# Secret Scouting *

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**Abstract**

VCs prefer secrecy when searching for targets. As a result, only the investments in viable startups are disclosed, but the failed ones are discarded silently. We extend the standard preemption game to explain the efficiency loss and the individual rationale of doing so. We show that secrecy creates pessimism. Compared to the fully disclosing case, VCs will stop hunting for startups too early in an initially promising industry. This could happen even if no technology failures are observed in realization. However, hiding failures becomes a dominant strategy when the return of the VC industry is right-skewed. VCs use secret scouting to make the competitors believe that the industry is a dead end and reduce the preemption threats.

**Key words:** Preemption, Venture Capital, Search, Disclosure.

**JEL Classification:** G14, G24, G32, D62, D83.

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# 1 Introduction

For venture capital firms (VCs), the role as a "scout" receives much less academic attention compared to the role as a "coach". However, fishing in a better pond can make as much, if not more, difference as being a better fisherman. Sourcing and screening projects are the first step of investments and help reduce monitoring efforts afterwards.[1] Yet, hunting for good projects at premature stages faces huge uncertainties and requires a costly experimentation process (Ewens et al., 2018).

Various strategies are taken to facilitate this process. In this paper, we focus on a critical feature of them: searching activities are kept in the dark until successful. Prominent VCs, e.g., Sequoia Capital, adopt scouts networks and let individual agents invest on behalf of them. The identity of the sponsoring VC is hidden until the funded startup proves to be promising, and a large follow-up round is publicly announced. The consequence of such strategies is that searching outcomes are asymmetrically disclosed: Only the good startups are publicly financed but the failed ones are buried underground quietly.

We model a game of VC scouting competition and explain these strategies as follows. First, we take the secret scouting process as given and compare it to an alternative scenario, which is that every VC discloses both successes and failures. We prove that secrecy generates an efficiency loss: An initially promising technology is discarded too soon since VCs become gradually more pessimistic. Then we address the follow-up question: What drives the adoption of secrecy? Our answer is the fear of preemption. If VCs could individually choose their disclosing strategy, they would only hide the failures if the first VC who finds a successful startup receives extremely more profits than runners-up. The implication is that secret scouting is an endogenous outcome as the return of the VC

[1] Baum and Silverman (2004) find VCs are able to pick winning startups based on partners, patents and human capital, which correlate with the characteristics that trigger a final exit. In the same spirit, Catalini et al. (2017) show firms achieving growth without venture capital are similar to those receiving VC funding. Once controlled for startups' initial quality, value added by VC is much smaller than previously documented.

industry becomes right-skewed (Hall and Woodward, 2010; Kerr et al., 2014).

Imagine that there are a group of VCs continuously scouting for startups in a new industry, which all use the same uncertain technology. Search friction exists so that every period, each VC only finds a startup with a certain probability. Conditional on a match, a VC perfectly learns the quality of the technology.[2] In the secret scouting case, if the startups rely on a good technology, the first VC who finds it out will publicly announce an investment and receive a higher return as a first-mover advantage. But if VCs learn that the technology is a bad one, they will leave the industry secretly. In the game, VCs continuously choose a costly effort to increase the periodic chance of reaching a startup.

Empirically, when new technology organizations seek for VC fundings, no news is bad news (Petkova et al., 2013). Our result hinges on a similar pessimism created by concealed failures. When the VCs compete in scouting but keep observing no announcements of investments, two things can happen. On the one hand, due to the search friction, it might be the case that every individual VC has not met a startup yet. Therefore no one is aware of the technology quality. On the other hand, it is also possible that some VCs have observed a technology failure and secretly left. These two cases are indistinguishable because quit decisions are private. However, VCs consider the second case more likely as time passes by. The technology gradually becomes less promising and the searching effort declines accordingly. In the end, all VCs stop hunting in this industry even without observing any failures.

Efficiency loss comes at the cost of secrecy. We compare the searching intensity in the secret scouting case to a public disclosing alternative where the VCs will reveal both the good and bad outcomes when reaching a startup. Since now failures are also observed, no investment can be perfectly inferred as a bad luck in searching: No VCs have met

[2] We assume VC has knowledge advantage at interpreting different signals to forecast the industry prospect (Gompers and Lerner, 2001; Ueda, 2004). The source may be due to VC connections (Hochberg et al., 2007) and human capital (Bottazzi et al., 2008).

a startup yet. As a result, all VCs will have the same belief on the technology as they initially do and exert a constantly high effort of searching until the first VC meets a startup. The public disclosing case is more efficient for the following two reasons. From the startups' perspective, if they use a good technology, they will almost surely meet a VC investor in the end. But in the secret scouting case, there is a strictly positive probability that they are ignored in the end. From the VCs' perspective, revealing failures helps them save additional costs of searching if the technology has already been known as unviable by someone else.

We then consider the endogenous choice of secrecy and explain how it correlates with the right-skewness of returns. In the model, once the first VC announces an investment and validates the technology, all other players could make follow-up moves but only receive a substantially less return. The difference between the returns of the first and the following investors quantifies the fear of preemption. Suppose that before the searching game starts, each VC can choose and commit to disclosing failures or not, and their choices are publicly observed. Commitment to secrecy is dominant if the fear of preemption is huge. This is because VCs benefit from others' diminished efforts of hunting startups. A rational individual VC knows its externalities on others' beliefs. Regardless of others' disclosing choices, secrecy will always reduce the degree of competition.

When discussing their preference of secrecy in early-stage scouting, VC partners claim that they want to protect the startups. The argument is that if a top-tier VC later stops financing, possibly due to liquidity reasons, it generates holdup problems for follow-up rounds.[3] However, our result highlights the flip side of the story. If a startup is a potential target for investments yet no VCs reveal public interest after a while, all partners would believe this firm is of poor quality. Then no further VCs are wiling to spend time on it and adverse selection endogenously occurs. This is the trick of secrecy. Each VC wants to

[3] This idea is related with Khanna and Mathews (2016) where the financing terms of the current VC investors affect third-parties' interactions with the startup.

eliminate competition by misguiding opponents into pessimism. However, while everyone does so, the adverse selection problem becomes an industry-wide phenomenon and in the end causes the dead-weight loss.

Our rationale is also different from the alternative explanations of VC's opacity in the literature. The first argument is that VCs are afraid of attracting competitors as their activities may signal optimistic belief about the industry. While that may explain why VCs delay the announcement of investing in promising startups, it cannot generate a tendency to hide failures. Second, venture capitalists may delay negative information about fund performance until a new fund is raised (Chakraborty and Ewens, 2017), which is broadly in line with VCs inflating NAVs for fund-raising reasons (Barber and Yasuda, 2017; Brown et al., 2018). Thirdly and closer related is Akcigit and Liu (2015). In their model, VCs are experimenting with a sequence of projects in turns. Hiding the first project's failure will waste competitors' resources in the dead end, which buys time for the informed investor to lead in the second project. This is possible but not necessarily required. In reality, VCs usually adopt a "spray-and-pray" strategy (Ewens et al., 2018) and screen a wide range of projects simultaneously. Our model is an extreme case: The informed VCs are totally indifferent about disclosing conditional on learning technology failures, since there is only one investment opportunity. Even so, commitment to secrecy is still dominant.

Broadly, this paper contributes to the knowledge of venture financing at its earliest stage, where information asymmetry and uncertainty baffle the operation of financial intermediation. There are growing empirical evidence on the value of VC connection from seed round (Kerr et al., 2011; Gonzalez-Uribe and Leatherbee, 2017) as well as knowledge on how VCs perceive and learn about new projects (Bernstein et al., 2017; Ewens et al., 2018). Searching for projects has been theoretically shown to affect the valuation and viability of ventures (Inderst and Müller, 2004; Nanda and Rhodes-Kropf, 2013; Hellmann and Thiele, 2015). We explicitly consider the efficiency loss generated within this process, and explain how secrecy becomes an industry-wide phenomenon.

Though the focus of this paper is on early-stage VC activities, the model explains more general phenomenons on disclosing, for example the "file drawer problem". Private research agents are reluctant to disclose failures though null or negative results are valuable as well. The model implies that if more transparent R&D outcomes are implemented, innovation efficiency will increase. Supporting evidence are available. Gross (2019) show USPTO's patent secrecy program in World War II has reduced and delayed follow-on invention. And before the passage of The American Inventors Protection Act (AIPA), only successful patent applications are announced but failed ones are kept as secret. AIPA requires mandatory publication of all patent applications 18 months after first filing. Graham and Hegde (2015) and Hegde et al. (2018) find that AIPA does promote knowledge spillover and cumulative innovation.

The current work is closely related with the application of preemption games to disclosure. For example, Hopenhayn and Squintani (2011, 2015) and Bobtcheff et al. (2016) show the timing of revealing successful findings are impacted by competitions. Our focus is not on the timing. Akcigit and Liu (2015) consider an innovation competition in which players decide whether to pursue a risky or safe bandit privately. The risky line can yield successful breakthrough (publicly observed) or a dead end, after which firms switch to the safe line for a smaller payoff. Since the winner takes all, secrecy after dead end is a dominant strategy to keep opponents wasting time as long as possible. Our model shares the same information externalities with Akcigit and Liu (2015). However, the dominance of secrecy is from an *ex ante* motivation: Players want to create pessimism and trick the opponents into giving up a potentially good target. Halac et al. (2017) consider how to optimally design communication between individual agents jointly with the prize-sharing rule. Moscarini and Squintani (2010) and Murto and Välimäki (2011) consider the opposite structure of information where only the exit after failures is publicly observable. Related with the disclosure of outcomes, Campbell et al. (2014) show that players with successful breakthroughs will hide their result in order to maintain partners' motivation as a team.

Lastly, our work is also associated with strategic experimentation literature (Bolton and Harris, 1999). In Keller et al. (2005) a breakthrough occurs randomly at exponential times. It publicly reveals the technology's good quality and generates positive payoff spillovers. Keller and Rady (2015) analyze the opposite case in which a breakdown arrives when the technology is bad. Our paper is different in the following two ways. First the arrival of results, which is reaching a startup in our model, does not depend on the underlying quality. Belief changes purely through the confusion about whether others have learned a bad outcome. Second, there is a first mover advantage in the payoff conditional on success, which creates negative payoff spillovers to runners-up along with "good news". Therefore, there is no encouraging effect as common in the experimentation literature.[4] In a similar spirit, Cripps and Thomas (2019) introduce congestion cost as negative payoff spillovers joint with benefits in positive information externalities.

The paper is organized as follows. Section 2 introduces the baseline model in secret scouting. We then compare the equilibrium strategy to a case with public disclosing. Section 3 considers the endogenous disclosure decision. Section 4 concludes.

## 2 Baseline Setup

Consider a game of $N$ VCs (players), indexed by $i = 1, ...N$. Each of them is consistently searching for a startup at $t \in [0, +\infty)$ in a new industry. All startups use the same, and therefore perfectly correlated technology. Its type $\theta$ is either $H$ (good) or $L$ (bad).

[4] See, for example, Bolton and Harris (1999).

The prior probability of having a good technology is $\pi_0 < 1$. The *ex ante* distribution is common knowledge to all VCs.

Search friction exists and stops VCs from reaching the startups with certainty. The individual instantaneous rate of finding a startup is $\lambda a_i$ independent of the technology quality.[5]. Each VC continuously determines efforts $a_{it}$ to exert at $t \in \mathbb{R}_+$. Effort is bounded and costly almost surely. We normalize the domain of effort to be $a_i \in [\phi, 1]$ and the flow cost to VC $i$ is $c_i(a_i) = c\,(a - \phi)$.[6] $\phi < 1$ indicates the default arrival rates when VCs stay idle. Effort choice for each VC remains private and unobserved.

Once a VC reaches a startup, it perfectly and privately learns the quality of the technology. The payoff structure is as follows. If the technology is good, the first player who successfully finds a startup ("Winner") will publicly announce the investment and receive first-mover payoff $W > c/\lambda + c\phi/r$. Like in any other preemption game, the first adoption at the same time ends the game for other "losers", who receive $K < W$ as second mover payoff.[7] On the other hand, a bad technology generates zero net profit for any VC. In the secret scouting case, we assume VCs leave the unviable startup with no public announcement. Abandoning it only terminates the game of the finding VC itself. Its discovery remains unobserved to the others. So they keep their own searching process until they also find a startup.

For each VC, the game ends either if $(i)$ it learns the quality of technology or $(ii)$ another VC publicly announces an investment. When the game continues, there is no flow payoff for all players. They are impatient, and discount future benefits and cost at a common discount rate $r$. The final payoff that VC $i$ receives depends on the scenarios. Define $\tau_i \in \mathbb{R}_+$ as the random arrival time when player $i$ reaches the startup and $\tau_{-i}$

[5] This rules out the possibility of learning qualities through arrival rates of results.

[6] The form of effort and the cost associated can be pecuniary, representing expenditures to hire scouts. In general they could be also non-pecuniary such as the monitoring and advising activities (Gompers, 1995; Lerner, 1995; Hellmann and Puri, 2002).

[7] The value of $W$ and $K$ are exogenously given and we abstract from concerns such as hiding good results to deter competition.

as the time when the asset is publicly adopted from $-i$. Then $\tau = \min\{\tau_i, \tau_{-i}\}$ is the stopping time for agent $i$. Neglecting all higher order terms, the expected profit for VC $i$ is

$$\mathbb{E}_t^i\Bigg\{\mathbb{I}(\tau=\tau_i)\left(e^{-r(\tau-t)}W\mathbb{I}(\theta=H)-\int_t^\tau e^{-r(s-t)}c(a_s)\mathrm{d}s\right) \\ +\mathbb{I}(\tau=\tau_{-i})\left(e^{-r(\tau-t)}K-\int_t^\tau e^{-r(s-t}c(a_s)\mathrm{d}s\right)\Bigg\}$$

where $\mathbb{I}(\cdot)$ is the indicator function. In the first line, VC $i$ finds the result before its opponents. It invests in the startup and enjoys $W$ only if $\theta = H$. But it stops searching regardless of the technology quality. In the second line, some competing VC $-i$ meets the startup first. Transaction happens and is publicly announced if $\theta = H$. VC $i$ stops searching immediately and takes the second mover payoff.

VC's objective is to choose effort $a_{it}$ to maximize the expected profit $V_t^i$. Since an announcement ends the game automatically, the public history can be mapped to the calendar time $t$ without any investments. We consider a pure public strategy for VC $i$, which is a measurable function $a_i : \mathbb{R}_+ \to [\phi, 1]$. $a_{it}$ is the instantaneous effort exerted by VC $i$ at $t$ if game continues.

A symmetric public perfect Bayesian equilibrium (PPBE) is a profile $a = (a_1, ..., a_n)$, such that

1. For any player $i$, given $a_j$, $j \neq i$, $a_i$ maximizes $V_t^i$ for all $t$;
2. For any player pair $(i, j)$, $i \neq j$, $a_i = a_j$ almost surely;
3. Players use Bayes' rule whenever possible.

If Multiple symmetric PPBE exist, we focus on the Pareto-optimal one.

Each rationally VC $i$ updates the probability $\pi_t$ of the technology being good (hereafter the belief). When no investments are announced, a single VC does not know whether it is because ($i$) all others fail to find a startup or ($ii$) some of them have found out the bad technology and left the market permanently. However, the cumulative probability that at least one startup is reached strictly increases over time. Thus, VCs believe case ($ii$) to be more likely and become pessimistic about the technology quality. The equilibrium efforts chosen by others will pin down how quickly VC $i$'s belief deteriorates and this belief in turn affects the effort decision of it.

Let $a_{-i} = \sum_{j \neq i} a_j$. Consider the belief changes from $t$ to $t + dt$. Ignoring higher order terms yields

$$\pi_{t+dt} = \frac{\pi_t(1 - \lambda a_{-it} dt)}{\pi_t(1 - \lambda a_{-it} dt) + (1 - \pi_t)}.$$

This generates the first order evolution of $\pi_t$:[8]

$$\frac{d\pi_t}{dt} = -\pi_t(1 - \pi_t)\lambda a_{-it}, \tag{1}$$

where $\pi_t$ has two absorbing states 0 and 1. Since $\lambda a_{-it} \geq (N-1)\lambda\phi > 0$, this belief is strictly decreasing while the game continues. The speed at which the belief deteriorates depends on the total effort exerted by competing VCs.

**Discussion.** In standard experimentation models, agents exert private efforts to influence the arrival rate of news. The project has uncertain qualities and only one specific type can produce news. Depending on the type of news, there are models about "breakthroughs" and "breakdowns". In this model, technology type by itself does not directly influence the arrival rate of news. For any single VC $i$, the arrival rate only depends on the effort choice. However, public announcement of investment by others terminates the game only if $\theta$ is $H$. This leads to a learning channel in the same spirit of collaborated experimentation models (breakthroughs). And this is why the belief is

[8]Since we consider symmetric equilibria, players share the same belief in equilibrium. Therefore we drop the subscript $i$ to reduce clutter.

drifting down strictly.

The current model is different as follows. First, as the arrival rate of news is type-invariant, individual effort has no direct effect on beliefs. Learning is purely due to externalities of others' efforts and hidden failures. Second, the game is "winner-take-more" and there is effective no "good news". For VC $i$, a "breakthrough" by other players verifies that the technology is good but meanwhile indicates that VC $i$ loses the contest and has to take $K < W$. Thus the free-riding motive is not a major concern in our model as it is hampered by the first mover advantage.

## 2.1 Value Function

$\pi_t$ is the state variable. Denote VC $i$'s equilibrium continuation value as $V(\pi_t)$. It satisfies the following equation from $t$ to $t + dt$:

$$\begin{aligned} V(\pi_t) =& \lambda a_{it} \pi_t W dt - c(a_{it} - \phi) dt + (1 - \lambda a_{it} dt) \Bigg( \pi_t \lambda a_{-it} K dt \\ &+ (1 - \pi_t \lambda a_{-it} dt) \frac{1}{1 + r dt} V(\pi_{t+dt}) \Bigg). \end{aligned} \tag{2}$$

Consider what happens at $t$. With probability $\lambda a_{it} dt$, VC $i$ meets a startup and receives $W$ with probability $\pi_t$. If VC $i$ does not find a startup, with probability $\lambda a_{-it} dt$ at least one competing VC $-i$ announces an investment given $\theta = H$. In this case VC $i$ receives the second mover payoff $K$. If a transaction does not happen, game proceeds to $t + dt$. With the first order approximation,

$$V(\pi_{t+dt}) = V(\pi_t) - V'(\pi_t) \pi_t (1 - \pi_t) \lambda a_{-it} dt.$$

Taking this to equation (2) and deleting higher order terms generates

$$rV(\pi_t) = \lambda a_{it}(\pi_t W - V(\pi_t)) + \lambda a_{-it}\pi_t(K - V(\pi_t)) - \pi_t(1-\pi_t)\lambda a_{-it}V'(\pi_t) - c(a_{it} - \phi). \tag{3}$$

As equation (3) shows, the game can end either in VC $i$ direct meeting the startup or any other opponents announcing investments. The first case generates more profit but also requires costly effort. The second case allows for free-riding benefits but is dominated in terms of payoff. The marginal benefit of exerting more effort is to increase searching possibility whereas the marginal cost of searching is constant. Thus, the effort decision for VC $i$ follows a simple rule:

$$a_{it}\begin{cases} = \phi & \lambda(\pi_t W - V(\pi_t)) < c \\ \in [\phi, 1] & \lambda(\pi_t W - V(\pi_t)) = c \\ = 1 & \lambda(\pi_t W - V(\pi_t)) > c. \end{cases} \tag{4}$$

Equation (4) explains why shirking in searching is sure to come in the end. The marginal benefit of effort, $\lambda(\pi_t W - V(\pi_t))$, depending on the belief $\pi_t$. When it is sufficiently low, the benefit is approaching 0. Exerting more effort would only guarantee a higher chance of finding a bad startup. Thus players tend to stop searching as time passes.

We derive an indifferent value function $V_I(\pi) = \pi W - c/\lambda$ from equation (4). If $V(\pi) = V_I(\pi)$, then VC $i$ is indifferent with any level of effort. The interpretation of $V_I$ is a "static" version of the game without learning. It is as if VC $i$ pays an upfront cost, immediately finds out the technology quality and gives up all free-riding opportunities. If $V(\pi) < V_I(\pi)$, the current waiting value is relatively small and a high effort is chosen to increase the chances of preempting others. On the contrary, if $V(\pi) > V_I(\pi)$, VCs will choose $a_i = \phi$ as free-riding incentives dominate.

In equilibrium, other VCs need to exert proper level of efforts $a_I$ to keep $i$ being indifferent. We solve it by putting $V_I$ back into equation (3) and restricting symmetric level of efforts,

$$a_I = \frac{r\left(\pi W - \frac{c}{\lambda}\right) - c\phi}{(N-1)\left(K + \frac{c}{\lambda} - W\right)\lambda\pi}. \tag{5}$$

Since the efforts of players are restricted to $[\phi,\, 1]$, the required $a_I$ may not be feasible when the belief $\pi$ is not in a proper region. If that happens, $a_i$ is a boundary solution $\phi$ or 1. Define $\Pi_F = \{\pi | a_I \in [\phi,\, 1]\}$ as the feasible set of $\pi$. The following lemma is important to characterize the equilibrium strategy.

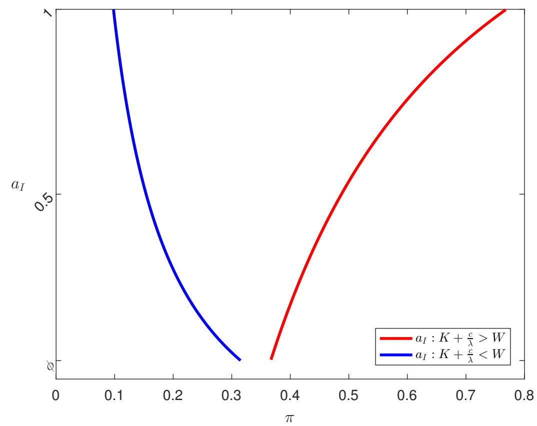
**Lemma 1.** *Suppose $\pi \in \Pi_F$. $\partial a_I / \partial \pi > 0$ if and only if $K + c/\lambda > W$.*

*Proof.* All proofs are neglected and shown in Section A. □

Lemma 1 indicates that the monotonicity of $a_I$ depends the cost of being follow-up investors. $K$ is our key parameter as it represents the fear of preemption or the return skewness in the VC industry. The following section shows the structure of equilibrium strategies changes as this monotonicity flips. Especially, we will separately solve the game given different levels of return skewness. Lemma 1 states that when the second mover payoff is sufficiently large, the required effort to make others indifferent is strictly decreasing as belief drifts down over time. However, when the game is "winner takes almost", VCs must backload efforts to keep their opponent indifferent.

The change in monotonicity hinges on the trade-off between preemption threats and free-riding benefits. At one hand, VCs are competing for bringing the first successful technology to the market. At the other hand, free riding successful investments from competitors saves the cost. When $K$ is large, free riding is profitable. However, this benefit is only valuable when VC $i$ believes the technology is a good one. When it is still optimistic, competing VCs could exert high levels of efforts. Even though this increases the probability of being preempted, it also increases the probability that VC $i$ free rides.

Figure 1: $a_I$ as Functions of $\pi$—High vs. Low Preemption




But when it becomes pessimistic, the marginal benefit of free riding is lower. Therefore competing VCs must exert lower efforts to make VC $i$ less concerned about preemption.

On the contrary, when $K$ is small, the game is very competitive and each VC faces severe threats of being preempted. Payoff in free riding is no longer sufficient to keep individual VCs indifferent. They must promise backloading the searching effort: When the technology is more likely to be good, they reduce searching intensities so that the cumulative probability of preemption $\lambda a_{-it}\pi_t$ is constant. Thus $a_I$ is decreasing with $\pi$ in this case.

## 2.2 Low Preemption Case

We now consider the low preemption case when $K + c/\lambda > W$. This represents a scenario where the first mover informs runners-up about the viability of a new technology and followers still have enough market shares to grab. We propose and prove that the equilibrium effort follows a two-threshold strategy:

$$a_{it} \begin{cases} = \phi & \pi_t < \underline{\pi} \\ = \frac{r\left(\pi W - \frac{c}{\lambda}\right) - c\phi}{(N-1)\left(K + \frac{c}{\lambda} - W\right)\lambda\pi} & \pi_t \in [\underline{\pi}, \bar{\pi}] \\ = 1 & \pi_t > \bar{\pi}. \end{cases} \tag{6}$$

The solution has an intuitive structure. When the belief is high ($\pi_t > \bar{\pi}$), VCs want to be the first one to find a startup. This is a "preemption region" where all players search with the maximal efforts to become the game winner. Then the belief goes down fast without investments until $\pi_t \in [\underline{\pi}, \bar{\pi}]$. Now the technology quality is questionable, and exerting full effort is no longer highly valuable. VCs cut off searching intensity by keeping each other indifferent with an intermediate level of efforts. This requires that all players use efforts $a_I$. Finally, there is a "pessimistic region". VCs shirk and accept the default arrival rate $\lambda\phi$ when they are very pessimistic ($\pi_t < \underline{\pi}$) because the marginal payoff is too low.

To solve the equilibrium thresholds, consider the preemptive region first. Replacing all efforts with 1 in equation (3) generates the value function $V_H$:

$$rV_H = \lambda\left(\pi W - V_H\right) + \lambda(N-1)\pi\left(K - V_H\right) - (N-1)\pi\left(1-\pi\right)\lambda V_H' - c\left(1-\phi\right). \tag{7}$$

Similarly in the pessimistic region, replacing all efforts with $\phi$ in equation (3) generates the value function $V_L$:

$$rV_L = \lambda\phi\left(\pi W - V_L\right) + \lambda\left(N-1\right)\phi\pi\left(K - V_L\right) - \left(N-1\right)\phi\lambda\pi\left(1-\pi\right)V_L'. \tag{8}$$

$V_H$ and $V_L$ correspond to the waiting value of players in the region $\pi_t > \bar{\pi}$ and $\pi_t < \underline{\pi}$

respectively. They follow closed form solutions as

$$
\begin{aligned}
V_H &= -\frac{c\,(1-\phi)}{(\lambda+r)} + \frac{\lambda(W+(N-1)(K+\frac{c(1-\phi)}{\lambda+r}))}{N\lambda+r}\pi + C_1\,(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda}{(N-1)\lambda}}, \\
V_L &= \frac{\lambda\phi(W+K\,(N-1))}{N\lambda\phi+r}\pi + C_2\,(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda\phi}{(N-1)\lambda\phi}}.
\end{aligned}
$$

It remains to pin down the constants $(C_1, C_2)$ and boundaries $(\underline{\pi}, \bar{\pi})$. Because $V_L$ is the value function at the lower bound. When $\pi$ approaches 0, players will have almost zero payoff so $V_L$ must be converging to 0. The intuition is that VCs believe the technology has zero returns almost surely and spend zero expenditure on hunting. This pins down $C_2 = 0$ and implies both $V_L$ and $V_I$ are linear in $\pi$.

For the lower boundary $\underline{\pi}$, notice $V_L$ is strictly larger than $V_I$ when $\pi$ is small. Therefore it would intersect $V_I$ from the above, which satisfies the optimal decision of effort by equation (4). So the boundary condition is

$$V_L(\underline{\pi}) = V_I(\underline{\pi}). \tag{9}$$

The upper boundary $\bar{\pi}$ is determined by the feasibility constraint of $a_I$

$$a_I(\bar{\pi}) = 1,$$

and then using value matching condition to pin down $C_1$

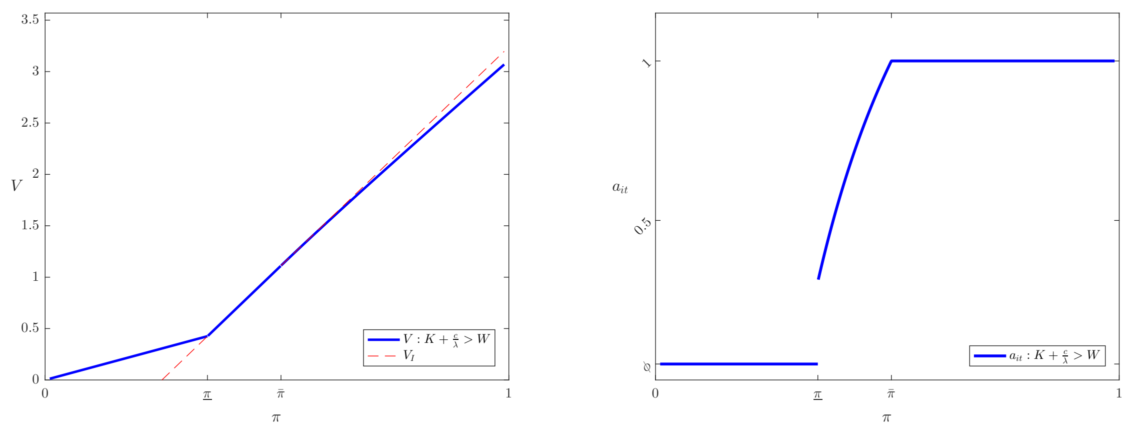
$$V_H(\bar{\pi}) = V_I(\bar{\pi}).$$

Notice for the upper boundary $\bar{\pi}$, we use a feasibility constraint instead of the common smooth pasting condition. As Lemma 2 suggests, we do not need to explicitly do so. By design, $a_I$ is solved to make VCs indifferent, which coincides with a full-effort decision at

$\bar{\pi}$. We also do not need a smooth pasting condition at the lower boundary. This is not possible as the two value functions are both linear. The kink at $\underline{\pi}$ does not violate the optimality. VCs have strictly higher payoff if they switch to lower efforts.

**Lemma 2.** $V_H'(\bar{\pi}) = W = V_I'(\bar{\pi})$.

Figure 2: Equilibrium Value Function and Effort Level —Low Preemption




(a) Value Function

(b) Effort Level

As $V_H$ is a concave function, it stays strictly below $V_I$ when $\pi_t > \bar{\pi}$. Together this confirms the strategy in equation (6) consists a PPBE.

**Proposition 3.** *When $K + c/\lambda > W$, the equilibrium strategy $a_i$ follows equation (6), where*

$$\underline{\pi} = \frac{c\left(\frac{r}{\lambda} + N\phi\right)}{\lambda\phi\left(N-1\right)\left(W-K\right) + rW},$$

*and*

$$\bar{\pi} = \frac{c\left(\phi + \frac{r}{\lambda}\right)}{rW + \left(N-1\right)\left(\left(W-K\right)\lambda - c\right)}.$$

Unlike "breakthrough" models, agents do not procrastinate at the beginning due to the fear of preemption. As the belief goes down, free-riding benefits can be utilized to match the cost of preemption. This stops when the belief is very low as marginal benefit of effort is almost 0.

The strategy in Proposition 3 is not the only symmetric PPBE. There are a continuum of equilibria dominated by this one. For any other $\bar{\pi}'$ with $\underline{\pi} \leq \bar{\pi}' < \bar{\pi}$, there exists a two-threshold equilibrium by replacing the pair $\{\underline{\pi}, \bar{\pi}\}$ with $\{\underline{\pi}, \bar{\pi}'\}$ in equation (6). In such equilibria, VCs keep the highest level of searching longer and has strictly lower expected payoff. As Figure 2 shows, once the VCs all switch to $a_i = 1$, their waiting value is strictly below the indifferent curve $V_I$. Individually each VC wants to preempt others by exerting more effort. But if all of them do so, the additional effort cancels out relatively. However, such actions exhaust the optimism quickly and result in earlier termination. Thus a larger upper boundary is beneficial for all players.

The strategy in Proposition 3 is also stable in the following sense. Suppose some VC $i$'s action trembles by $\varepsilon$ in $[t, t + dt]$ but no investment occurs during this period. Then after $t + dt$, the original strategy is still a PPBE. This is because VC $i$'s deviation in efforts is private and unobserved. It will not affect the belief of competing VCs, who still assume VC $i$ used the original strategy. And their strategies continue to hold since they are based on public information. Since there is no private learning and VC $i$ knows its deviation would not affect others' efforts, its belief stays as if there was no deviation. This implies the original strategy is still an equilibrium from $t + dt$ for all players.

## 2.3 High Preemption Case

While the low preemption case is still reasonable in many cumulative innovation environment, it is off the trend in VC industries. For example, Myspace was once the major startup competitor to Facebook around 2006. But now it is ranked around 4,000$^{th}$ globally in terms of web traffic and receives very limited advertising attention while Facebook still takes top 3. The returns of investments on these two companies are not even comparable.

So in this section we focus on the case where first mover grabs substantially more than followers.

The high preemption condition $K + c/\lambda > W$ diminishes the free-riding benefits. The equilibrium strategy has only one threshold corresponds to $\underline{\pi}$ in Proposition 3. Adopting $a_I$ in the middle region of a two-threshold strategy is no longer an equilibrium. To see this, first notice $a_I$'s monotonicity flips and the new feasibility constraint is

$$a_I(\pi^\dagger) = \phi.$$

Now for a given player $i$, we can interpret the waiting values $V_L(\pi^\dagger)$ and $V_I(\pi^\dagger)$ respectively as follows:

1. $V_L(\pi^\dagger)$: All VCs exert $\hat{a}_i = \hat{a}_{-i} = \phi$ for $\pi \le \pi^\dagger$.

2. $V_I(\pi^\dagger)$: VC $i$ exerts $\tilde{a}_i = \phi$. Others exert $\tilde{a}_{-i} = \tilde{a}_I$ for $\underline{\pi} \le \pi \le \pi^\dagger$ and $\tilde{a}_{-i} = \phi$ for $\pi < \underline{\pi}$.

In the second case we utilize the fact that when $\tilde{a}_{-i} = \tilde{a}_I$, $V_I$ for player $i$ is independent of its own effort. We can show $V_L(\pi^\dagger) > V_I(\pi^\dagger)$ and by equation (6), shirking is the optimal choice. This is because in the second case, $\tilde{a}_{-i} > \phi = \hat{a}_{-i}$ when $\underline{\pi} \le \pi \le \pi^\dagger$. It hurts VC $i$ because the *ex post* degree of competition increases, which makes it more likely to receive a substantially small second mover payoff.

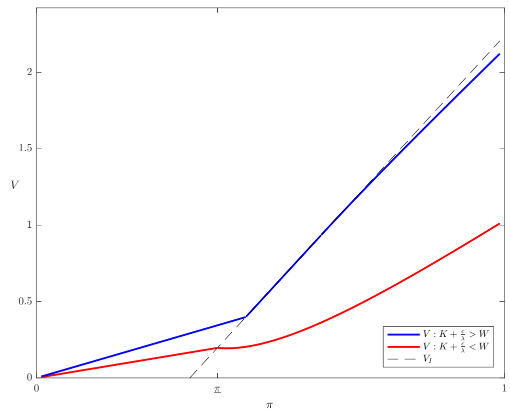
**Proposition 4.** *When $K + c/\lambda > W$,*

$$a_i = \begin{cases} 1 & \pi_t > \underline{\pi} \\ = \phi & \pi_t \le \underline{\pi} \end{cases}$$

*where*

$$\underline{\pi} = \frac{c\,(r + N\lambda\phi)}{\lambda\phi\,(N-1)\,(W-K) + rW}.$$

Figure 3: Equilibrium Waiting Value—High vs. Low Preemtpion




As before, the strategy still starts with the highest searching intensities and ends up with shirking. However, when preemption fear is large, the intermediate region with moderate efforts is gone. Instead, VCs extend the preemption region. The intuition for deviating from $a_i = a_I$ to $a_i = 1$ is simple. Players no longer value the free-riding opportunities and are motivated to compete for the first place.

Figure 3 indicates that the expected payoff is lower when preemption is higher. The reasons are twofold. A direct effect is an "insurance effect". Players will receive less payoff when losing the games. The indirect effect comes from the change of equilibrium strategies. VCs no longer gradually reduce effort in the indifferent region. This not only increases the chance of being preempted, but also expedites the termination of searching due to faster pessimism.

## 2.4 Public Disclosure

We now compare the efficiency loss in the secret scouting case to a public disclosing scenario. The latter is a case where VCs are upfront with the technology outcome and there is no hidden failures. In this case, observing no public investment could be only due the fact that no one finds a startup. Thus the belief is constant as time passes by and

VCs never become pessimistic. In other words, the game is a repeated one. Whenever a single player meets the startup, regardless of the quality, game ends for all the others. The bellman equation becomes

$$rV_{Pub}(\pi) = \lambda a_i(\pi W - V_{Pub}(\pi)) + \lambda a_{-i}(\pi K - V_{Pub}(\pi)) - c(a_i - \phi). \tag{10}$$

Comparing to equation (3), the first-order derivative no longer enters the function since the belief is constant. Solving $V_P(\pi)$ yields

$$V_{Pub} = \frac{\lambda a_i \pi W + \lambda a_{-i}\pi K - c(a_i - \phi)}{r + \lambda(a_i + a_{-i})}. \tag{11}$$

The expression of equation (11) follows a simple interpretation with growth models. The effective discount rate is the original discount rate $r$ with the instantaneous rate of ending $\lambda(a_i + a_{-i})$. The expected payoff at each instant is from either the first or the second mover payoffs net of the effort cost.

The first order condition of equation (10) indicates the effort decision rule still follows equation (4). With the same trick, we solve $a_{Pub}$ such that $V_{Pub} = V_I$,

$$a_{Pub} = \frac{r\left(\pi W - \frac{c}{\lambda}\right) - c\phi}{\lambda(N-1)(\pi K - \pi W + \frac{c}{\lambda})} < a_I.$$

Define the expected payoff when all players are exerting zero efforts as

$$\underline{V}_{Pub}(\pi) = \frac{\lambda\phi(W + (N-1)K)\pi}{r + N\phi\lambda},$$

and the expected payoff when all players are exerting full efforts as

$$\overline{V}^{Pub}(\pi) = \frac{\lambda \pi W + (N-1)\lambda\pi K - c(1-\phi)}{r + N\lambda}.$$

And lastly, the two boundaries $\pi^\dagger$ and $\pi^\ddagger$ are pinned down by

$$\underline{V}_{Pub}(\pi^\dagger) = V_I(\pi^\dagger),$$
$$\overline{V}^{Pub}(\pi^\ddagger) = V_I(\pi^\ddagger).$$

$\pi^\dagger$ and $\pi^\ddagger$ coincide with the boundaries of feasibility set of $a_{Pub}$. The following Lemma provides useful benchmarks for analyzing the equilibrium strategies.

**Lemma 5.** *$a_{Pub}(\pi^\dagger) = \phi$, $a_{Pub}(\pi^\ddagger) = 1$. $\partial a_{Pub}/\partial\pi > 0$ if and only if $\pi^\ddagger > \pi^\dagger$.*

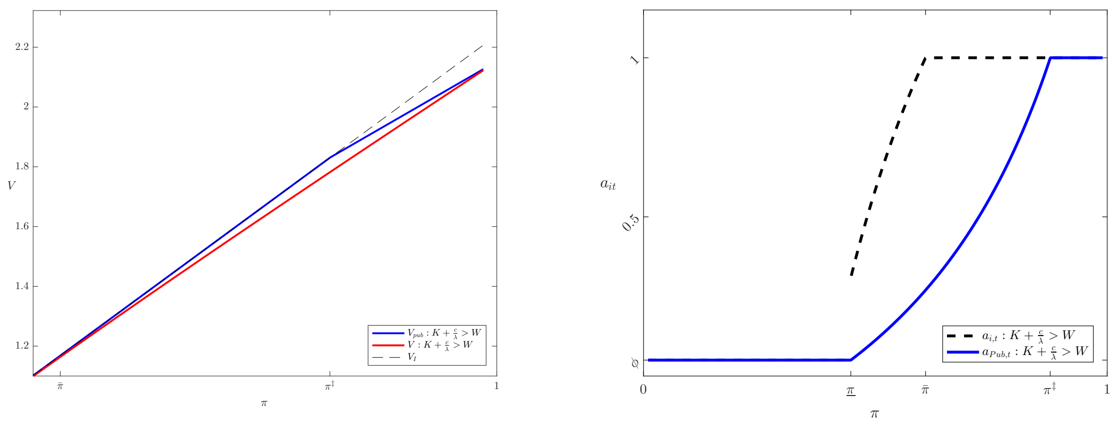
Suppose $\pi^\ddagger > \pi^\dagger$ so $\partial a_{Pub}/\partial\pi > 0$. This is the low preemption scenario with public disclosure. The equilibrium strategy follows a similar two-threshold structure with boundaries $\pi^\dagger$ and $\pi^\ddagger$. Compare $(\pi^\dagger, \pi^\ddagger)$ to $(\underline{\pi}, \bar{\pi})$ in the secret scouting case. Notice first $\underline{V}_{Pub}(\pi) = V_L(\pi)$. This is because in either cases VCs enter into an absorbing state of action: Exerting no more effort until game ends. Though belief is strictly drifting down with hidden failures, it does impact the actions at all. Thus the lower boundaries are the same, i.e., $\pi^\dagger = \underline{\pi}$.

Second the upper boundaries are both decided by $a_I(\bar{\pi}) = 1$ and $a_{Pub}(\pi^\ddagger) = 1$. Since $a_{Pub}(\pi) < a_I(\pi)$, it is straightforward to see $\pi^\ddagger$ is greater than $\bar{\pi}$. In other words, the preemption region lasts longer in the secret scouting case. This is because hidden failures generate information externalities and leads early terminations, which reduce the waiting payoffs. In this case, VCs are motivated to find a startup sooner by exerting more efforts. This is summarized by the following proposition.

**Proposition 6.** *i) If $\partial a_P/\partial\pi > 0$, players exert constant level of efforts until any result is revealed. $a_i = 1$ if $\pi > \pi^\ddagger$ and $a_i = \phi$ if $\pi < \pi^\dagger$. If belief $\pi$ is in $[\pi^\dagger, \pi^\ddagger]$, equilibrium action is pinned down by $a_{Pub}(\pi)$.*

*ii) Compared to the secret learning case, the upper threshold shifts rightwards $\pi^\ddagger > \bar{\pi}$ and the lower threshold stays the same $\pi^\dagger = \underline{\pi}$. Early termination drives down the*

Figure 4: Value Function and Effort Level —Low Preemtpion & Public Experimentation




(a) Value Function

(b) Effort Level

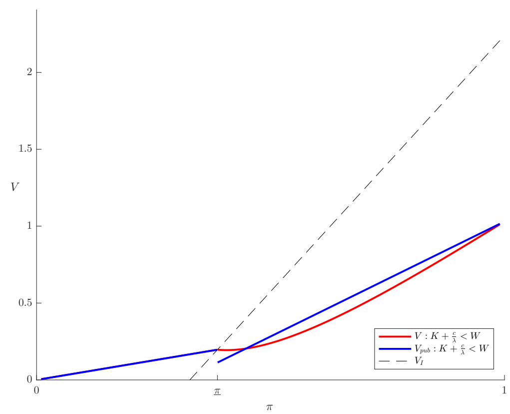
*continuation value of VCs given the same initially optimistic industry:* $V_{Pub} > V_I$ *if* $\pi > \bar{\pi}$.

On the contrary, in the high preemption case players follow a simple switching rule pinned down by $\pi^{\dagger}$. Since $\underline{V}_{Pub}(\pi) = V_L(\pi)$, VCs follow the exactly same strategy as they do in Proposition 4. In both cases, VCs cannot align their efforts to make each other indifferent as the free-riding channel is shut down. However, the continuation value of players is still different since in the public disclosing case a constant effort is taken.

Here VCs are not necessarily better off with disclosing failures. In the secret scouting case, players suffer from the cost of early termination. This cost is larger with an initially optimistic belief. In other words, they expect to give up searching for good startups due to adverse selections. But hidden failures also reduce the degree of *ex post* competitions. A given VC's competitors are also trapped by pessimism. This is beneficial when *ex ante* the belief is already low enough, so the competitors would quit very soon.

**Proposition 7.** *If* $\partial a_P/\partial \pi < 0$, *players exert constant level of effort where the strategy*

Figure 5: Equilibrium Value Function—High Preemtpion & Public Experimentation




*follows the same in Proposition 4. There exists a $\pi^\star$ such that $V_{Pub} > V_I$ if and only if $\pi > \pi^\star$.*

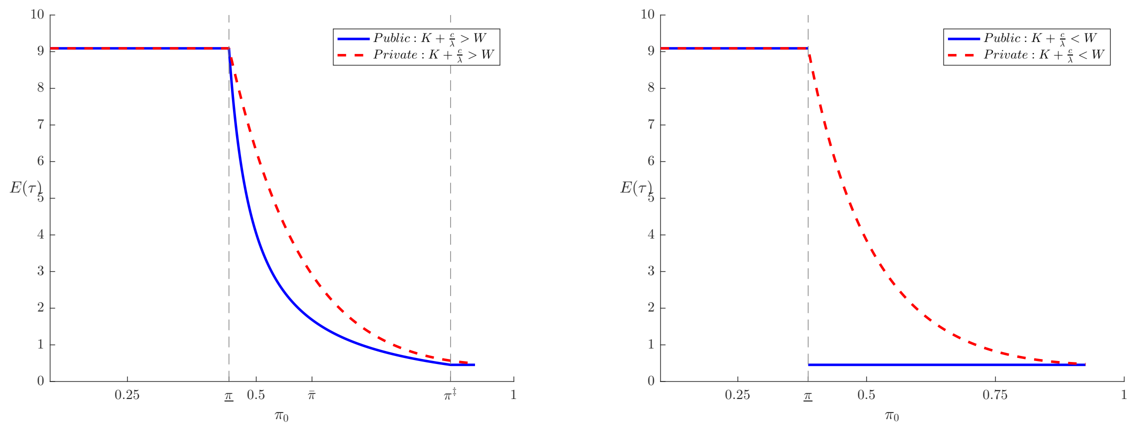
As Figure 5 shows, the expected payoff is no longer continuous. There is a jump at $\pi^\dagger$. But we do not need to have a value matching condition since the belief is constant. Locally to the right $\pi^\dagger$, players are better off if they collectively choose $a_i = \phi$. However, exerting full search efforts is a dominant strategy and coordination failure occurs.

## 2.5 Startup Welfare

In this section we highlight the efficiency cost of secrecy on the startups side. The utility of startups may come from different sources. We are interested in the expected waiting time before it meets a VC investor. This is of importance because it measures how fast a new technology can be financed. We simulate the model solutions through backward inductions and plot the waiting time against different parameters of interest.

We start with showing given different initial beliefs about the technology quality, how long a typical startup needs before meeting an investor. Since equilibrium strategies depend on $K$, we separately plot low and high preemption cases. In Figure 6(a), players' efforts follow a two-threshold strategy. It takes strictly less time of searching when failures

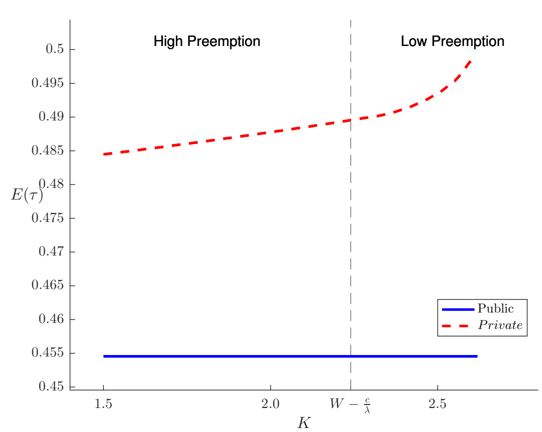
Figure 6: Expected Discovery Time Given Initial Belief —Private & Public Experimentation




(a) Low Preemption Case (b) High Preemption Case

are publicly disclosed unless initial belief is sufficiently low. In the latter case, all players shirk in searching. The same result holds for Figure 6(b), where players follow a simple one-threshold equilibrium with preemption. In either case, financing under secrecy is delayed due to pessimism.

Figure 7: Expected Discovery Time Given Second Mover Payoff




A related question is that given an initially optimistic technology, how the second mover payoff impacts the expected financing time. In the public disclosing case, a constant highest level of efforts is always optimal. In the secret scouting case, the fear of preemption forces high level of searching to persist for a longer time. Figure 7 shows that startups expect to meet VCs slightly faster as industry return becomes more right-skewed.

Does this imply right-skewness of return spurs innovation? The answer is no. Financing is globally delayed compared to the public disclosing case. We show in the following section, if VCs can *ex ante* commit to a disclosing strategy, secret scouting is an endogenous outcome only when the fear of preemption is large. The efficiency loss due to early-termination cannot be offset by a marginally increased efforts as $K$ decreases.

# 3 Endogenous Disclosure

In this section, we show how VCs endogenously opt for secrecy. Suppose prior to the searching game, all VCs can choose and commit to one of the following two disclosing strategies. The first is secret scouting in which a VC only announces the investment in a good startup but leaves the bad technology silently. The second is public disclosing in which a VC reveals the technology quality regardless of $\theta$. Players make simultaneous decisions, which are observable at the beginning of the searching game. The main goal is to show how secrecy endogenously occurs due to the fear of preemption.

We analyze a case where $N = 2$ to simplify the algebra. Besides, we restrict the initial belief to be sufficiently optimistic:

$$\pi_0 > \frac{c}{\lambda} \frac{r + 2\lambda\phi}{rW + \lambda\phi(W - K)}. \tag{12}$$

Given equation (12), the technology is promising so that all VCs are willing to exert the highest searching efforts when the game starts. In the previous sections, we have solved cases when all players commit to either secret scouting or public disclosing. It remains to show the case when one player hides the failure secretly (indexed by $S$) and the other publicly discloses all results (indexed by $P$).

Asymmetric disclosing strategies generate different belief processes of VCs. VC $S$ has a constant belief $\pi_0$ as it perfectly knows no failures are observed by VC $P$. On the contrary, VC $P$ updates its belief according to

$$d\pi_{Pt} = -\lambda a_{St}\pi_{Pt}\left(1-\pi_{Pt}\right)dt.$$

$\pi_{Pt}$ is the state variable for both players. For VC $S$, as $\pi_{Pt}$ changes, the searching effort of its opponent adjusts and therefore VC $S$ faces a different degree of preemption threats. Its value function follows

$$\begin{aligned} rV_S\left(\pi_{Pt}\right) = & -c\left(a_{St}-\phi\right)+\lambda a_{St}\left(\pi_0 W - V_S\left(\pi_{Pt}\right)\right)+\lambda a_{Pt}\left(\pi_0 K - V_S\left(\pi_{Pt}\right)\right) \\ & -\lambda a_{St}\pi_{Pt}\left(1-\pi_{Pt}\right)V_S'\left(\pi_{Pt}\right). \end{aligned} \tag{13}$$

VC $S$'s value function consists of two parts. The first part is the payoff when VCs find a startup. This happens either VC $S$ does so with instantaneous probability $\lambda a_{St}$ or VC $P$ finds one with $\lambda a_{Pt}$. The expected payoff only depends on VC $S$'s initial belief $\pi_0$. The second part reflects how the continuation value changes when the opponent's belief decreases. First-order condition implies

$$a_{St}\begin{cases} =\phi & \text{if } V_S\left(\pi_{Pt}\right) > \pi_0 W - c/\lambda - \pi_{Pt}\left(1-\pi_{Pt}\right)V_S'\left(\pi_{Pt}\right) \\ \in[\phi,\,1] & \text{if } V_S\left(\pi_{Pt}\right) = \pi_0 W - c/\lambda - \pi_{Pt}\left(1-\pi_{Pt}\right)V_S'\left(\pi_{Pt}\right) \\ 1 & \text{if } V_S\left(\pi_{Pt}\right) < \pi_0 W - c/\lambda - \pi_{Pt}\left(1-\pi_{Pt}\right)V_S'\left(\pi_{Pt}\right). \end{cases} \tag{14}$$

Compared to equation (4), VC $S$'s marginal benefit of effort has an additional term. The logic is that it could change its searching effort to impact how fast VC $P$ becomes pessimistic. By manipulating its opponent's belief, VC $S$ could reduce the preemption threats. On the contrary, VC $P$ has a value function similar with equation (3):

$$
\begin{aligned}
rV_P\left(\pi_{Pt}\right) = & -c\left(a_{Pt}-\phi\right)+\lambda a_{Pt}\left(\pi_{Pt}W-V_P\left(\pi_{Pt}\right)\right)+\lambda a_{St}\pi_{Pt}\left(K-V_P\left(\pi_{Pt}\right)\right) \\
& -\lambda a_{St}\pi_{Pt}\left(1-\pi_{Pt}\right)V_P'\left(\pi_{Pt}\right).
\end{aligned}
\tag{15}
$$

VC $P$ uses the same decision rule as equation (4). As before, once $\pi_{Pt}$ becomes sufficiently small, VC $P$ exerts 0 searching efforts. Suppose $a_{Pt} = \phi$ if $\pi_P < \check{\pi}$. Notice when the threshold $\check{\pi}$ is crossed, the game also becomes a repeated one for VC $S$. Its opponent's action enters into an absorbing state and its personal belief is a constant. Though VC $P$ continues to become more pessimistic, it generates no additional benefit for VC $S$ as it already faces the lowest degree of competition. Therefore $V_S'\left(\pi_{Pt}\right) = 0$ if $\pi_P < \check{\pi}$. Define its waiting value as $\bar{V}_S$ when VC $P$ exerts $a_{Pt} = \phi$:

$$
r\bar{V}_S = \max_{a_{St}} -c\left(a_{St}-\phi\right)+\lambda a_{St}\left(\pi_0 W-\bar{V}_S\right)+\lambda\phi\left(\pi_0 K-\bar{V}_S\right),
$$

and the action choice in (14) reduces to a simple comparison between $\bar{V}_S$ and $\pi_0 W - c/\lambda$. Lemma 8 implies when the initial belief is optimistic, VC $S$ will fully utilize its opponent pessimism and exert highest searching efforts.

**Lemma 8.** *Suppose $\pi_0$ satisfies equation (12). Then VC $S$ will take highest effort, i.e., $a_{St} = 1$, when VC $P$ shirks in searching with $a_{Pt} = \phi$.*

Lemma 8 implies the payoff that VC $S$ has when its opponent $P$ stops exerting efforts follows

$$
\bar{V}_S(\pi_0) = \frac{\lambda\pi_0 W+\lambda\phi\pi_0 K-c(1-\phi)}{r+\lambda+\lambda\phi}.
$$

It remains to pin down $\check{\pi}$. VC $P$'s value function when $\pi_P < \check{\pi}$ follows

$$V_{L,P}(\pi_{Pt}) = \frac{\lambda\phi W + \lambda K}{r + \lambda + \lambda\phi}\pi_{Pt}. \tag{16}$$

We can compare $V_{L,P}$ with $V_L$, where both players constantly exert efforts equal $\phi$.[9] Now VC $P$ faces a higher fear of preemption. This changes the effective discount rate to $r + \lambda + \phi\lambda > r + 2\lambda\phi$. However, this also increases the probability that VC $P$ receives a follower payoff $K$ even when it is very pessimistic. In other words, the free riding benefit is larger. These two effects work in the opposite direction and the latter dominates only when the runners-up payoff is sufficiently large. Therefore $V_{L,P}(\pi_{Pt}) > V_L(\pi_{Pt})$ if and only if

$$K > \frac{\lambda\phi}{r + \lambda\phi}W. \tag{17}$$

Lastly, the lower bound $\check{\pi}$ is pinned down by

$$V_{L,P}(\check{\pi}) = V_I(\check{\pi}) = \check{\pi}W - \frac{c}{\lambda},$$

which yields

$$\check{\pi} = \frac{c(r + \lambda + \lambda\phi)}{\lambda(rW + \lambda(W - K))}.$$

Proposition 9 summarizes the equilibrium strategies of players. VC $P$ follows a simple one-threshold strategy in which it exerts the highest searching efforts before $\check{\pi}$ and shirks afterwards. The strategy of VC $S$ depends on the second place payoff. When $K$ is sufficiently small, it benefits from its opponent's shirking so it would like to accelerate the speed at which VC $P$ becomes more pessimistic. This requires VC $S$ uses full efforts

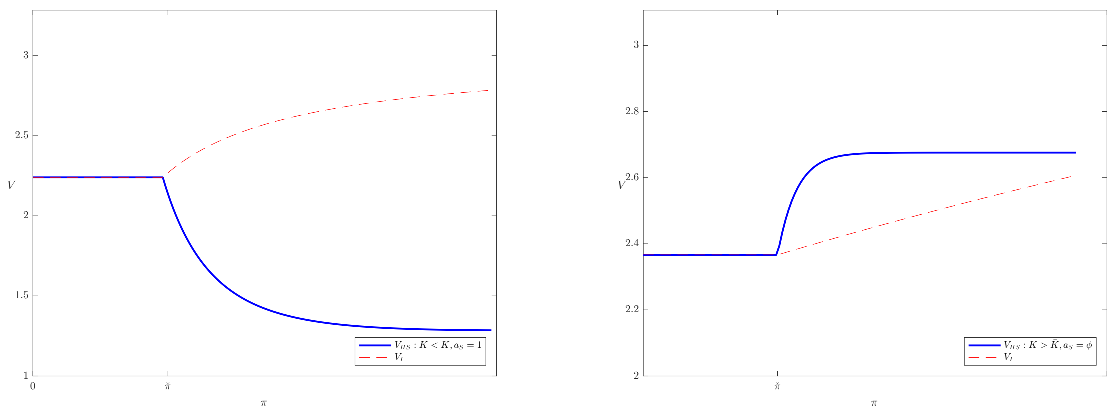
[9] In the two player case,

$$V_L = \frac{\lambda\phi W + \lambda\phi K}{r + 2\lambda\phi}\pi.$$

in searching constantly.

On the contrary, when $K$ is sufficiently large, players actually take turns to make full efforts. In this case, free-riding becomes a dominant benefit. VC $S$ wants to postpone its opponent's shirking as much as possible. This requires it to cut the initial searching intensity. Figure 8 plots the waiting value of VC $S$ in different cases.

Figure 8: Value Function for $S$ —High vs. Low Preemtpion




(a) Value Function for $S$, $K < \underline{K}$

(b) Value Function for $S$, $K > \bar{K}$

**Proposition 9.** *There exits $\underline{K}$ and $\bar{K}$, $\underline{K} < \bar{K}$, such that*

1. *Regardless of $K$, VC $P$ follows a one-threshold strategy:*

$$a_P = \begin{cases} 1 & \pi_P > \check{\pi} \\ \phi & \pi_P \leq \check{\pi}. \end{cases}$$

2. *If $K < \underline{K}$, VC $S$ always exerts full effort, $a_S(\pi_{pt}) \equiv 1$.*

3. *If $K > \bar{K}$, VC $S$ starts with the lowest effort until VC $P$ shirks, after which it exerts*

*full efforts:*

$$a_S = \begin{cases} \phi & \text{if } \pi_{pt} \geq \check{\pi} \\ 1 & \text{if } \pi_{pt} < \check{\pi}. \end{cases}$$

Through backward induction, the first-stage disclosing game follows a simple simultaneous $2 \times 2$ static game format. As along as $V_{Pub}(\pi_0) < \bar{V}_S(\pi_0)$, commit to public disclosing cannot be an equilibrium. At least one player could deviate to hiding failures and therefore become a "VC $S$". Doing so will not change its own efforts but reduces the *ex post* degree of competition.

At the extreme case when $K < \lambda\phi W/(r + \lambda\phi)$, commitment to secrecy becomes a dominant strategy. Regardless of what the competing VC chooses, each player strictly prefers to having a pessimistic competitor. Therefore secret scouting becomes a prisoner dilemma. Our result implies the right-skewness of returns in the VC industry has an impact on the disclosing choice when searching startups. The valuation gap between the first winner startup and a runner-up can be now as large as 100 times. This huge first mover advantage gives rise to the dominance of secrecy.

**Proposition 10.** *1. Public disclosing cannot be an equilibrium disclosing strategy if $V_{Pub}(\pi_0) < \bar{V}_S(\pi_0)$;*

*2. If $K < \frac{\lambda\phi}{r+\lambda\phi}W$, there exists a unique equilibrium such that both players commit to secret scouting.*

The result of Proposition 10 can be extended generally to other innovation settings. For example, there is a famous publication bias that researchers will not submit negative and null results. In our model, there are no reputation concerns. A failed technology, though generating no payoffs, is correctly identified. We believe this bias is instead due to increased competition in publication. If a scholar concerns that her current research has been validated as dead ends by someone else, she would spend less time on every single new project. If everyone understands the externalities of hiding failures, they could use this as tools to reduce the fear of preemption.

# 4 Conclusion

We extend the standard preemption game to explain how VCs search for startups with uncertain technologies. In reality, hiding failed startups is widely observed. This feature of secrecy creates efficiency loss through a channel of pessimism. VCs will question the quality of the technology after observing that no investments are publicly announced. Even though secrecy is costly, hiding failures is an arms race to reduce the *ex post* fear of preemption. If return is extremely right-skewed, VCs rely on the secrecy to trick their opponents into a pessimistic belief so that they will stop searching. This can happen even though in realization no technology failures are observed. Therefore though full transparency about searching outcomes could improve social welfare, it cannot be sustained as an equilibrium without intervention.

# References

Akcigit, U., Liu, Q., 2015. The Role of Information in Innovation and Competition. Journal of the European Economic Association 14 (4), 828–870.

Barber, B. M., Yasuda, A., 2017. Interim Fund Performance and Fundraising in Private Equity. Journal of Financial Economics 124 (1), 172–194.

Baum, J. A., Silverman, B. S., 2004. Picking Winners or Building them? Alliance, Intellectual, and Human Capital as Selection Criteria in Venture Financing and Performance of Biotechnology Startups. Journal of Business Venturing 19 (3), 411–436.

Bernstein, S., Korteweg, A., Laws, K., 2017. Attracting Early-Stage Investors: Evidence from a Randomized Field Experiment. The Journal of Finance 72 (2), 509–538.

Bobtcheff, C., Bolte, J., Mariotti, T., 2016. Researcher's Dilemma. The Review of Economic Studies 84 (3), 969–1014.

Bolton, P., Harris, C., 1999. Strategic Experimentation. Econometrica 67 (2), 349–374.

Bottazzi, L., Da Rin, M., Hellmann, T., 2008. Who are the Active Investors?: Evidence from Venture Capital. Journal of Financial Economics 89 (3), 488–512.

Brown, G. W., Gredil, O. R., Kaplan, S. N., 2018. Do Private Equity Funds Manipulate Reported Returns? Journal of Financial Economics.

Campbell, A., Ederer, F., Spinnewijn, J., 2014. Delay and Deadlines: Freeriding and Information Revelation in Partnerships. American Economic Journal: Microeconomics 6 (2), 163–204.

Catalini, C., Guzman, J., Stern, S., 2017. Hidden in Plain Sight: Venture Growth With and Without Venture Capital. Tech. rep., MIT Working Paper.

Chakraborty, I., Ewens, M., 2017. Managing Performance Signals through Delay: Evidence from Venture Capital. Management Science 64 (6), 2875–2900.

Cripps, M. W., Thomas, C. D., 2019. Strategic experimentation in queues. Theoretical Economics 14 (2), 647–708.

Ewens, M., Nanda, R., Rhodes-Kropf, M., 2018. Cost of Experimentation and the Evolution of Venture Capital. Journal of Financial Economics 128 (3), 422–442.

Gompers, P., Lerner, J., 2001. The Venture Capital Revolution. Journal of Economic Perspectives 15 (2), 145–168.

Gompers, P. A., 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. The Journal of Finance 50 (5), 1461–1489.

Gonzalez-Uribe, J., Leatherbee, M., 2017. The Effects of Business Accelerators on Venture Performance: Evidence from Start-up Chile. The Review of Financial Studies 31 (4), 1566–1603.

Graham, S., Hegde, D., 2015. Disclosing Patents' Secrets. Science 347 (6219), 236–237.

Gross, D. P., 2019. The Consequences of Invention Secrecy: Evidence from the USPTO Patent Secrecy Program in World War II. NBER Working Paper Series 25545.

Halac, M., Kartik, N., Liu, Q., 2017. Contests for experimentation. Journal of Political Economy 125 (5), 1523–1569.

Hall, R. E., Woodward, S. E., 2010. The Burden of the Nondiversifiable Risk of Entrepreneurship. American Economic Review 100 (3), 1163–94.

Hegde, D., Herkenhoff, K., Zhu, C., 2018. Patent Disclosure.

Hellmann, T., Puri, M., 2002. Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence. The Journal of Finance 57 (1), 169–197.

Hellmann, T., Thiele, V., 2015. Friends or Foes? the Interrelationship between Angel and Venture Capital Markets. Journal of Financial Economics 115 (3), 639–653.

Hochberg, Y. V., Ljungqvist, A., Lu, Y., 2007. Whom You Know Matters: Venture Capital Networks and Investment Performance. The Journal of Finance 62 (1), 251–301.

Hopenhayn, H. A., Squintani, F., 2011. Preemption Games with Private Information. The Review of Economic Studies 78 (2), 667–692.

Hopenhayn, H. A., Squintani, F., 2015. Patent Rights and Innovation Disclosure. The Review of Economic Studies 83 (1), 199–230.

Inderst, R., Müller, H. M., 2004. The Effect of Capital Market Characteristics on the Value of Start-Up Firms. Journal of Financial Economics 72 (2), 319–356.

Keller, G., Rady, S., jan 2015. Breakdowns. Theoretical Economics 10 (1), 175–202.

Keller, G., Rady, S., Cripps, M., 2005. Strategic Experimentation with Exponential Bandits. Econometrica 73 (1), 39–68.

Kerr, W. R., Lerner, J., Schoar, A., 2011. The Consequences of Entrepreneurial Finance: Evidence from Angel Financings. The Review of Financial Studies 27 (1), 20–55.

Kerr, W. R., Nanda, R., Rhodes-Kropf, M., September 2014. Entrepreneurship as Experimentation. Journal of Economic Perspectives 28 (3), 25–48.

Khanna, N., Mathews, R. D., 2016. Posturing and Holdup in Innovation. The Review of Financial Studies 29 (9), 2419–2454.

Lerner, J., 1995. Venture Capitalists and the Oversight of Private Firms. the Journal of Finance 50 (1), 301–318.

Moscarini, G., Squintani, F., 2010. Competitive Experimentation with Private Information: The Survivor's Curse. Journal of Economic Theory 145 (2), 639–660.

Murto, P., Välimäki, J., may 2011. Learning and information aggregation in an exit game. The Review of Economic Studies 78 (4), 1426–1461.

Nanda, R., Rhodes-Kropf, M., 2013. Innovation and the Financial Guillotine. Tech. rep., National Bureau of Economic Research.

Petkova, A. P., Rindova, V. P., Gupta, A. K., 2013. No News is Bad News: Sensegiving Activities, Media Attention, and Venture Capital Funding of New Technology Organizations. Organization Science 24 (3), 865–888.

Ueda, M., 2004. Banks versus Venture Capital: Project Evaluation, Screening, and Expropriation. The Journal of Finance 59 (2), 601–621.

# A Omitted Proofs

## Proof of Lemma 1

*Proof.* Take derivative of $a_I$,

$$\begin{aligned} a_I' &= (\frac{r\pi W - c(\frac{r}{\lambda}+\phi)}{(N-1)(K+\frac{c}{\lambda}-W)\lambda\pi})' \\ &= \frac{c(\frac{r}{\lambda}+\phi)(N-1)(K+\frac{c}{\lambda}-W)}{((N-1)(K+\frac{c}{\lambda}-W)\lambda\pi)^2} \end{aligned}$$

Thus $a_I' > 0$ if and only if $K + \frac{c}{\lambda} - W > 0$. □

## Proof of Lemma 2

*Proof.* Use the value matching condition $V_H = \pi W - \frac{c}{\lambda}$ and smooth pasting condition $V_H' = W$ in equation (7)

$$\begin{aligned} & r(\pi W - \frac{c}{\lambda}) = c + \lambda(N-1)\pi\left(K - \pi W + \frac{c}{\lambda}\right) - (N-1)\pi\left(1-\pi\right)\lambda W - c\left(1-\phi\right) \\ \Longrightarrow\ & r(\pi W - \frac{c}{\lambda}) = \lambda(N-1)\pi\left(K - W + \frac{c}{\lambda} + (1-\pi)W\right) - (N-1)\pi\left(1-\pi\right)\lambda W + c\phi \\ \Longrightarrow\ & r(\pi W - \frac{c}{\lambda}) = \lambda(N-1)\pi\left(K - W + \frac{c}{\lambda}\right) + c\phi \\ \Longrightarrow\ & \pi(rW + (N-1)\left((W-K)\lambda - c\right)) = c\left(\phi + \frac{r}{\lambda}\right) \\ \Longrightarrow\ & \pi = \bar{\pi} \end{aligned}$$

□

## Proof of Proposition 3

*Proof.* First notice when $\pi < \frac{c}{\lambda W}$, $V_I < 0$. The player's waiting value must be non-negaitve. This implies $V > V_I$ if $\pi$ is sufficiently small. By equation (4), $a_t = \phi$ for any $i$. Consider any $\pi$ that all players use $a_t = \phi$ when belief is smaller than $\pi$, then VC $i$'s value function follows $V_L = \frac{\lambda\phi(W+K(N-1))}{N\lambda\phi+r}\pi$. Thus, $V_L \geq V_I$ if and only if $\pi \leq \underline{\pi}$.

During $[\underline{\pi}, \bar{\pi}]$, players are indifferent with regard to actions as $V = V_I$. Thus using $a_t = a_I$ is a weakly dominant strategy. If $\pi > \bar{\pi}$, $a_I$ is no longer feasible. It remains to show $V_H$ defined by equation (7) satisfies $V_H < V_I$ for all $\pi > \bar{\pi}$. Firstly, since $\hat{\pi} = \frac{c\left(\phi+\frac{r}{\lambda}\right)}{rW+(N-1)((W-K)\lambda-c)}$ , this value must be strictly smaller than 1 as it is a probability, which yields

$$c(r + \lambda\phi) < \lambda[rW + (N-1)(\lambda(W-K) - c)] \tag{18}$$

Secondly, $V_H = -\frac{c(1-\phi)}{(\lambda+r)} + \frac{\lambda(W+(N-1)(K+\frac{c(1-\phi)}{\lambda+r}))}{N\lambda+r}\pi + C_1(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda}{(N-1)\lambda}} = \pi W - \frac{c}{\lambda}$ at $\bar{\pi}$. Thus $C_1 < 0$ if and only if

$$\begin{aligned}
&-\frac{c}{\lambda} + \frac{c(1-\phi)}{(\lambda+r)} + \bar{\pi}(W - \frac{\lambda(W+(N-1)(K+\frac{c(1-\phi)}{\lambda+r}))}{N\lambda+r}) < 0 \\
\Leftrightarrow &\bar{\pi}\frac{rW + (N-1)[\lambda(W-K) - \frac{\lambda}{r+\lambda}c(1-\phi)]}{r+N\lambda} < \frac{c(\phi+\frac{r}{\lambda})}{r+\lambda} \\
\Leftrightarrow &\bar{\pi} < \frac{r+N\lambda}{r+\lambda}\frac{c(\phi+\frac{r}{\lambda})}{rW+(N-1)[\lambda(W-K) - \frac{\lambda}{r+\lambda}c(1-\phi)]} \\
\Leftrightarrow &(\lambda+r)(rW+(N-1)\lambda(W-K)) - (N-1)\lambda c(1-\phi) < \\
&(N\lambda+r)(rW+(N-1)\lambda(W-K)) - (N\lambda+r)(N-1)c \\
\Leftrightarrow &-rW - (N-1)\lambda(W-K) + (N-1)c + c\phi + c\frac{r}{\lambda} < 0
\end{aligned}$$

which is equivalent to equation (18). Take second order derivative of $V_H$

$$V_H'' = C_1\frac{r+\lambda}{(N-1)\lambda}(1+\frac{r+\lambda}{(N-1)\lambda})(1-\pi)^{\frac{r+\lambda}{(N-1)\lambda}-1}\pi^{-(\frac{r+\lambda}{(N-1)\lambda}+2)} < 0$$

Thus $V_H$ is a concave function. Since it satisfies smooth pasting condition at $\bar{\pi}$, $V_H < V_I$ for all $\pi > \bar{\pi}$. $\square$

## Proof of Proposition 4

*Proof.* The proof for the region $\pi < \underline{\pi}$ is the same as the of Proposition 3. For all $\pi > \underline{\pi}$, first consider $V_H'$ at $\underline{\pi}$ with value matching condition

$$r(\underline{\pi}W - \frac{c}{\lambda}) = c + \lambda(N-1)\underline{\pi}\left(K - \underline{\pi}W + \frac{c}{\lambda}\right) - (N-1)\underline{\pi}\left(1-\underline{\pi}\right)\lambda V_H' - c\left(1-\phi\right)$$
$$\Longrightarrow r(\underline{\pi}W - \frac{c}{\lambda}) = \lambda(N-1)\underline{\pi}\left(K - W + \frac{c}{\lambda} + (1-\underline{\pi})W\right) - (N-1)\underline{\pi}\left(1-\underline{\pi}\right)\lambda V_H' + c\phi$$
$$\Longrightarrow \underline{\pi}(rW + \lambda(N-1)(W-K-\frac{c}{\lambda})) - c(\frac{r}{\lambda}+\phi) = \lambda(N-1)\underline{\pi}\left(1-\underline{\pi}\right)\left(W - V_H'\right)$$

Thus $W < V_H'$ if and only if

$$\underline{\pi} > \frac{c(\frac{r}{\lambda}+\phi)}{rW + \lambda(N-1)(W-K-\frac{c}{\lambda})} = \bar{\pi}$$

Denote $\tilde{\pi}$ as the value of $\pi$ such that $a_I(\tilde{\pi}) = \phi$. By Lemma 1, $a_I' < 0$ in this case and hence $\bar{\pi} < \tilde{\pi} = \frac{c(\frac{r}{\lambda}+\phi)}{rW+\lambda(N-1)\phi(W-K-\frac{c}{\lambda})}$. $\underline{\pi} > \tilde{\pi}$ is equivalent to

$$\frac{c\left(\frac{r}{\lambda}+N\phi\right)}{\lambda\phi\left(N-1\right)\left(W-K\right)+rW} > \frac{c(\frac{r}{\lambda}+\phi)}{rW+\lambda(N-1)\phi(W-K-\frac{c}{\lambda})}$$
$$\Longleftrightarrow rW + \lambda(N-1)\phi(W-K) > c(\frac{r}{\lambda}+N\phi)$$
$$\Longleftrightarrow rW + \lambda(N-1)\phi(W-K) > c(\frac{r}{\lambda}+\phi) + (N-1)\phi c$$

Last line holds as $W > \frac{c}{\lambda} + \frac{c\phi}{r}$ and $W - K - \frac{c}{\lambda} > 0$. This implies $V_H'(\underline{\pi}) < W = V_I'(\underline{\pi})$. We then show $V_H < V_I$ for all $\pi > \underline{\pi}$. Suppose not, then there exist $\pi^\star > \underline{\pi}$ such that

$V_H(\pi^\star) = \pi^\star W - \frac{c}{\lambda}$ and $V_H'(\pi^\star) > W$. By equation (7),

$$\begin{aligned} rV_H(\pi^\star) &< \lambda(\pi^\star W - \pi^\star W - \frac{c}{\lambda}) + \lambda(N-1)\pi^\star(K - \pi^\star W - \frac{c}{\lambda}) - (N-1)\pi^\star(1-\pi^\star)\lambda W - c(1-\phi) \\ &= \lambda(N-1)\pi^\star\left(K - W + \frac{c}{\lambda} + (1-\pi^\star)W\right) - (N-1)\pi^\star\left(1-\pi^\star\right)\lambda W + c\phi \\ &= \lambda(N-1)\pi^\star\left(K - W + \frac{c}{\lambda}\right) + c\phi \end{aligned}$$

Since $W > K + \frac{c}{\lambda}$, the RHS is decreasing in $\pi^\star$. Thus

$$\begin{aligned} rV_H(\pi^\star) &< \lambda(N-1)\bar{\pi}\left(K - W + \frac{c}{\lambda}\right) + c\phi \\ &= -\bar{\pi}(rW + \lambda(N-1)\left(W - K - \frac{c}{\lambda}\right)) + r\bar{\pi}W + c\phi \\ &= -c(\frac{r}{\lambda} + \phi) + r\bar{\pi}W + c\phi \\ &= r\bar{\pi}W - c\frac{r}{\lambda} \\ &< r(\pi^\star W - \frac{c}{\lambda}) \end{aligned}$$

which is contradictory to the assumption that $V_H(\pi^\star) = \pi^\star W - \frac{c}{\lambda}$. Thus $V_H < V_I$ for all $\pi > \underline{\pi}$, which implies $a_{it} = 1$ in the region. □

## Proof of Lemma 5

*Proof.* i)

$$\begin{aligned} &\overline{V}^{Pub}(\pi) = V_I(\pi) \\ \Longleftrightarrow &\frac{\lambda\pi W + (N-1)\lambda\pi K - c(1-\phi)}{r + N\lambda} = \pi W - \frac{c}{\lambda} \\ \Longleftrightarrow &\lambda(N-1)(\pi K - \pi W + \frac{c}{\lambda}) = r\left(\pi W - \frac{c}{\lambda}\right) - c\phi \\ \Longleftrightarrow &a_{pub}(\pi) = 1 \end{aligned}$$

ii)

$$
\begin{aligned}
&\underline{V}_{Pub}(\pi) = V_I(\pi) \\
\Longleftrightarrow &\frac{\lambda\phi(W + (N-1)K)\pi}{r + N\phi\lambda} = \pi W - \frac{c}{\lambda} \\
\Longleftrightarrow &\lambda(N-1)(\pi K - \pi W + \frac{c}{\lambda})\phi = r(\pi W - \frac{c}{\lambda}) - c\phi \\
\Longleftrightarrow &a_{pub}(\pi) = \phi
\end{aligned}
$$

iii) Take derivative of $a_{pub}$,

$$
\begin{aligned}
a'_{pub} &= \left(\frac{r\left(\pi W - \frac{c}{\lambda}\right) - c\phi}{\lambda(N-1)(\pi K - \pi W + \frac{c}{\lambda})}\right)' \\
&= \frac{\lambda(N-1)(\frac{c}{\lambda}rW - (c\frac{r}{\lambda} + c\phi)(W-K))}{(\lambda(N-1)(\pi K - \pi W + \frac{c}{\lambda}))^2}
\end{aligned}
$$

Thus, $a'_{pub} > 0$ if and only if $\frac{c}{\lambda}rW > (c\frac{r}{\lambda}+c\phi)(W-K)$. Meanwhile, $\pi^\dagger = \frac{c\frac{r}{\lambda}+c\phi+\lambda\phi(N-1)\frac{c}{\lambda}}{rW+\lambda\phi(N-1)(W-K)}$ and $\pi^\ddagger = \frac{c\frac{r}{\lambda}+c\phi+\lambda(N-1)\frac{c}{\lambda}}{rW+\lambda(N-1)(W-K)}$.

$$
\begin{aligned}
&\pi^\dagger < \pi^\ddagger \\
\Longleftrightarrow &\frac{c\frac{r}{\lambda} + c\phi + \lambda\phi(N-1)\frac{c}{\lambda}}{rW + \lambda\phi(N-1)(W-K)} < \frac{c\frac{r}{\lambda} + c\phi + \lambda(N-1)\frac{c}{\lambda}}{rW + \lambda(N-1)(W-K)} \\
\Longleftrightarrow &[c\frac{r}{\lambda} + c\phi + \lambda\phi(N-1)\frac{c}{\lambda}](W-K) < \\
&\frac{c}{\lambda}[rW + \lambda\phi(N-1)(W-K)] \\
\Longleftrightarrow &(c\frac{r}{\lambda} + c\phi)(W-K) < \frac{c}{\lambda}rW
\end{aligned}
$$

□

## Proof of Proposition 6

*Proof.* The argument for $\pi < \pi^{\ddagger}$ is logically the same as Proposition 3. Since $\overline{V'}^{Pub}(\pi) = \frac{\lambda W + (N-1)\lambda K}{r+N\lambda} < W = V_I'(\pi)$, $\overline{V}^{Pub}(\pi) < V_I(\pi)$ for all $\pi > \pi^{\ddagger}$. To see the second part of the statement, suppose there exists a $\pi$ such that $V_H(\pi) = \overline{V}^{Pub}(\pi)$, i.e.

$$
\begin{aligned}
&-\frac{c\,(1-\phi)}{(\lambda+r)} + \frac{\lambda(W + (N-1)(K + \frac{c(1-\phi)}{\lambda+r}))}{N\lambda + r}\pi + C_1\,(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda}{(N-1)\lambda}} = \frac{\lambda\pi W + (N-1)\lambda\pi K - c(1-\phi}{r+N\lambda} \\
\Longleftrightarrow & C_1\,(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda}{(N-1)\lambda}} = \frac{c\,(1-\phi)}{(\lambda+r)} - \frac{c(1-\phi)}{r+N\lambda}(\frac{\pi\lambda}{\lambda+r} + 1)
\end{aligned}
$$

Notice the RHS is positive as

$$
\begin{aligned}
&\frac{c\,(1-\phi)}{(\lambda+r)} - \frac{c(1-\phi)}{r+N\lambda}(\frac{\pi\lambda}{\lambda+r} + 1) > 0 \\
\Longleftrightarrow & \frac{1}{\lambda+r} > \frac{\frac{\pi\lambda}{\lambda+r} + 1}{r+N\lambda} \\
\Longleftrightarrow & r + N\lambda > \pi\lambda + \lambda + r
\end{aligned}
$$

The last line holds as $N \geq 2$ and $\pi \leq 1$. However the LHS is negative as $C_1 < 0$, which is contradictory. Thus $V_H(\pi) < \overline{V}^{Pub}(\pi)$. □

## Proof of Proposition 7

*Proof.* The first half of the statement is the same as Proposition 4. For the second half, notice in this case $\pi^{\ddagger} < \pi^{\dagger}$. Thus $\overline{V}^{Pub}(\pi^{\dagger}) < V_I(\pi^{\dagger}) = V_H(\pi^{\dagger})$. The first inequality comes from $\overline{V'}^{Pub}(\pi) < V_I'(\pi)$ and the second equality comes from value matching condition at $\pi^{\dagger}$.

$$\overline{V}^{Pub}(\pi) - V_H(\pi)$$
$$= \frac{c\,(1-\phi)}{(\lambda+r)} - \frac{c(1-\phi)}{r+N\lambda}(\frac{\pi\lambda}{\lambda+r}+1) - C_1\,(1-\pi)\left(\frac{1-\pi}{\pi}\right)^{\frac{r+\lambda}{(N-1)\lambda}}$$

which implies $\lim\limits_{\pi\to 1} \overline{V}^{Pub}(\pi) - V_H(\pi) = \frac{c(1-\phi)}{(\lambda+r)} - \frac{c(1-\phi)}{r+N\lambda}(\frac{\lambda}{\lambda+r}+1) = \frac{c(1-\phi)}{(\lambda+r)}(1-\frac{2\lambda+r}{N\lambda+r}) > 0$. As both $\overline{V}^{Pub}(\pi)$ and $V_H(\pi)$ are continuous functions. By intermediate value theorem, there exists a $\pi^\star$ such that $\overline{V}^{Pub}(\pi) > V_H(\pi)$ if $\pi > \pi^\star$.

$\pi > \pi^\star$ is also a sufficient condition for $\overline{V}^{Pub}(\pi) > V_H(\pi)$. This is because $V_H(\pi)$ is a convex function in the high preemption scenario. Thus $V_H(\pi)$ has at most two intersections with the linear function $\overline{V}^{Pub}(\pi)$. However if there were two intersections, $V_H(\pi)$ will be strictly greater than $\overline{V}^{Pub}(\pi)$ for all $\pi$ larger than the second intersection. This is contradictory to the fact that $\overline{V}^{Pub}(\pi) - V_H(\pi)$ at a neighbor of $\pi = 1$. Therefore $\overline{V}^{Pub}(\pi)$ intersects with $V_H(\pi)$ only once. □

## Proof of Lemma 8

*Proof.* Suppose $a_{St} = \phi$, then
$$\bar{V_S} = \frac{\lambda\phi\pi_0(W+K)}{r+2\lambda\phi}$$

$\bar{V_S} > \pi_0 W - \frac{c}{\lambda}$ if and only if

$$c > \lambda\frac{r\pi_0 W + \lambda\phi\pi_0(W-K)}{r+2\lambda\phi}$$

which is contradictory to equation (12). To verify $a_{St} = 1$ is indeed optimal, if so

$$\bar{V_S} = \frac{\lambda\pi_0 W + \lambda\phi\pi_0 K - c(1-\phi)}{r+\lambda+\lambda\phi}$$

$\bar{V}_S < \pi_0 W - \frac{c}{\lambda}$ if and only if

$$c < \lambda \frac{r\pi_0 W + \lambda\phi\pi_0(W-K)}{r+2\lambda\phi}$$

Thus $a_{St} = 1$, $a_{Pt} = \phi$ and $\bar{V}_S = \frac{\lambda\pi_0 W + \lambda\phi\pi_0 K - c(1-\phi)}{r+\lambda+\lambda\phi}$ if $\pi_2 < \check{\pi}$. □

## Proof of Proposition 9

*Proof.* We first show $\check{\pi} > \hat{\pi}$. Thus $P$'s strategy follows a simple switching rule. Suppose not, then

$$\begin{aligned}
&\check{\pi} < \hat{\pi} \\
\Longleftrightarrow &\frac{c(r+\lambda+\lambda\phi)}{\lambda(rW+\lambda(W-K))} < \frac{c\left(\phi+\frac{r}{\lambda}\right)}{rW+((W-K)\lambda-c)} \\
\Longleftrightarrow &rW+\lambda(W-K) < c(r+\lambda+\lambda\phi) \\
\Longleftrightarrow &\check{\pi} > 1
\end{aligned}$$

which is contradictory to the fact that $\check{\pi} \leq 1$ as a probability.

**S's Optimal Action.** Suppose $a_P = 1$ if $\pi > \check{\pi}$ (we will validate this is indeed the case later). We start with defining the indifferent curve for $S$ as

$$V_{SI}(\pi_{Pt}) = \pi_0 W - \frac{c}{\lambda} - \pi_{Pt}(1-\pi_{Pt}) V'_{SI}(\pi_{Pt})$$

which follows a general solution

$$V_{SI}(\pi_{Pt}) = \pi_0 W - \frac{c}{\lambda} + C_{SI}\frac{1-\pi_{Pt}}{\pi_{Pt}}$$

$C_{SI}$ is a constant pinned down by the boundary condition

$$V_{SI}(\check{\pi}) = \bar{V}_S$$

Suppose locally to the right of $\check{\pi}$, $S$ exerts full effort $a_{St} = 1$ , then

$$\begin{aligned} r\overline{V}_{H,S}(\pi_{Pt}) &= -c(1-\phi) + \lambda\left(\pi_0 W - \overline{V}_{H,S}(\pi_{Pt})\right) + \lambda\left(\pi_0 K - \overline{V}_{H,S}(\pi_{Pt})\right) \\ &- \lambda\pi_{Pt}(1-\pi_{Pt})\overline{V}'_{H,S}(\pi_{Pt}) \end{aligned} \tag{19}$$

ODE (19) has a general form of solution as $\overline{V}_{H,S}(\pi_P) = \frac{-c(1-\phi)+\lambda\pi_0 W+\lambda\pi_0 K}{(r+2\lambda)} + \overline{C}_{HS}\frac{\lambda}{r+2\lambda}(\frac{1-\pi_P}{\pi_P})^{\frac{r+2\lambda}{\lambda}}$, where $\overline{C}_{HS}$ is pinned down by the same boundary condition $\overline{V}_{H,S}(\check{\pi}) = \bar{V}_S$. Similarly, if $a_{St} = \phi$ to the right of $\check{\pi}$, then

$$r\underline{V}_{H,S}(\pi_{Pt}) = \lambda\phi\left(\pi_0 W - \underline{V}_{H,S}(\pi_{Pt})\right) + \lambda\left(\pi_0 K - \underline{V}_{H,S}(\pi_{Pt})\right) - \lambda\phi\pi_{Pt}(1-\pi_{Pt})\underline{V}'_{H,S}(\pi_{Pt}) \tag{20}$$

ODE (19) has a general form of solution as $\underline{V}_{H,S}(\pi_{Pt}) = \frac{\lambda\phi\pi_0 W+\lambda\pi_0 K}{(r+\lambda+\lambda\phi)} + \underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}}$, where $\underline{C}_{HS}$ is pinned down by the same boundary condition $\overline{V}_{H,S}(\check{\pi}) = \bar{V}_S$.

First consider $S$'s indifferent curve with the boundary condition $V_{SI}(\check{\pi}) = \bar{V}_S = \frac{\lambda\pi_0 W+\lambda\phi\pi_0 K-c(1-\phi)}{r+\lambda+\lambda\phi}$. This generates

$$\begin{aligned} C_{SI}\frac{1-\check{\pi}}{\check{\pi}} &= \left(\frac{\lambda\pi_0 W + \lambda\phi\pi_0 K - c(1-\phi)}{r+\lambda+\lambda\phi} - \pi_0 W + \frac{c}{\lambda}\right) \\ &= \bar{V}_S - (\pi_0 W - \frac{c}{\lambda}) \\ &< 0 \end{aligned}$$

where the second line comes from Lemma ??. Thus $C_{SI} < 0$ and $V'_{SI} = -C_{SI}\frac{1}{\pi_P^2} > 0$.

Suppose $a_S = 1$ if $\pi > \check{\pi}$. Then $\overline{V}_{H,S}(\pi_P) = \frac{-c(1-\phi)+\lambda\pi_0 W+\lambda\pi_0 K}{(r+2\lambda)} + \overline{C}_{HS}\frac{\lambda}{r+2\lambda}(\frac{1-\pi_P}{\pi_P})^{\frac{r+2\lambda}{\lambda}}$.

By value matching condition ($\overline{V}_{H,S}(\breve{\pi}) = \bar{V}_S$),

$$\overline{C}_{HS}\frac{\lambda}{r+2\lambda}(\frac{1-\breve{\pi}}{\breve{\pi}})^{\frac{r+2\lambda}{\lambda}} = \frac{\lambda\pi_0 W + \lambda\phi\pi_0 K - c(1-\phi)}{r+\lambda+\lambda\phi} - \frac{-c(1-\phi)+\lambda\pi_0 W + \lambda\pi_0 K}{(r+2\lambda)}$$

Notice if $K < \frac{\lambda\pi_0 W - c(1-\phi)}{\pi_0(r+\lambda)}$, the RHS is positive and thus $\overline{C}_{HS} > 0$. This implies $\overline{V}'_{H,S} = -\overline{C}_{HS}(\frac{1}{\pi_P}-1)^{\frac{r+2\lambda}{\lambda}}\frac{1}{\pi_P^2} < 0$. By $V_{SI}(\breve{\pi}) = \overline{V}_{H,S}(\breve{\pi})$ and the monotonicity of them two, $\overline{V}_{H,S} < V_{SI}$ if $\pi > \breve{\pi}$ and $a_S = 1$ is optimal. Notice $K < \frac{\lambda\pi_0 W - c(1-\phi)}{\pi_0(r+\lambda)}$ is a sufficient but unnecessary condition. Denote the solution of equation (19) with respect to $K$ as $\overline{V}_{H,S}(\pi;K)$. $\overline{V}_{H,S}(\pi;K)$ is continuous function of $K$ and $\frac{\partial\overline{V}_{H,S}(\pi;K)}{\partial K} > 0$. This implies there exists $\underline{K}$ such that $\overline{V}_{H,S} < V_{SI}$ for all $\pi > \breve{\pi}$ if $K < \underline{K}$.

Suppose $a_S = \phi$ if $\pi > \breve{\pi}$. Then $\underline{V}_{H,S}(\pi_{Pt}) = \frac{\lambda\phi\pi_0 W + \lambda\pi_0 K}{(r+\lambda+\lambda\phi)} + \underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}}$. By value matching condition ($\underline{V}_{H,S}(\breve{\pi}) = \bar{V}_S$),

$$\begin{aligned}\underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\breve{\pi}}{\breve{\pi}})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}} &= \frac{\lambda\pi_0 W + \lambda\phi\pi_0 K - c(1-\phi)}{r+\lambda+\lambda\phi} - \frac{\lambda\phi\pi_0 W + \lambda\pi_0 K}{(r+\lambda+\lambda\phi)} \\ &= \frac{\lambda(1-\phi)(\pi_0 W - \pi_0 K - \frac{c}{\lambda})}{r+\lambda+\lambda\phi}\end{aligned}$$

Notice $\underline{C}_{HS} < 0$ if $K > W - \frac{c}{\lambda\pi_0}$. Meanwhile,

$$\begin{aligned}&\underline{V}_{H,S}(\pi_P) - V_{SI}(\pi_P) \\ =&\int_{\breve{\pi}}^{\pi_P}\underline{V}'_{H,S}d\pi - \int_{\breve{\pi}}^{\pi_P}V'_{SI}d\pi \\ =&\underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}} - \underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\breve{\pi}}{\breve{\pi}})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}} \\ &-(C_{SI}\frac{1-\pi_{Pt}}{\pi_{Pt}} - C_{SI}\frac{1-\breve{\pi}}{\breve{\pi}}) \\ =&\underbrace{\underline{C}_{HS}\frac{\lambda\phi}{r+\lambda+\lambda\phi}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda+\lambda\phi}{\lambda\phi}} - C_{SI}\frac{1-\pi_{Pt}}{\pi_{Pt}}}_{f(\pi_P)} \\ &+\frac{\lambda\phi\pi_0 W + \lambda\pi_0 K}{(r+\lambda+\lambda\phi)} - \pi_0 W + \frac{c}{\lambda}\end{aligned}$$

Take derivatives of $f(\pi_P)$. We have $f'(\pi_P) = (C_{SI} - \underline{C}_{HS}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda}{\lambda\phi}})\frac{1}{\pi_P^2}$ and $f'(\pi_P) > 0$

if and only if $C_{SI} - \underline{C}_{HS}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda}{\lambda\phi}} > 0$. If $\underline{C}_{HS} < 0$, the function $C_{SI} - \underline{C}_{HS}(\frac{1-\pi_P}{\pi_P})^{\frac{r+\lambda}{\lambda\phi}}$ is decreasing in $\pi_P$ and $\lim_{\pi_p \to 1} f'(\pi_P) = C_{SI} < 0$. Thus it's sufficient to check $f(1) + \frac{\lambda\phi\pi_0 W + \lambda\pi_0 K}{(r+\lambda+\lambda\phi)} - \pi_0 W + \frac{c}{\lambda} > 0$, which is equivalent to

$$
\begin{aligned}
&\frac{\lambda\phi\pi_0 W + \lambda\pi_0 K}{(r+\lambda+\lambda\phi)} - \pi_0 W + \frac{c}{\lambda} > 0 \\
\Rightarrow & K > \frac{(r+\lambda)\pi_0 W - \frac{c}{\lambda}(r+\lambda+\lambda\phi)}{\lambda\pi_0} \\
&= W - \frac{c}{\lambda\pi_0} + \frac{1}{\lambda\pi_0}(r\pi_0 W - c\frac{r}{\lambda} - c\phi)
\end{aligned}
$$

Let $\bar{K} = W - \frac{c}{\lambda\pi_0} + \frac{1}{\lambda\pi_0}(r\pi_0 W - c\frac{r}{\lambda} - c\phi) > W - \frac{c}{\lambda\pi_0}$. The statement is proved.

**P's Optimal Action.** The part of proof when $a_S = 1$ is the same as Proposition 4. Consider the case when $a_S = \phi$ and $a_P = 1$ for all $\pi > \breve{\pi}$. Then $P$'s value function follows

$$
rV_P(\pi_{Pt}) = -c(1-\phi) + \lambda(\pi_{Pt} W - V_P(\pi_{Pt})) + \lambda\phi\pi_{Pt}(K - V_P(\pi_{Pt})) - \lambda\phi\pi_{Pt}(1-\pi_{Pt}) V_P'(\pi_{Pt}) \tag{21}
$$

Use the value matching condition at $\breve{\pi}$,

$$
\begin{aligned}
r(\breve{\pi}W - \frac{c}{\lambda}) &= \lambda\phi\breve{\pi}\left(K - W + \frac{c}{\lambda} + (1-\breve{\pi})W\right) - \lambda\phi\breve{\pi}(1-\breve{\pi}) V_P' + c\phi \\
\Longleftrightarrow \breve{\pi}(rW + \lambda\phi(W - K - \frac{c}{\lambda})) - c(\frac{r}{\lambda} + \phi) &= \lambda\phi\breve{\pi}(1-\breve{\pi})(W - V_P')
\end{aligned}
$$

Thus $V_P' < W$ if and only if $\breve{\pi} > \frac{c(\frac{r}{\lambda}+\phi)}{rW + \lambda\phi(W-K-\frac{c}{\lambda})}$. When $K > W - \frac{c}{\lambda}$, $\frac{c(\frac{r}{\lambda}+\phi)}{rW + \lambda\phi(W-K-\frac{c}{\lambda})} < \frac{c(\frac{r}{\lambda}+\phi)}{rW + \lambda(W-K-\frac{c}{\lambda})} = \hat{\pi}$ as $\phi < 1$. We've already shown that $\breve{\pi} > \hat{\pi}$. Thus $V_P' < W$. Suppose $V_P$ crosses $V_I$ from the bottom at some $\pi^\star > \breve{\pi}$. Then it must be the case that $V_P(\pi^\star) =$

$\pi^\star W - \frac{c}{\lambda}$ and $V_P'(\pi^\star) > W$. By equation (21),

$$\begin{aligned} rV_P(\pi^\star) &< \lambda(\pi^\star W - \pi^\star W - \frac{c}{\lambda}) + \lambda\phi\pi^\star(K - \pi^\star W - \frac{c}{\lambda}) - \lambda\phi\pi^\star(1-\pi^\star)W - c(1-\phi) \\ &= \lambda\phi\pi^\star\left(K - W + \frac{c}{\lambda} + (1-\pi^\star)W\right) - \lambda\phi\pi^\star(1-\pi^\star)W + c\phi \\ &= \lambda\phi\pi^\star\left(K - W + \frac{c}{\lambda}\right) + c\phi \end{aligned}$$

However, the last line is larger than $r(\pi W - \frac{c}{\lambda})$ if and only if $\pi^\star < \frac{c(\frac{r}{\lambda}+\phi)}{rW+\lambda\phi(W-K-\frac{c}{\lambda})} < \check{\pi}$, which is contradictory. □

## Proof of Proposition 10

*Proof.* 1) Following the proof of Proposition 9, $\overline{V}_{H,S}(\pi_P) = V_{pub}(\pi_0) + \overline{C}_{HS}\frac{\lambda}{r+2\lambda}(\frac{1-\pi_P}{\pi_P})^{\frac{r+2\lambda}{\lambda}}$. Value matching condition ($\overline{V}_{H,S}(\check{\pi}) = \bar{V}_S$) implies $\overline{C}_{HS} > 0$ if $\bar{V}_S > V_{pub}(\pi_0)$. Then it follows $\overline{V}_{H,S}(\pi_0) > V_{pub}(\pi_0)$. This implies player is better off with no disclosure if the other is disclosing given that $\bar{V}_S > V_{pub}(\pi_0)$.

2) If $K < \frac{\lambda\phi}{r+\lambda\phi}W$ and both players are not disclosing, then they follow a simple switching strategy with threshold $\underline{\pi} = \frac{c\left(\frac{r}{\lambda}+N\phi\right)}{\lambda\phi(N-1)(W-K)+rW}$. Since $\frac{\lambda\phi}{r+\lambda\phi}W < \frac{\lambda\pi_0 W - c(1-\phi)}{\pi_0(r+\lambda)}$, by the proof of Proposition 9, both players use $a_i = 1$ if $\pi > \check{\pi}$ . Notice $\check{\pi} < \underline{\pi}$ by $K < \frac{\lambda\phi}{r+\lambda\phi}W$. Now consider $P$'s decision. No matter he switches to no-disclosure or not, his value function follows equation (7). The only difference is that the boundary is shifted to the right if he deviates. Denote $V_P(\pi;\tilde{\pi})$ as the solution to (7) when the boundary condition is $V_P(\tilde{\pi}) = V_I(\tilde{\pi})$. One could easily show that $\frac{\partial V_P(\pi;\tilde{\pi})}{\partial\tilde{\pi}} > 0$. Thus deviation is optimal for $P$. □