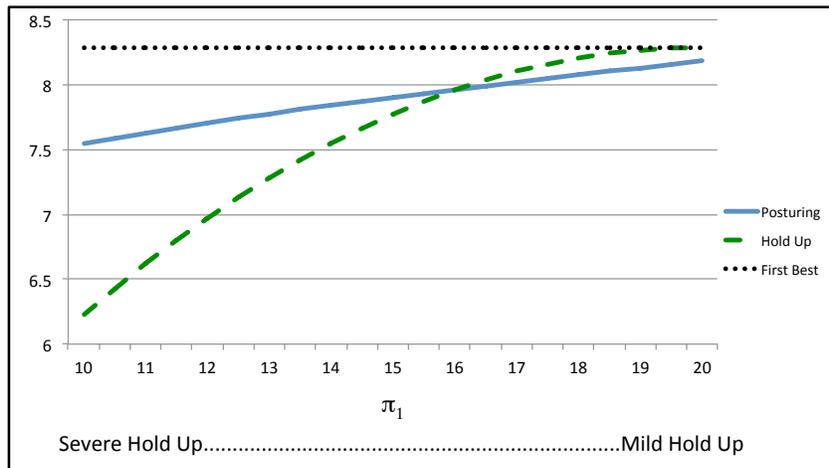


Figure 4: Ex Ante Firm Value as a Function of Hold Up Severity with $\hat{s} = \underline{s} + 0.25 * (1 - \underline{s}))$

# 7. Empirical Implications

In this section we explore the empirical implications of our model. First consider in greater detail how the second round equity purchase is priced in the Posturing versus the Hold Up equilibria. As noted above, the implied price per share of the purchase can be expressed as $\frac{I_2}{\alpha_2}$. First consider $\alpha_2 = \alpha_2^P$, i.e., the Posturing model. If $\alpha_1 = 0$, the price reduces to $\frac{I_2}{\alpha_2^P} = \hat{s}\pi_2$, which is equal to expected firm value per share conditional on $s = \hat{s}$. If the VC has no existing stake, it is willing to pay no more than expected firm value for the stock. From above, the stock must be priced such that the VC with the lowest signal in the pool, $\hat{s}$, is just indifferent over the purchase. Thus, the price must reflect expected firm value from the perspective of the VC given that signal. However, since this price holds for the entire pool of signals $s \geq \hat{s}$, if the VC's initial equity stake is zero the equity that is purchased at time 2 will on average be underpriced relative to fundamentals.

Turning to the Hold Up model, given the result that $\alpha_2^H > \alpha_2^P$, the stake sold to the VC at time 2 will be underpriced even more than in the posturing model. This is intuitive since the lack of need to posture through the time 2 contract frees up the VC to exploit its bargaining power, which results in it buying its time 2 stake at a lower price. Thus, the need to posture unambiguously increases the purchase price per share observed in the second round.

However, since $\alpha_2^P$ is decreasing in $\alpha_1$, the purchase price in the posturing equilibrium must rise as the VC's pre-existing stake grows. Indeed, $\alpha_2^P$ can become quite small for higher levels of $\alpha_1$, or even approach zero, implying an effectively infinite purchase price. The reason why the time 2 stake size decreases in the VC's time 1 stake is because a higher initial stake makes it harder for the VC to convince the third parties that its signal is high (since by convincing third parties it also gets a boost to the value of its initial stake). In this sense, creating the feedback loop from time 2 purchase price to value becomes more difficult. Thus, to maximize firm value, the signal must become stronger, even to the extent that the

purchase price is inflated above fundamental value.

Furthermore, the endogenous choice of $\alpha_1$ *reinforces* the result that the need for posturing increases the VC's later round purchase price, as the equilibrium $\alpha_1$ is higher in the Posturing model. Thus, the potential for greater overall efficiency in the Posturing equilibrium (which is reflected in both a higher $\alpha_1$ that achieves optimal effort and a higher likelihood of funding since project NPV is higher) is directly tied to higher later stage (and lower early stage) prices.

Given these comparisons, cross sectional differences in price paths and efficiency can be expected depending on whether the Posturing or Hold Up model is applicable. Putting all of these observations together, we have three important empirical implications of our model:

***Implication 1:*** A steeper price path across VC financing rounds should be observed in industries where posturing is more likely.

***Implication 2:*** Prices in later stage financing rounds are more likely to be inflated above fundamental value in such industries.

***Implication 3:*** A higher probability of initial funding *and* greater rates of ex post success should be observed in such industries.

Posturing is more likely to occur in industries where third party actions are important, third parties are not directly controlled by the firm, and where they are skeptical about a firm's prospects and therefore harder to persuade. As noted in the introduction, some industry characteristics that could predict posturing are the importance of human capital and difficulty of retaining skilled employees (e.g., employees of software/tech companies), the need to attract a large network of independent contractors to use the firm's innovation or create complementary products (e.g., app developers or users for a mobile ecosystem or social media platform), and more generally any industry where employees, customers, or suppliers have good alternative options (e.g. fast growing industries with multiple competing firms). Similarly, posturing to deter competition is more likely where multiple technologies or brands vie for market leadership, and earlier revelation of a competitive advantage could

forestall lengthy price wars or potential entry by new entrants (i.e., newer markets where the important competitive edge held by some firms is not obvious).

Next we explore some comparative statics of our model to derive additional implications. When $s$ is uniformly distributed we have an unambiguous set of results with respect to $\hat{s}$, which measures how difficult it is to convince the third parties. (Note that all comparative statics in this section with respect to the various stake sizes ($\alpha$'s) are derived under the assumption that there is an interior solution for that stake size in $(0,1)$).

**Proposition 6** *Assume $s$ is uniformly distributed on $[0,1]$. Then, in equilibrium, $\alpha_1^P$ is increasing in $\hat{s}$, while $\alpha_2^P$ is decreasing in $\hat{s}$.*

An increase in $\hat{s}$ corresponds to an increase in the difficulty of convincing third parties that the firm's prospects are sufficiently good, i.e., a higher level of skepticism with respect to firm prospects. In the Posturing model this directly decreases $\alpha_2^P$ as the VC is required to signal a higher value by buying at a higher price at the later stage. In addition, an increase in $\hat{s}$ decreases the firm's ex ante expected profitability (a late exit will be feasible in fewer states). Thus, the initial stake increases to reduce $E$'s effort given the lower profitability. This indirectly decreases the second period stake and amplifies the direct effect of $\hat{s}$ on the second stage price. We thus have the following implication:

***Implication 4:*** An increase in third party skepticism should lead to higher second stage prices and lower first stage prices in industries where posturing is likely.

Below in Figure 5 we illustrate this pricing effect using the numerical example from Figures 3 and 4. Specifically, we graph the effective second stage price for the Posturing model (the thin solid line) as $\hat{s}$ increases, as well as the (static) second stage price from the Hold Up model (the dashed line) assuming that $s = \underline{s}$ (which corresponds to the highest second stage price that can be observed in that model). In addition, the thicker solid line gives the actual expected firm value conditional on $s \geq \hat{s}$, or $\frac{1+\hat{s}}{2}\pi_2$, as a reference point. As this figure clearly shows, the Posturing model involves stake purchases in the second round at prices inflated above fundamentals over a large part of the parameter space, while the

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Hold Up model never does. In addition, the price inflation in the Posturing model can be quite extreme as the third parties become harder to convince.
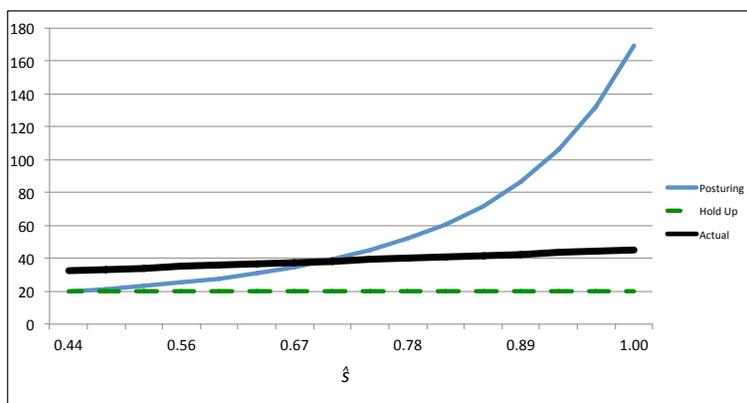


Figure 5: Second Stage Price Per Share as a Function of Third Party Skepticism, $\hat{s}$

Another set of results comes from variation in the profitability of a late versus an early exit. In particular, consider an increase in $\pi_2$ holding $\pi_1$ constant. This will imply that the hold up problem is more significant since there is relatively less value available without additional financing. This will make the Hold Up model relatively less efficient, while tightening the Posturing constraint (i.e., making it harder to signal since lower types have more incentive to pretend to be a higher type). In fact, we have the following result:

**Proposition 7** *In equilibrium, $\alpha_1^P$ ($\alpha_1^H$) is invariant (decreasing) in $\pi_2$, while $\alpha_2^P$ ($\alpha_2^H$) is decreasing (increasing) in $\pi_2$.*

In the Posturing model, as it becomes harder to signal the VC must leave more ex post surplus to the entrepreneur, implying a lower late stage stake. However, this does not affect the first stage stake since the greater profitability of the project also implies higher optimal effort. In the Hold Up model, on the other hand, the increase in $\pi_2$ means that the VC gets an even greater proportion of the ex post surplus, so the first round stake must decrease to increase $E$'s effort. We thus have the following implication:

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***Implication 5:*** When the profitability of a late exit increases compared to an early exit (making the hold up problem more severe), a steeper price path should be observed in industries where posturing is likely, while a flatter price path should be observed in industries where it is not.

We also have a number of comparative statics with respect to the investment costs.

**Proposition 8** *In equilibrium, $\alpha_1^P$ ($\alpha_1^H$) is increasing (increasing) in $I_1$ and decreasing (increasing) in $I_2$, while $\alpha_2^P$ is decreasing in $I_1$ and increasing in $I_2$, and $\alpha_2^H$ is unaffected by both. Furthermore, the first stage price is decreasing in $I_1$ for both the Posturing and Hold Up models, and the second stage price in the Posturing model is increasing in $I_1$.*

When $I_1$ increases, all else equal the project is less profitable. In both models, this implies a larger stake for the VC at time 1 because it is optimal to reduce $E$'s effort when the project is less profitable. In the Posturing model this also decreases the time 2 stake taken by the VC indirectly. Thus, in that model, transactions with higher later-stage pricing and lower early-stage pricing will correspond to those with higher initial investment costs. This yields the following implication:

***Implication 6:*** When early stage investment costs rise, a steeper price path should be observed.

An increase in $I_2$ both decreases the profitability of the project, reducing the optimal effort level, and affects the bargaining game and continuation payoffs for the later stage in the Posturing model. On balance, although optimal effort should be lower, we get a higher $\alpha_1$ and lower early stage pricing in the Posturing model because the negative effect on $E$'s continuation payoff is dominant. In the Hold Up model, since the second stage bargaining game is not affected the only relevant force is the reduction in optimal effort, so the first round stake increases. This yields our final implication:

***Implication 7:*** When late stage investment costs rise, a higher first round price should be observed in industries where posturing is likely, and a lower first round price should be observed in industries where it is not.

# 8.  Conclusion

We show that the need to signal high values to third parties can have a significant impact on the hold-up problem inherent in many multi-stage relationships, such as those between entrepreneurs and venture capitalists. If potential competitors are eager to enter the firm's market, or employees, customers, suppliers, or future investors are reluctant to deal with the firm, the venture capitalist can have a strong incentive to purchase at high prices in later financing rounds to create excitement and induce desired actions by third parties. These prices can even exceed fundamental value when the VC takes a large initial stake or the third parties are particularly skeptical. Furthermore, the need to posture can actually increase the venture's value since it enables more efficient ex ante contracting by limiting the opportunity for ex post opportunism. This induces greater value-creating effort by the entrepreneur. These results provide a number of unique testable implications.

# Appendix 1

Throughout the paper we have maintained a reduced form characterization of third parties. In this appendix, we briefly discuss a more micro-founded version of our model when the third parties are potential competitors. Assume the firm faces a downward sloping demand curve, $D - \beta p$, where $p$ is the price per unit. Assume the good state in the base model corresponds to the firm having the potential to invest $I_2$ in new technology that results in a low marginal cost, denoted $c_F$, while the bad state corresponds to it having a prohibitively high marginal cost. Assume further that there is a competitor with a known marginal cost $c_P > c_F$. Finally, assume that if both firms are active in the market they compete a la Bertrand, and the competitor must make an entry/stay decision (where investing to enter or stay in the market costs $c_E$) before knowing the final state.

In this model a monopolist will set its price $p$ to maximize total profit, $(D - \beta p)(p - c_i)$, which yields $p^* = \frac{D + \beta c_i}{2\beta}$ and maximized profit of $\frac{(D - \beta c_i)^2}{4\beta}$, where $i \in \{F, P\}$. Clearly, the competitor will enter/stay only if it has a high enough chance of being a monopolist. Conditional on an agreement between $E$ and the VC to work toward a late exit, the competitor will enter/stay (assuming a financing equilibrium in which $E$ and the VC work toward a late exit only if $s \geq s^*$ for some threshold $s^*$) if and only if $\frac{1 - s^*}{2} \frac{(D - \beta c_P)^2}{4\beta} \geq c_E$. Since the left-hand side clearly decreases in $s^*$, this implicitly defines a threshold $\hat{s}$ for which if $s^* = \hat{s}$ in equilibrium, the competitor is just indifferent.

Similarly, the firm will find it worthwhile to invest $I_2$ in the low marginal cost technology, and thus work toward dominating the market and attempting a late exit, only if it is positive NPV to do so. If we assume $c_P$ is sufficiently close to $c_F$ that the firm's expected duopoly profit, $(D - \beta c_P)(c_P - c_F)$, is below $\pi_1$, the firm will not work toward a late exit if it expects competition. Conditional on being a monopolist, it is profitable to move toward a late exit if $s \geq \underline{s} = \frac{I_2 + \pi_1}{\pi_2}$, where $\pi_2$ is replaced by $\frac{(D - \beta c_F)^2}{4\beta}$. From $E$ and the $VC$'s point of view, $c_P$ and $c_E$ affect only $\hat{s}$, so there will always exist a range of these costs such that $\hat{s} \in \{\underline{s}, 1\}$ and the results of the Posturing model are directly applicable. In particular, the comparative

static results with respect to $\hat{s}$ now translate into comparative statics with respect to these costs. These will have the opposite sign to those in the base model since $\hat{s}$ is decreasing in both $c_P$ and $c_E$.

# Appendix 2

**Proof of Proposition 1:** Funding the firm is profitable ex ante if, at the optimal $e$,

$$e\left(Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - I_2) + Pr[s < \underline{s}]\pi_1\right) + (1 - e)I_1 - I_1 - c(e) > 0 \qquad (17)$$

$$\implies e\left(Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2) + Pr[s < \underline{s}]\pi_1\right) > e(I_1 + Pr[s > \underline{s}]I_2) + c(e).$$

In equilibrium, since $E$ has the bargaining power the VC will be held to a zero expected payoff ($E$ will demand a transfer equal to the VC's expected payoff under any proposed contract in equilibrium), i.e., the VC's participation constraint will be satisfied as an equality (as long as this does not violate $E$'s wealth constraint). Given the assumption that the VC gets the full payoff $I_1$ upon liquidation of a non-viable firm, this implies

$$e\left(Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2(\alpha_1(1 - \alpha_2) + \alpha_2)) - I_2) + Pr[s < \underline{s}]\pi_1\alpha_1\right) + (1 - e)I_1 - I_1 - \tau = 0$$

$$(18)$$

$$\implies$$

$$\alpha_1(Pr[s \geq \underline{s}]E[s|s \geq \underline{s}](1-\alpha_2)\pi_2+Pr[s < \underline{s}]\pi_1)+\alpha_2 Pr[s \geq \underline{s}]E[s|s \geq \underline{s}]\pi_2-Pr[s \geq \underline{s}]I_2 = I_1+\frac{\tau}{e}$$

$$(19)$$

must hold in equilibrium. It is straightforward to show that with $\tau = 0$, this last expression corresponds to the expression one gets by setting the right hand side of (6) equal to the right hand side of (3). In other words, any pair $(\alpha_1, \alpha_2)$ that induces optimal effort also sets the VC's expected payoff to zero assuming $\tau = 0$.

Now assume the project is ex ante profitable and consider a proposed contract with $\alpha_2 = 0$. Then solving (18) for $\alpha_1$ yields $\alpha_1 = \frac{I_1+Pr[s \geq \underline{s}]I_2}{Pr[s \geq \underline{s}]E[s|s \geq \underline{s}]\pi_2+Pr[s < \underline{s}]\pi_1} \equiv \alpha_1^{CC}$, which, by inspection of (17), is between zero and one whenever the project is positive NPV. Thus, a contract with $\alpha_2 = 0$, $\alpha_1 = \alpha_1^{CC}$, and $\tau = 0$ gives first best effort and satisfies the VC's participation constraint with equality while allowing $E$ to capture the full surplus, and is therefore optimal and achieves first best. Finally, it is straightforward to show that raising $\alpha_2$ above zero while lowering $\alpha_1$ so as to keep (18) satisfied will maintain the features of this

equilibrium as long as $\alpha_1$ and $\alpha_2$ remain in the range $[0, 1]$, which will occur over some range since $\alpha_1^{CC}$ is strictly in that range. **QED**

**Proof of Proposition 2:** (a) When (9) holds, the right-hand side of (11) is always less than the right hand side of (3), so the optimal contract will set $\alpha_1 = 0$ to elicit the maximum possible effort. Note that the lack of effort by the entrepreneur is the only source of inefficiency in this contract (the only other possible inefficiency would be a sub-optimal choice of when to attempt a late exit, but this does not occur because it is always optimal for the VC to make the renegotiation offer when the product is viable and $s \geq \underline{s}$). Since no other changes to the contract can induce greater effort, it remains to show that $\tau > 0$.

As above, the VC's ex ante participation constraint will be satisfied as an equality in the time zero negotiation as long as $E$'s wealth constraint is not violated. Given the renegotiation game in the Hold Up model, this implies

$$e(Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - (1-\alpha_1)\pi_1 - I_2) + Pr[s < \underline{s}]\alpha_1\pi_1) + (1-e)I_1 - I_1 - \tau = 0 \quad (20)$$

$$\implies$$

$$\alpha_1\pi_1 + Pr[s \geq \underline{s}](E[s|s \geq \underline{s}]\pi_2 - \pi_1) - Pr[s \geq \underline{s}]I_2 = I_1 + \frac{\tau}{e} \quad (21)$$

It is straightforward to show that with $\tau = 0$, this last expression corresponds to the expression one gets by setting the right hand side of (11) equal to the right hand side of (3). In other words, if full efficiency could be achieved in the Hold Up model, the $\alpha_1$ that induces optimal effort also sets the VC's expected payoff to zero assuming $\tau = 0$. Here, though, the $\alpha_1$ that would achieve this is negative, so $\alpha_1 = 0$ is chosen. This implies that the optimal contract must satisfy the VC's participation constraint with equality at a positive $\tau$. To see this, note that the left hand side of (21) increases in $\alpha_1$, so constraining $\alpha_1$ to zero away from its (negative) optimum increases the left hand side, which implies that $\tau$ must be increased above zero to keep the equation (and thus the VC's participation constraint) at equality. This proves the first part of the result.

(b) For the second part of the result, it suffices to note that since optimal effort can be achieved with a positive $\alpha_1$ when (9) does not hold, from the proof of part (a) above the VC's participation constraint will be satisfied with equality at that optimal $\alpha_1$ with $\tau = 0$.

**QED**

**Proof of Proposition 3:** First we show the existence of the proposed equilibrium with a critical signal $s^* = \hat{s}$. Using Bayes' rule, the third parties' posterior beliefs about $s$ given an offer of $\alpha_2 = \alpha_2^P$ are given by $E[s|\alpha_2 = \alpha_2^P] = E[s|s \geq \hat{s}] \geq q$. Given these beliefs, it is optimal for $E$ to accept the offer if his expected payoff exceeds $(1 - \alpha_1)\pi_1$. This is ensured since funding is positive NPV (since only VCs with $s > \underline{s}$ make offers, and it is optimal to attempt an IPO whenever $s \geq \hat{s}$), and the VC with $s = \hat{s}$ is made indifferent at $\alpha_2 = \alpha_2^P$. The latter implies that $E$ at least breaks even relative to the early exit option payoff of $(1 - \alpha_1)\pi_1$ conditional on $s = \hat{s}$, given the new funding contract and a late exit attempt, and he can only do better conditional on a higher $s$ since his stake is the same for all such $s$. VCs with $s < \hat{s}$ strictly prefer an early exit given the required stake offer $\alpha_2^P$, so are happy to make no offer. Finally, out-of-equilibrium third party beliefs that any stake offer other than $\alpha_2^P$ comes from a low type (e.g., from a type with $s = 0$) prevents deviation by any VC with $s \geq \hat{s}$ to any other $\alpha_2$ since it will lead to rejection.

Next we show that this equilibrium is the most efficient signaling equilibrium. One possible type of alternative equilibrium is one in which the VC always lets the firm be sold in an early exit (or, equivalently, makes an offer it knows will be refused with probability one). To prevent deviation by the VC to a smaller stake when $s$ is high, out-of-equilibrium beliefs that any stake offer must come from a VC with a low $s$ can be specified. Thus, such an equilibrium always exists, but it is clearly less efficient.

Any equilibrium in which the third parties are sometimes convinced, on the other hand, must be a threshold equilibrium similar to that derived above, i.e, it can have at most one equity stake size offered by all types of VCs for which the offer will be accepted (where the VC's "type" refers to its signal, $s$). To see this, first consider a proposed equilibrium

in which there are multiple stake sizes that lead to sufficiently strong beliefs for the third parties. In such a case the types who are supposed to offer the smaller stake will optimally deviate to the largest stake (the third parties will remain convinced, and the VC will get a higher proportion of the payoff), so this cannot be an equilibrium. Therefore, all equilibria in which a late exit is ever attempted are threshold equilibria.

It therefore remains to characterize what threshold equilibria exist alongside the most efficient one derived above. It is straightforward to show that *any* $s \geq \underline{s}$ can serve as the critical threshold $s^*$ in a valid signaling equilibrium that is otherwise identical to that characterized in the Proposition. These equilibria exist because lower types are unwilling to pay the high price to mimic higher types. Thus, there is always a system of beliefs that is consistent with any "minimum" price required to believe the VC is in the higher pool that is expected to attempt a late exit. Such a minimum price is supported by out of equilibrium beliefs that any VC offering lower than the minimum price must be a low type. However, any such equilibrium is clearly less efficient than that characterized in the Proposition since it involves foregoing profitable late exit attempts. Finally, note that no threshold equilibrium with a critical threshold $s^* < \hat{s}$ can exist because following a stake offer, third parties will have posterior belief about $s$, given by Bayes' rule, that $E[s|\alpha_2 = \alpha_2^P] = E[s|s \geq s^*] < q$ (where the inequality follows from the definition of $\hat{s}$), and thus will not be convinced. **QED**

**Proof of Proposition 4:** First consider the case where $\alpha_1^P \geq 0$. Since it optimizes the effort level, and the subsequent stage 2 sub game ensures sufficiently strong third party beliefs, the offer of $\alpha_1^P$ is optimal for $E$ if it makes the VC accept and keeps the VC at its participation constraint, which is an ex ante expected payoff of zero. It was shown in the proof of Proposition 1 that this holds with a transfer of $\tau = 0$ whenever the right hand side of (6) is equal to the right hand side of (3), which is clearly still true when $\underline{s}$ is replaced by $\hat{s}$ in (6) to account for the third party constraint. The fact that $\alpha_1^P > \alpha_1^H$ follows directly from the fact that $\alpha_2^P < \alpha_2^H$ and that *both* $\alpha_1^P$ and $\alpha_1^H$ are derived from setting the right hand side of (6) (replacing $\underline{s}$ with $\hat{s}$) equal to the right hand side of (3), which yields (19)

(replacing $\underline{s}$ with $\hat{s}$) assuming $\tau = 0$, and it is clear that the left hand side of (19) (replacing $\underline{s}$ with $\hat{s}$) is increasing in both $\alpha_2$ and $\alpha_1$.

Now consider the case with $\alpha_1^P < 0$. As in the Hold Up model the optimal contract must set $\alpha_1 = 0$ to elicit the maximum possible effort (the lack of effort is the only source of inefficiency in this contract, and no other changes to the contract can induce greater effort). Also as noted above, since any pair $(\alpha_1, \alpha_2)$ that induces optimal effort (i.e., sets the right hand side of (6) (replacing $\underline{s}$ with $\hat{s}$) equal to the right hand side of (3)) satisfies the VC's participation constraint with equality given $\tau = 0$, the optimal contract derived here when $\alpha_1^P < 0$ must satisfy the VC's participation constraint with equality at a positive $\tau$. To see this, note that the left hand side of (19) (replacing $\underline{s}$ with $\hat{s}$) increases in $\alpha_1$, so constraining $\alpha_1$ to zero away from its (negative) optimum increases the left hand side, which implies that $\tau$ must be increased above zero to keep the equation (and thus the VC's participation constraint) at equality. **QED**

**Proof of Proposition 5:** Consider cases where (9) holds, so that there is less than first best entrepreneurial effort in the Hold Up model, but it is still profitable for $E$ to seek funding under the optimal contract. First assume $\hat{s} = \underline{s}$. Since $\alpha_2^P < \alpha_2^H$ and $\alpha_1^P > \alpha_1^H$, and there are no differences in the outcomes of the Hold Up and Posturing models except differences in entrepreneurial effort and therefore the probability of a viable product, $\alpha_1^P > 0$ will sometimes hold, in which cases the equilibrium in the Posturing model will achieve the first best (leading to higher firm value and greater efficiency than in the inefficient Hold Up model). Whenever $\alpha_1^P < 0$ holds, both models will have $\alpha_1 = 0$ in equilibrium and will have less than first best effort. However, the fact that $\alpha_2^P < \alpha_2^H$ implies greater effort in the Posturing model equilibrium, and hence higher firm value and greater efficiency. Now consider case with $\hat{s} > \underline{s}$. Clearly, efficiency in the Posturing model must change continuously with $\hat{s}$, so for any set value of the other parameters the above results must hold for some range of $\hat{s}$ as it rises above $\underline{s}$.

Now consider cases where (9) does not hold, so that there is first best effort in both the

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Hold Up and Posturing models. In this case, efficiency is identical across models for $\hat{s} = \underline{s}$, but for $\hat{s} > \underline{s}$ the Posturing model is less efficient because some profitable late exit attempts must be foregone. **QED**

**Proof of Proposition 6:** The result for $\alpha_1^P$ follows by taking the derivative of (16) with respect to $\hat{s}$ using a uniform distribution for $s$ on $[0, 1]$ (i.e., replacing as follows in (16): $E[s|s \geq \hat{s}] = \frac{1+\hat{s}}{2}$, $Pr[s \geq \hat{s}] = 1 - \hat{s}$, and $Pr[s < \hat{s}] = \hat{s}$), which yields $\frac{2(1-\hat{s}^2)(I_1+I_2)}{(1+\hat{s}^2)^2\pi_1} > 0$. For $\alpha_2^P$ notice from (15) that it is decreasing in $\alpha_1$, so the indirect effect through $\alpha_1$ is negative, and it is also directly decreasing in $\hat{s}$. **QED**

**Proof of Proposition 7:** All of the results are obvious by inspection from the definitions of the various stake sizes. **QED**

**Proof of Proposition 8:** The results for $\alpha_1^P$, $\alpha_1^H$, and $\alpha_2^H$ follow by inspection from (16), (13), and (8). For $\alpha_2^P$, note from (15) that it is directly increasing in $I_2$ and decreasing in $\alpha_1$, so that the direct and indirect effects of $I_2$ are reinforcing, and also note that it is unaffected by $I_1$ other than through $\alpha_1$. The result for the second stage price per share in the Posturing model, $\frac{I_2}{\alpha_2^P}$, with respect to $I_1$ follows since it does not depend directly on $I_1$. The derivative for the first stage price per share in the Posturing model is $\frac{\partial \frac{I_1}{\alpha_1^P}}{\partial I_1} = \frac{\frac{Pr[s \geq \hat{s}]I_2(\hat{s}-E[s|s \geq \hat{s}])}{\pi_1(\hat{s}Pr[s<\hat{s}]+E[s|s \geq \hat{s}]Pr[s \geq \hat{s}])}}{\alpha_1^{P2}} < 0$. The derivative for the first stage price per share in the Hold Up model is $\frac{\partial \frac{I_1}{\alpha_1^H}}{\partial I_1} = \frac{\frac{Pr[s \geq \hat{s}](I_2+\pi_1-E[s|s \geq \hat{s}]\pi_2)}{\pi_1}}{\alpha_1^{H2}} < 0$. **QED**

# Appendix 3

Here we show that the most efficient signaling equilibrium is the only equilibrium of the time 2 sub game in the Posturing model that survives the continuous-type analog of the Divinity refinement of Banks and Sobel (1987). Divinity places conditions on out of equilibrium beliefs as follows. First, when the receiver of the signal observes an out-of-equilibrium move by the sender of the signal, the receiver's posterior beliefs cannot put weight on types of the sender who could not profit from the deviation (i.e., no matter what the receiver's response is these types never want to deviate). Second, for types who could profit from the deviation under some circumstances, the relative weighting of the types is constrained by their relative "likelihood" to make the deviation. In particular, if a type $i$ finds the deviation profitable for a weakly larger set of best responses by the receiver than a type $j$, then the receiver's posterior has to put at least as much *relative* weight on $i$ versus $j$ as was true in the prior belief distribution. In words, when comparing two types that could profit from deviating, the receiver's updated beliefs cannot tilt (relative to how those two types were weighted in the prior distribution) toward types that find deviation less profitable. In the current model with continuous types, the analogue condition relevant to our set of equilibria is that if higher types find a given deviation more profitable, the third parties' posterior belief distribution must weakly first-order stochastically dominate the truncated prior distribution, where the truncation is done to exclude only the range of types that could never profit from the deviation.

Now we simply need to show that the most efficient signaling equilibrium survives this refinement, and that the other signaling equilibria, which were characterized in the proof of Proposition 3 above, do not. First note that in any proposed signaling equilibrium with late exit attempts, VCs in the pool that are expected to offer the equilibrium price $\alpha_2^P$ would all benefit from deviating to a lower price if third parties would still be convinced, but those with higher signals would stand to profit *more* from such a deviation. Thus, after any deviation to a lower price, the third parties' posterior must put positive weight only on VCs whose

signals are such that the deviation could be profitable, and it must first order stochastically dominate the truncated prior that also includes only those same types. Now notice that in the most efficient signaling equilibrium, which is characterized in Proposition 3, the third parties have a posterior following an offer of $\alpha_2^P$ that equals the left-truncated prior where the truncation occurs at $s = \hat{s}$. Also, the price implied by $\alpha_2^P$ just makes the type with $s = \hat{s}$ indifferent to buying at the equilibrium price and attempting a late exit. Now consider a deviation to a lower price. In this case, the equilibrium can be supported by posterior beliefs that equal the prior truncated at the type, say $s^{**} < \hat{s}$, that is just indifferent to paying this lower price assuming the third parties will be convinced. These beliefs satisfy the Divinity condition and leave the third parties unconvinced, so the equilibrium survives.

Now consider a proposed equilibrium with a critical level $s^*$ that is greater than $\hat{s}$. In this proposed equilibrium, the equilibrium price given a late exit attempt will be set so that the VC with signal $s^*$ is just indifferent. Now consider a deviation to a lower price that leaves a type $s^{***} \in (\hat{s}, s^*)$ just indifferent to offering the price assuming the third parties will be convinced. The most pessimistic beliefs allowable under the Divinity refinement correspond to a left-truncation of the prior at the type with $s = s^{***}$. But since $s^{***} > \hat{s}$, the third parties will be convinced by this posterior, and the deviation will be profitable. Thus, no signaling equilibrium with a critical level above $\hat{s}$ can survive the Divinity refinement.

Finally, consider the only other type of signaling equilibrium that exists, one in which a late exit is never attempted. I.e., one in which any price offer leaves the third parties unconvinced. Now consider a deviation to a price offer that sets a type $s^{****} > \hat{s}$ just indifferent to attempting a late exit if third parties are convinced. As above, the most pessimistic beliefs allowable under the Divinty refinement correspond to a left-truncation of the prior at the type with $s = s^{****}$. But since $s^{****} > \hat{s}$, the third parties will be convinced by this posterior, and the deviation will be profitable. **QED**

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