

Non-Precautionary Cash Hoarding and the Evolution of Growth Firms

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Abstract

We analyze the trade-off faced by growth firms between hoarding cash (and delaying investment) and incurring dilution from external financing. Such non-precautionary hoarding features a self-reinforcing effect: firms with better investment opportunities hoard less, yet grow successful and cash-rich more quickly. We show that non-precautionary hoarding affects the choice between public and private financing, and analyze how both respond to product market competition. Our insights help explain puzzling empirical evidence, such as why private firms hoard less than public firms, and why competition drives some firms to prefer cash hoarding and public financing, while having the opposite effect on others.

Keywords: cash hoarding; cash holdings; public versus private financing; growth firms; competition; real options

JEL Classification: G31, G32, D92

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1 Introduction

Our knowledge about cash hoarding and investment is mainly framed by a literature that seeks to explain empirical patterns in large and mature firms. Some of the most important rationals for cash hoarding identified by this literature include building up cash reserves for precautionary or tax reasons (Opler et al., 1999; Bates et al., 2009). In this paper, we take a somewhat different perspective: that of a growth firm, whose main source of valuation is based on its investment opportunities, but which lacks the necessary cash to undertake these opportunities—arguably one of the most important settings in corporate finance.

The motive for cash hoarding in which we are interested is a very basic but important one: Should firms pressed with a funding need for financing a growth opportunity delay investment to hoard cash, so as to reduce the dilution associated with external financing, or invest sooner and accept dilution? We show that the analysis of such non-precautionary hoarding gives a new perspective on the financing decisions of growth firms, and how these decisions are endogenously intertwined with the firms' cash hoarding policies.

One reason why non-precautionary hoarding (i.e., hoarding after investment opportunities have come about) gives a new perspective is that some of the factors that drive firms to reduce such hoarding, drive firms to *increase* hoarding before an investment opportunity arises (precautionary hoarding). For example, we show that firms with better opportunities have incentives to invest sooner and hoard less after arrival of an investment opportunity, while from a precautionary hoarding perspective, firms expecting the arrival of better opportunities hoard more. This gives rise to several questions.

One is how hoarding incentives interact with the decision to raise public or private financing. We show that a self-selection effect can explain the existing empirical evidence that private firms hoard less cash than comparable public firms (Gao et al., 2013). Another question is how product market competition affects hoarding and the public-private decision. In line with recent evidence, we show that competition does not have a one-way effect on investment and hoarding (Akdogu and MacKay, 2008), despite theoretical predictions for such an effect in the existing literature (Grenadier, 2002). This is also reflected in the firm's decision to raise public or private financing. Specifically, our results could help explain why some empirical studies find that product market competition increases a firm's propensity to raise public financing, while others find the exact opposite (Chod and Lyandres, 2011; Chemmanur et al., 2010).

We derive our insights in a simple dynamic model in which a firm wants to make something “big and bold.” In our baseline setting, entrepreneurs and financiers may have

a different vision about the future. Such differences may lead to disagreement about the optimal course of action and make external financing costly (Dittmar and Thakor, 2007; van den Steen, 2005, 2010). Hoarding cash seems then a natural way for growth businesses to gain some elbow room and reduce dependence on costly external financing.

An important cost of such non-precautionary cash hoarding is that it may lead to delays in investment. We show that in an environment with more profitable investment opportunities, shorter delays are optimal. Intuitively, firms with better opportunities are willing to depend more on external funding, because the cost of delay is increasing in the attractiveness of the opportunities. Thus, there is a self-reinforcing effect, where firms with a higher growth potential also choose to expand more quickly. Furthermore, being more successful, these firms might end up being cash-rich as they mature despite pursuing a low-cash strategy in their growth phase. Using these results as a starting point, we derive a number of novel insights.

Stark implications come up when relating the interaction of non-precautionary cash hoarding and investment to a firm's choice between public and private financing. Private financing may allow for a greater alignment in vision with financiers. However, it is not without costs as private firms might face financiers with a stronger bargaining power who, at the very least, need to be compensated for the cost of holding illiquid claims. Trading off these effects, the paper shows that firms for which the choice between public and private financing is endogenous, hoard less cash and invest more quickly when they raise private financing. The reason is that firms that choose private financing are those that stand to benefit most from alignment—i.e., those that need to depend heavily on external financing, as they want to invest more quickly. Our analysis implies that these are the firms with better investment opportunities, which is in line with recent empirical evidence (e.g., Gomes and Phillips, 2012).

The results are unaffected even if private financiers enjoy pricing power, as private financiers take into account the firm's outside option of raising public financing and internalize the impact of their bargaining power on cash hoarding and investment delay. Thus, competition among private financiers plays a secondary role on the decision to raise public or private financing and non-precautionary hoarding. This is in stark contrast to the effect of product market competition, which is exogenous to the firm and, thus, does not feature mitigating effects.

In particular, a novel insight of our model is that product market competition has a dual effect on both hoarding and a firm's public vs. private financing choice. On the one hand, our model features the standard incentives to speed up investment in the face of competition based on the threat of losing one's first-mover advantage (Grenadier,

2002). However, on the other hand, our setting highlights that there is a countervailing force: an increase in competition reduces future profits, which makes delaying investment to hoard cash less costly. Therefore, the standard prediction that competition will lead firms to speed up investment and reduce hoarding will only apply when having a first-mover advantage is of paramount importance. Relating these insights to our predictions on public and private financing, we expect that firms for which the effect of competition on profits is more important (and the effect on the first-mover advantage is secondary) will be more willing to hoard and delay investments and, hence, seek (less aligned) public financing. Alternatively, if the first-mover advantage dominates, competition makes delay and hoarding less desirable and more aligned private financing dominates.

We extend the model along several dimensions. First, we show that the firm’s cash hoarding policy can reveal its growth prospects in the presence of asymmetric information. More specifically, adding problems of asymmetric information to our setting leads to less hoarding (firms with better investment opportunities hoard even less), but qualitatively does not change our results. Second, we extend our model to discuss optimal financing and payout policies. Paying out cash would not be optimal as it worsens the funding problem. Furthermore, if firms can issue less-disagreement sensitive securities, such as debt, they hoard less cash. We also relate non-precautionary hoarding to problems of effort incentives ala Holmstrom and Tirole (1997), and find qualitatively similar results.

The results of our paper could reconcile a number of puzzling empirical findings and give rise to novel empirical predictions. First, our model can explain the counter-intuitive findings (from a precautionary perspective) that private firms hoard less cash than public firms (Gao et al., 2013; Farre-Mensa, 2014). Second, our results could shed light on recent evidence documenting a non-monotonic relation between competition and investment timing (Akdogu and MacKay, 2008). Third, the finding that the direction of the effect of competition on hoarding depends on the importance of the first-mover advantage could help explain why some studies find that competition increases a firm’s propensity to go public, while other studies find the opposite (Chod and Lyandres, 2011; Chemmanur et al., 2010). Some of our implications follow from the finding that precautionary hoarding is increasing, while non-precautionary hoarding is decreasing in the quality of the investment opportunity (although growth opportunities trigger both types of hoarding).¹ The latter implies that growth firms engaging in non-precautionary hoarding should have higher announcement returns when making new investments with a higher proportion of outside (public) financing. More broadly, our analysis points to a self-reinforcing mechanism,

¹We expect that precautionary hoarding—i.e., hoarding cash before the arrival of a growth opportunity—better describes more mature firms.

in which firms with better opportunities also invest more quickly. As these firms mature, they are likely to end up with large cash holdings due to their success despite their original low-cash strategy.

Our paper mainly relates to the fast growing literature on cash. Firms hoard cash because they may be unable to frictionlessly raise financing for new investments. Agency conflicts are one important such friction (Jensen, 1986).² Alternatively, firms may hoard cash as a precautionary measure. Bolton et al. (2011) show that firms will keep a positive balance even if this necessitates costly external financing, since the marginal benefit of avoiding to seize operations is very high. In such cases, firms with stronger cash flow streams need to hoard less cash (Acharya et al., 2012). Related, Almeida et al. (2004) show that financially constrained firms save more cash out of cash flows.³ Existing evidence finds strong support for the precautionary motive for hoarding cash (Opler et al., 1999; Bates et al., 2009). However, we are not aware of empirical work explicitly investigating delay of investment due to cash hoarding. In this paper we argue that this channel is important, as such non-precautionary hoarding has contrasting cross-sectional implications compared to precautionary hoarding. This could help explain puzzling patterns, for example, in the financing of public versus private firms.

The insights of our analysis relating the quality of investment opportunities and public-private financing further differentiates our paper from Boyle and Guthrie (2003) and Bolton et al. (2013). While these papers also analyze cash hoarding in the context of lumpy investment and costly external financing, they do not analyze the endogenous relation between cash hoarding, competition, and the decision to be public or private.⁴

Furthermore, our results on how product market competition affects investment delay and hoarding complement prior theories, which predict that competition makes firms invest more quickly, as they try to realize a first-mover advantage (Grenadier, 2002; Novy-Marx, 2007). Such theories would seem to imply that competition would decrease non-

²Dittmar and Mahrt-Smith (2007) and Pinkowitz et al. (2006) show that cash is worth less when agency problems between inside and outside shareholders are greater, and Nikolov and Whited (2013) identify low managerial ownership as a key factor driving agency costs. In contrast, Opler et al. (1999) and Bates et al. (2009) find no evidence relating agency problems to cash holdings.

³In Hugonnier et al. (2015), a firm would hoard cash, because it may not be able to find a financier. Furthermore, in the recent literature on risk management, Acharya et al. (2013) show that firms with high aggregate risk exposure prefer cash to credit lines, and Rampini and Viswanathan (2010) argue that the opportunity cost of risk management is higher for constrained firms. Key in these papers is that cash and/or credit lines help to avoid liquidity problems, which is different from our focus on financing existing growth opportunities (note also that credit lines are not common for growth firms, see Sufi, 2009).

⁴Our paper also adds a new perspective for why firms might prefer to stay private when exploring growth opportunities. This contributes to recent theories that have focused on private investors' greater tolerance for failure (Ferreira et al., 2012).

precautionary hoarding. We show, however, that such a conclusion could be wrong. Key is how strongly competition puts the first-mover advantage at risk relative to the adverse effect of competition on long-term profitability. The latter effect (i.e., competition eroding long term profitability) makes delay less costly and hence stimulates non-precautionary hoarding. This is also different from the standard view that competition increases the firm’s *precautionary* need for cash by making the firm less profitable and, hence, more vulnerable to liquidity shocks (Hoberg et al., 2012; Morellec et al., 2014).⁵

Our paper is organized as follows. Section 2 presents the model. Section 3 contains the main analysis, which relates disagreement to cash hoarding, endogenizes the choice between private and public financing and analyzes the effects of competition. In section 4, we analyze various extensions. Section 5 discusses empirical implications. Section 6 concludes.

2 Model

Our baseline model features a firm run by a sole owner-manager (henceforth, manager). This firm already generates revenues, but is still a growth firm with a potentially profitable expansion still ahead of it. We model this in the following natural way. Suppose that the firm has an existing asset in place producing stochastic cash flows. If they are not paid out or invested, these cash flows accumulate in the form of cash reserves within the firm according to

$$dw_t = \mu w_t dt + \sigma w_t dZ_t, w_0 > 0. \tag{1}$$

where μ and $\sigma > 0$ are constant and $(Z_t)_{t \geq 0}$ is a standard Brownian motion. This simple reduced-form formulation for how the level of cash changes within the firm is sufficient for our purposes. A key assumption is that $\mu < r$, where r is the constant discount rate used by all. This assumption, which is standard in the real options literature, implies that the firm has only a weak ability to generate cash, and keeping the firm going is costly to insiders. Specifically, in our setting, this assumption implies that the opportunity cost associated with hoarding cash is paying out w_t together with effectively closing operations. This is precisely the feature we want to capture for a growth firm for which the investment

⁵Lyandres and Palazzo (2015) argue that a firm can use cash as a commitment device to quickly enter a market. This has a negative effect on rivals’ willingness to enter and, hence, desire to hoard precautionary cash. Our analysis shows that focusing on such precautionary hoarding motives can explain only one part of the cash dynamics within a firm. In particular, the predictions for cash hoarding revert after the investment opportunity arises. Then, firms, facing less attractive investment opportunities because of competition, will have a stronger incentive to engage in non-precautionary hoarding, as delaying investment is not as expensive.

opportunity is the main component of valuation and absent which the firm constitutes an unprofitable business. At the same time, this setting is sufficiently flexible to allow us to discuss payout policies and to capture the likelihood of default (because if w_t hits zero, the firm does not recover).⁶ Though for most of the main text, we refer to w_t as cash, an alternative interpretation is that w_t represents the net worth the firm builds up over time, which is available as a safe collateral free of any financing frictions.

The reason the manager is willing to keep the firm going is that this firm has generated a profitable investment opportunity, requiring an investment of K . Initially, the manager does not have cash at hand for making the investment, but she has discretion over the timing of the investment. Our approach makes use of the standard real options framework (McDonald and Siegel, 1986; Dixit and Pindyck, 1994), but differs from this framework in one important aspect: the firm is cash-constrained and the manager may not be able or willing to invest in a positive NPV project even if she can raise capital from financiers in a competitive capital market.⁷ In our baseline model, the unwillingness to raise external financing is due to differences in vision leading the entrepreneur to believe that her firm is undervalued by outsiders.

Vision and Disagreement At $t = 0$, the manager and the financier publicly observe a signal about the profitability of the project. If the signal is good and the firm invests K , its discounted expected cash flows become θX_G . If the signal is bad and the firm invests K , its expected discounted cash flows become θX_B . The parameter θ can be seen as a publicly observable indicator of the attractiveness of the firm's (or industry's) growth prospects. We assume that $K > \theta X_B$ for all θ , so that a bad signal translates into a negative NPV project. Furthermore, $\theta X_G > K$ at least for some θ , so that investing after a good signal could increase value. All features of our model are common knowledge, and the cash flows and the level of cash are costlessly verifiable. Furthermore, we assume that all parties are risk neutral and protected by limited liability.

The main feature of our vision- (or disagreement-) based model is that although both parties observe the same signal, they may interpret it differently. More specifically, whatever inference is made by the manager, the financier believes that the inference is correct only with probability $\rho \in (0, 1)$. The agreement parameter ρ is common knowledge and

⁶The main advantage of (1) is that it allows us to solve everything in closed form. At the cost of losing this tractability, we could specify a cash flow process generating the cash level w_t as in Bolton et al. (2013), but such alternative formulations do not lead to further insights.

⁷Related to our finance application is the work of Grenadier and Malenko (2011) who analyze real options signaling games. Morellec and Schürhoff (2011) and Bouvard (2014) analyze financial contracting and real options financing under asymmetric information.

might depend on the nature of the investment opportunity.⁸ In our baseline model, ρ and the expected discounted cash flows prior to investment θX are initially constant over time.

In what follows, we only need to consider the case in which the manager observes a good signal (i.e., infers that the project is good). This is because if the manager observes a bad signal and the financier agrees that the project is bad, it is never undertaken and the cash at hand is paid out. If the financier disagrees and believes that the project is good, the best course of action for the manager is to pay out all available cash and sell the firm to the external financier. Hence, when the manager receives a bad signal, there will not be any hoarding, and the cash at hand is paid out regardless of whether the financier agrees or disagrees.⁹

Outside Financing We initially assume that at the time at which the manager raises capital to make the investment, she is facing a competitive capital market. We model this by allowing the manager to make a take-it-or-leave-it offer for which the financier just breaks even.¹⁰ The manager sells equity to raise $K - w$ for the investment outlay K . The financier's equity stake α must satisfy

$$\begin{aligned} K - w &= \alpha \theta (\rho X_G + (1 - \rho) X_B) \\ &= \alpha \theta W^F \end{aligned} \tag{2}$$

where $W^F := \rho X_G + (1 - \rho) X_B$. θW^F stands for the financier's assessment of the firm's value, capturing that the financier shares the manager's assessment with probability ρ , and disagrees with probability $(1 - \rho)$. From (2), the equity share that needs to be promised to the financier is

$$\alpha = \frac{K - w}{\theta W^F}. \tag{3}$$

⁸Disagreement in a corporate finance context is usually introduced by postulating heterogenous priors in the sense of Kurz (1994a,b)—e.g., Boot et al. (2008). However, disagreement can also arise due to overconfidence on the part of either management or financiers (Bernardo and Welch, 2001; Daniel et al., 1998), and alternatively through excessive pessimism (Coval and Thakor, 1998) or optimism (Manove and Padilla, 1999).

⁹The reduced-form framework we have presented above can be generalized along a number of dimensions. First, it easily extends to introducing a general process for the cash flows generated after investment. Second, we can make the NPV of the investment opportunity stochastic, and allow for delay to help resolve disagreement. Finally, instead of disagreement, we could assume that the manager's reluctance to raise external financing is due to the negative effect this would have on her incentives to exert effort (as in Holmstrom and Tirole, 1997). We discuss these and other extensions, such as introducing information asymmetry, in Section 4.

¹⁰To streamline the exposition, we add more structure to the analysis in the following sections. In particular, we analyze the choice between public and private financing and allow for bargaining power to be in the hands of financiers in the case of private financing.

Define $\theta W^M := \theta X_G$ as the manager's assessment of the firm's value. The manager's net expected payoff at the point in time that she raises $K - w_t$ and co-invests w_t is:

$$V(w_t, \theta) := \left(1 - \frac{K - w_t}{\theta W^F}\right) \theta W^M - w_t. \quad (4)$$

Inspecting $V(w_t, \theta)$, we obtain:

Lemma 1 *The manager's expected payoff $V(w_t, \theta)$ from raising $K - w_t$ and investing K is increasing in the co-investment w_t , the agreement parameter ρ , and the profitability parameter θ .*

3 The Growth Firm's Decision to Hoard Cash

3.1 Non-Precautionary Cash Hoarding and Speed of Growth

We will now derive how the potential lack of alignment between management and financiers—inducing disagreement—affects the timing of investment decisions, and in turn impacts the amount of cash the firm hoards prior to undertaking the investment. We solve for the value of the real option to invest using standard dynamic programming methods (Dixit and Pindyck, 1994). The problem is that of finding the optimal stopping rule w^* (i.e., the level of cash holdings at which the investment is made) that maximizes the value of the option to invest U . This involves trading-off the benefit of reducing the funding cost against the time value of money lost from investing later, where

$$U(w_t, w^*, \theta) = \max E \left[\frac{1}{1 + rdt} [U(w_t + dw_t, w^*, \theta)] \right]. \quad (5)$$

Applying Ito's lemma, we obtain

$$rU = \mu w \frac{\partial U}{\partial w} + \frac{1}{2} \sigma^2 w^2 \frac{\partial^2 U}{\partial w^2}.$$

This equation is solved subject to the following boundary conditions. First, the manager's expected payoff at the time of investment should be equal to her payoff from investment: $U(w_t, w^*, \theta)|_{w_t=w^*} = V(w_t, \theta)|_{w_t=w^*}$. Second, the manager chooses the investment trigger so as to maximize her value at the endogenous investment threshold: $\frac{\partial}{\partial w^*} U(w_t, w^*, \theta)|_{w_t=w^*} = 0$. Finally, the option to hoard cash becomes worthless as the value of cash tends to zero: $\lim_{w_t \rightarrow 0} U(w_t, w^*, \theta) = \max \left[0, \left(1 - \frac{K}{\theta W^F}\right) \theta W^M \right]$. Indeed, if the existing business falters ($w_t \rightarrow 0$), then it almost surely does not recover (cf. (1)), and

the manager can invest only if she raises all financing externally. If that is not possible, the firm has no purpose, and ceases to exist.

Suppose, first, that disagreement is sufficiently strong such that $K > \theta W^F$. Then, solving this optimization problem yields the following expression for the manager's expected payoff

$$U(w_t, w^*, \theta) = \left(\left(1 - \frac{K - w^*}{\theta W^F} \right) \theta W^M - w^* \right) \left(\frac{w_t}{w^*} \right)^\beta \quad (6)$$

where β is the positive root of $\frac{1}{2}\sigma^2 y(y-1) + \mu y - r = 0$, and $\mu < r$ implies that $\beta > 1$. Intuitively, the expression in (6) can be interpreted as the manager's expected payoff from investing at w^* multiplied by the probability of reaching the cash level w^* and investing. Trading off the marginal cost (due to $\mu < r$) and the benefit of delay, the value maximizing investment threshold w^* is given by

$$w_\theta^* = \min \left[\frac{\beta}{\beta - 1} (K - \theta W^F) \frac{W^M}{(W^M - W^F)}, K \right], \quad (7)$$

where the upper bound on w^* follows from the restriction that $\alpha \geq 0$ (cf. (3)).¹¹

If, instead, disagreement is not so strong ($K < \theta W^F$), the manager is better off investing immediately as the cost of delay outweighs the potential gains from avoiding dilution by hoarding cash.

Proposition 1 *If disagreement is sufficiently strong ($K > \theta W^F$), it is optimal for the manager to hoard cash and delay the investment. The optimal cash level is given by (7). This threshold is decreasing in θ and ρ —i.e., there is less cash hoarding when the investment opportunity is better and when there is less disagreement.*

What this proposition points at is that delaying is costlier when the investment opportunity is better, implying that the manager will hoard less cash. Furthermore, the cost of delay weighs more when there is less disagreement. Thus, the manager will hoard less cash when there is more alignment with the financier. An important implication of Proposition 1 is that firms with better investment opportunities choose to expand more quickly. This points at a self-reinforcing mechanism leading to an accelerated divergence over time between firms with good and bad investment opportunities.

¹¹We omit this bound from our analysis when it does not lead to confusion.

3.2 Cash Hoarding in Public vs. Private Firms

We now analyze how non-precautionary cash hoarding endogenously depends on the choice between public and private financing.¹² For this purpose, we explore the following trade-off faced by firms at the intersection between public and private ownership. On the one hand, the firm might more easily avoid disagreement if it chooses private financing. For example, private financiers are often closely involved and intensely monitor firms in which they invest. The manager might also be willing to offer private financiers access to sensitive information that it might be unwilling to disclose to the public market (Bhattacharya and Ritter, 1983; Maksimovic and Pichler, 2001). All of this may help financiers to better understand the business (Ferreira et al., 2012) and help to align priorities and vision. Coordinating negotiations with a small number of private financiers is also easier especially when raising financing in tough times (Brunner and Krahen, 2008). On the other hand, a private financier's closer involvement with the firm and the associated privileged information might give him certification power over the firm and, as a result, bargaining power (Rajan, 1992). At the very least, private financiers need to be compensated for holding illiquid claims in the firm potentially making such financing more expensive.

More formally, we assume that there is a higher degree of alignment between a firm and its private financiers: $\rho^{priv} > \rho^{pub}$. Private financiers, however, face an illiquidity cost L for holding an illiquid claim. Furthermore, we allow private financiers to have bargaining power and extract rents.¹³ We model the bargaining power by giving the financiers the right to make a take-it-or-leave-it offer to the manager at any given point in time. If the manager rejects this offer, she could go for public financing or return for a new offer at a later point in time. We denote the financier's profit when providing financing for $K - w$ by $\varepsilon(w)$, so that the stake demanded by the financier satisfies

$$\alpha = \frac{(K - w + L) + \varepsilon(w)}{\theta W^F(\rho^{priv})}. \quad (8)$$

Expression (8) makes it clear that the stake demanded by the private financier depends on his bargaining power. Whether this will lead the firm to hoarding more or less cash

¹²We are comparing here growth firms that can afford to choose either financing form. This is arguably the relevant case in empirical studies analyzing the effect of public and private financing on cash, such as Gao et al. (2013).

¹³Our results readily extend to variable illiquidity costs, as long as these costs do not increase linearly in the financier's stake. A linear increase leads to a trivial solution in which either public or private financing is always cheaper. Furthermore, note that one could interpret L more broadly as the cost difference between staying private and going public. Again, if this net cost is too low (potentially negative) or high, we would have a corner solution.

when choosing private financing compared to public financing depends on how $\varepsilon(w)$ is endogenously set by the financier.

We start by analyzing the role of the financier's bargaining power in shaping the decision to raise public or private financing. The attractiveness of the investment opportunity θ plays a key role. Suppose that θ can take values between $[\underline{\theta}, \bar{\theta}]$ and let $A \subseteq [\underline{\theta}, \bar{\theta}]$ be the subset of values for which the manager would prefer private financing if the private financier had no bargaining power (i.e., $\varepsilon(w) = 0$ for all w).

Proposition 2 *(i) Regardless of whether or not the financier has bargaining power, the manager prefers private financing for the same set of values θ . (ii) The bargaining power of the financier does not affect the firm's cash hoarding policy.*

Proposition 2 shows that neither the public-private decision nor the hoarding decision is affected by the bargaining power of the financier. The first part of Proposition 2 is based on a simple observation. The private financier's bargaining power is restricted by the manager's outside option of choosing public over private financing. Thus, the best the financier can do is extract as much profit as possible from the manager without making her prefer to go for public financing. Intuitively, losing the firm to the public market and losing all rents could never be optimal for the private financier if by slightly reducing the markup, the financier could preserve some positive profit. Hence, the set of values θ for which the firm prefers private financing is unchanged.

Though a private financier can extract rents from the manager for the values in A for which the manager strictly prefers private financing, it is important to realize that this is done by anticipating the effect the pricing has on the manager's hoarding and investment decisions. For a manager who is just indifferent between public and private financing, there will be no effect, as for such a firm the mark-up is zero. Even for firms that strictly prefer private financing, the effect is only on profits, and not on the hoarding policy. This is because the best way for the financier to maximize his payoff is to offer a pricing schedule for which the manager's and financier's joint surplus is maximal. Any deviation from this imposes a cost not only on the manager, but also on the financier. Thus, the financier maximizes his profits by offering terms for which the manager implements the same hoarding and investment decision as when the financier does not have bargaining power.

Using part (i) of Proposition 2, we can show that a firm that chooses to be private hoards less cash than it would hoard as a public firm, and that a firm with better investment opportunities is more likely to stay private:

Proposition 3 (i) *A firm that chooses private financing hoards less cash (and invests sooner) than it would if choosing public financing.* (ii) *There is a cutoff value for θ , such that the manager prefers private financing if the attractiveness of the firm’s investment opportunity θ is above this cutoff.*

To understand the proposition, observe that the time-value-cost of delay is the same regardless of the firm’s public or private status. Hence, the choice between public and private financing is driven by the differential effects of cash hoarding on the costs of outside financing. The higher alignment with private financiers ($\rho^{priv} > \rho^{pub}$) is most valuable when there is a substantial need for external financing. Hence, firms that seek to raise more external financing—i.e., that hoard less—choose to remain private. This result could help explain the surprising empirical findings of Gao et al. (2013) and Farre-Mensa (2014) that private firms hoard less than comparable public firms.

Proposition 3 states further that growth firms with better investment opportunities are more likely to remain private. Intuitively, since these firms are prepared to raise more external financing to avoid delay (Proposition 1), they benefit more from the higher agreement and alignment with financiers under private ownership.

3.3 Product Market Competition and the Public-Private Decision

While competition among financiers has a limited effect on the firm’s cash hoarding policy, the same is not true about product market competition. In particular, a common argument against delaying investment is that competition in the product market could lead the firm to lose its first-mover advantage (Carlson et al., 2006; Grenadier, 2002). More intensive competition should then lead firms to minimize hoarding, as they try to keep this advantage. In this section, we argue that this effect could revert once we consider that competition also reduces future profits and, thus, makes delaying investment to hoard less costly. Hence, the net effect of competition on cash hoarding could be positive or negative. This also has an impact on the firm’s decision to raise public or private financing.

To show this, we extend the baseline model in the following way: Suppose that the likelihood that a competitor with a similar idea enters the market before the firm invests follows an exponential distribution with parameter λ . This modeling choice is standard in the literature on competition among growth firms (Loury, 1979; Weeds, 2002). The entry parameter $\lambda \in [0, \infty)$ could be interpreted as a measure of the intensity of competition. Competition reduces profits, including those of the first-mover. This could be because

even a first-mover's market share declines with a larger number of competitors or because competition makes differentiation more difficult. We model this by assuming that the first-mover's equilibrium expected payoff after investing is $\pi(\lambda)\theta W^{F,M}$, where $\pi(\lambda) \leq 1$ is differentiable with $\pi'(\lambda) \leq 0$. The equilibrium expected profits if the firm loses its first-mover advantage before investing is given by $\xi(\lambda)\pi(\lambda)\theta W^M$, where $\xi(\lambda) \leq 1$ is differentiable and captures the cost of losing this advantage. As in the related literature, this reduced-form way of modeling competition captures the main forces behind it.¹⁴

We now have two perspectives to consider. Take, first, the perspective of a firm for which holding on to the first-mover advantage is very valuable. For such a firm, competition creates incentives to invest sooner, as suggested by the prior literature, which leaves less time for cash hoarding. If, instead, an increase in competition leads to a strong erosion of future profits, there is a countervailing effect, driving the firm to increase hoarding. Specifically, the erosion of future profits reduces the attractiveness of the investment opportunity and, similar to Proposition 1, makes hoarding and delay less costly. This latter effect of competition is especially clear-cut if the firm no longer has a first-mover advantage before investing. In this case the firm hoards more cash than it would have hoarded had it retained a first-mover advantage.

Proposition 4 *Competition will increase hoarding if there is no first-mover advantage or if the profit decrease from losing this advantage ($\xi(\lambda)$ and $\xi'(\lambda)$) is low relative to the decrease in future profits $\pi'(\lambda)$ from facing more competition after investment.*

We can now combine the insights of Propositions 3 and 4 to derive implications for how product market competition and its effect on cash hoarding affect the firm's decision to raise public or private financing.

Corollary 1 *(a) A firm is more likely to raise public financing and expand hoarding in the face of increased product market competition if the impact of competition on future profitability is more important than (preserving) the first-mover advantage.*

(b) A firm is more likely to stay private and speed up investment if realizing a first-mover advantage is of paramount importance.

To conclude this section, it is worth mentioning that competition could also drive firms to reduce the size K of investment (which we have assumed to be fixed). A smaller

¹⁴The extent to which $\xi(\lambda)$ and $\pi(\lambda)$ decline depends on the way one chooses to model competition after entry. Rather than committing to a specific modeling choice, we limit ourselves to discussing how $\xi(\lambda)$ and $\pi(\lambda)$ affect hoarding. See Grenadier (2002) and Novy-Marx (2007) for models deriving different speeds of decline in a setting in which firms compete on quantity and try to time market demand.

K will mechanically reduce the need for cash. However, this would not change the starting point of our analysis that (for any K) firms with better investment opportunities make investments with a higher proportion of external financing.

3.4 Discussion: Relating Non-Precautionary to Precautionary Hoarding

Non-precautionary hoarding describes how much a firm delays investing in an existing investment opportunity to reduce its dependence on dilutive external financing. In this section, we relate this motive to the standard precautionary argument that a firm hoards cash in anticipation of a future growth opportunity (i.e., pre-arrival of an opportunity).

Consider a firm that does not yet have an investment opportunity in $t = 0$, but expects that such an opportunity may present itself at some future point in time. We assume that the time until this event follows an exponential distribution with parameter λ_a . To avoid costly delay following the arrival of the investment opportunity, the manager could start hoarding cash prior to its arrival. This would be optimal if the profitability of the investment opportunity and its probability of arrival are sufficiently large. In this case, the manager sets aside all cash and continues to hoard until the investment opportunity arrives or until she has accumulated sufficient capital to be able to fully finance it without external financing.¹⁵

Proposition 5 *If the probability of arrival and the profitability of the investment opportunity are sufficiently high, the manager sets aside all her initial cash and continues to hoard until the investment opportunity arrives (or until she has sufficient funds at hand). Upon arrival of the investment opportunity, the manager follows the hoarding and investment policies set out in Propositions 1-4.*

Proposition 5 has several implications. One is that the forces that drive firms to reduce precautionary hoarding, such as a lower profitability of investment opportunities, drive the firm to increase *non-precautionary* hoarding after such opportunity arises. This also explains why precautionary theories fail to explain the evidence that private firms hoard less cash than comparable public firms.¹⁶

¹⁵Observe that every additional dollar saved is more valuable than the previous one. This is because an additional dollar not only allows to make the investment earlier, but it also reduces the time the already hoarded cash will remain locked-up in the firm prior to undertaking the investment.

¹⁶Note that we do not have in mind here the (obvious) conclusion that following more precautionary hoarding there is less need for non-precautionary hoarding, but that the incentives are opposite.

Another implication of Proposition 5 is that a firm that expects a future growth opportunity will target a specific precautionary cash level. Non-precautionary hoarding can then be understood as describing deviations from this level when the hoarded amount turns out to be insufficient.¹⁷

4 Extensions and Robustness

In this section we discuss several extensions. First, we argue that non-precautionary hoarding could reveal private information, which could help explain announcement effects when firms decide to raise public financing (Section 4.1). Section 4.2 discusses how cash hoarding and investment decisions are affected when the manager can use debt instead of equity financing and may pay out cash—i.e., pay dividends and/or buy back shares. Finally, Section 4.3 extends our results to a setting in which the financing friction is an incentive problem ala Holmstrom and Tirole (1997) rather than disagreement.

4.1 Can Cash Hoarding Reveal Growth Prospects?

In this section, we show that our insights on non-precautionary hoarding remain valid in the presence of private information and that hoarding could convey valuable information to financiers regarding a firm’s growth prospects. We introduce asymmetric information by making the parameter θ privately known to the manager, but not to financiers. It is common knowledge that θ is drawn from a CDF F on $[\underline{\theta}, \bar{\theta}]$. Let $\hat{\theta}$ be the financiers’ belief about the now unobservable type θ . In (3) we now have $\alpha = \frac{K-w}{\hat{\theta}W^F}$ and (4)-(6) need to take into account $\hat{\theta}$ —i.e., we write $V(w_t, \hat{\theta}, \theta)$ and $U(w_t, w^*, \hat{\theta}, \theta)$. Our assumption that the manager has access to a competitive market for capital and can make a take-it-or-leave-it offer to the financier gives rise to a game of signaling, as the manager is privately informed about the firm’s type.

An equilibrium candidate in pure strategies for the signaling game can be characterized with a triple of functions (w_θ^*, μ^*, π) , where w_θ^* is the cash level that a manager of type θ chooses as target for hoarding; μ^* is the financier’s posterior belief that maps w_θ^* into the set of probability distributions over the type set $\theta \in [\underline{\theta}, \bar{\theta}]$; and π represents the financier’s decision to finance the project, where $\pi : w_\theta^* \rightarrow [0, 1]$, with $\pi = 1$ corresponding to accepting and $\pi = 0$ corresponding to rejecting the offer. Our equilibrium concept is that

¹⁷In the online appendix, we have extended our model to make the value of the investment opportunity and disagreement stochastic. This gives the manager additional reasons to hoard cash, but does not change that firms with more profitable investment opportunities delay and hoard less.

of a Perfect Bayesian Equilibrium. To deal with a potential multiplicity of equilibria, the equilibrium set is refined with D1. This standard refinement requires that, upon observing a deviation, the financier restricts his out-of-equilibrium beliefs to the set of types who are most likely to have deviated.

Summarizing, the manager maximizes (5) subject to the condition that the proposed contract is individually rational for a financier who makes zero profit (i.e., analogously to (3), $\alpha = \frac{K-w}{\theta W^F}$) and who uses Bayes rule on the equilibrium path to form his posterior beliefs μ^* when drawing an inference $\hat{\theta}$ about the firm's type. Note that since the expected cash flow of the investment is linear in θ , we can use $\hat{\theta} = \int_{\underline{\theta}}^{\bar{\theta}} \theta d\mu^*(\theta)$ to summarize the financier's beliefs about θ .

In a separating equilibrium of the resulting game, the proposed contract must be incentive compatible. More formally, suppose that there is a monotonic differentiable function w_θ^* which outside financiers use to infer the manager's type given her choice of investment threshold. Then, if the manager decides to exercise at $\hat{w} \in w_\theta^*([\underline{\theta}, \bar{\theta}])$, outside financiers infer that the type is $w_\theta^{*-1}(\hat{w})$ and the manager's expected payoff is

$$U(w_t, \hat{w}, w_\theta^{*-1}(\hat{w}), \theta) = \left(\left(1 - \frac{K - \hat{w}}{w_\theta^{*-1}(\hat{w}) W^F} \right) \theta W^M - \hat{w} \right) \left(\frac{w_t}{\hat{w}} \right)^\beta,$$

which generalizes (6). Since the investment decision must be on the optimal path, w_θ^* solves:

$$w_\theta^* = \arg \max_{\hat{w} \in w_\theta^*([\underline{\theta}, \bar{\theta}])} U(w_t, \hat{w}, w_\theta^{*-1}(\hat{w}), \theta) \quad (9)$$

where, assuming that a separating equilibrium exists, we evaluate the respective FOC at $w_\theta^{*-1}(\hat{w}) = \theta$. This problem is well-behaved. Lemma 2 in the Appendix shows that single crossing with respect to cash hoarding holds. Intuitively, while hoarding helps to reduce the dependence on external financing, it is costly (as $\mu < r$) and firms with better investment opportunities face higher costs of delay than firms with worse investment opportunities. At any level of hoarding and for all beliefs $\hat{\theta}$, the better firms would gain more (or lose less) from reducing hoarding. Hence, delaying is most costly for good types.¹⁸ Given this insight, we can now show that there is a unique separating equilibrium satisfying the standard equilibrium refinement D1.

Proposition 6 *(i) In a setting combining differences in vision and asymmetric information, there is a unique separating equilibrium in which the manager separates with the*

¹⁸The single crossing property does *not* depend on our assumption that the manager's assessment of the firm's value is linear in θ . It is sufficient that the firm's value is increasing in θ .

amount of cash she uses to co-finance her investment. In this equilibrium, better types hoard less cash than lower quality types. When asymmetric information is present, firms reduce hoarding and delay investment less. (ii) There is no pooling equilibrium that survives D1.

To see the intuition behind Proposition 6, recall that disagreement makes it optimal for growth firms to delay investment and hoard cash, but firms with better investment opportunities hoard and delay less. This is the key feature that makes separation possible, as firms with better investment opportunities will signal their types by hoarding less than firms with worse investment opportunities.

Part (ii) of Proposition 6 follows from the fact that a downward deviation from any pooling level of cash hoarding is always preferred by the highest quality type using arguments similar to those underpinning the single crossing result (cf. Lemma 2 in the Appendix). Thus, by D1 this type would be able to credibly deviate, making it impossible to sustain a pooling equilibrium.

The separation result in Proposition 6 implies that our preceding results extend straightforwardly to a setting involving asymmetric information. Furthermore, relating to our analysis of public and private financing, we obtain that the external-to-internal financing mix can help explain announcement effects surrounding lumpy investments financed with public financing.

Corollary 2 *The value of a growth firm's stock as assessed by financiers increases in the proportion of external-to-internal financing used for undertaking the investment.*

4.2 Type of Financing and Payouts

Introducing optimal security design in our analysis requires finding the financing contract that would minimize the friction coming from disagreement. That is, from the manager's perspective, the financier should be least sensitive to whether the project turns out to be good (as the manager believes) or bad (as the financier suspects could be the case). This is reminiscent of the intuition in the earlier security design literature (Nachman and Noe, 1994), in which the manager prefers to issue debt since, as a less information-sensitive security, it minimizes underpricing. Intuitively, being able to issue a security that makes the financier's payoff less sensitive to disagreement is similar to having less disagreement in the first place. This analysis, which involves modeling the cash flow process after investment, is relegated to the appendix.

On payout policies we can be brief. For firms in need of funds to finance growth, engaging in payouts worsens the financing problem. Thus, payouts are not optimal. This does not change in the presence of asymmetric information: for a signaling mechanism to be credible, the manager must spend more on share repurchases (or dividends) than she receives from issuing new securities.

Proposition 7 *(i) The manager optimally hoards less cash to co-finance an investment if she has access to (less information-sensitive) debt financing. (ii) A growth firm in need of financing for new investments will not pay out cash in the presence of disagreement.*

We conclude this section by noting that an alternative interpretation of w_t is that it is part of the firm's assets in place that are not plagued by disagreement, moral hazard, or other information frictions. Apart from cash, this could include property, plant and equipment, inventories, and accounts receivables from stable customers, which the firm accumulates over time. Combining the insights from Proposition 7 and Section 3, our results could be more generally interpreted in the context of a growth firm building up information insensitive assets to reduce its dependence on risky external financing (which is marred by various frictions).

4.3 Dilution of Effort Incentives and Non-Precautionary Hoarding

We have derived our non-precautionary hoarding results assuming that the manager and the financier have different visions. However, non-precautionary hoarding could also be caused by other financing frictions. We have already discussed information asymmetry. Another friction for growth firms is that external financing dilutes ownership and, hence, could reduce the manager's incentives to exert effort, increasing the cost of external financing (Holmstrom and Tirole, 1997).¹⁹

Specifically, suppose that conditional on being undertaken, the investment succeeds with probability e , in which case it yields θW . With probability $1 - e$, it fails and yields zero. Let the success probability e reflect the effort exerted by the manager at cost $\frac{e^2}{2\nu}$ (assumed is that effort is undertaken after the investment). It is straightforward to show that there will be cash hoarding also in such a setting, and managers with better projects (high θ) have incentives to hoard less. Assuming again equity financing, the manager's problem now is to choose the co-investment w_θ^* and the optimal level of effort \hat{e} that

¹⁹We thank Andrey Malenko for suggesting this discussion.

maximize her expected payoff

$$\left(\left(1 - \frac{K - w_\theta^*}{e^* \theta W} \right) \widehat{e} \theta W - w_\theta^* - \frac{\widehat{e}^2}{2\nu} \right) \left(\frac{w}{w_\theta^*} \right)^\beta, \quad (10)$$

where e^* is the equilibrium level of effort anticipated by the financier. We verify in the Appendix that such a formulation does not qualitatively alter our results.

5 Empirical Implications

We conclude with a discussion of the main empirical implications stemming from our model. We stress that these implications are *not* about what determines target cash ratios in mature firms, which is the focus of precautionary based theories (Proposition 5; Opler et al., 1999). Instead, non-precautionary hoarding focuses on growth firms lacking funds for undertaking investment opportunities already on their radar screen. In particular, younger growth firms fit our model, as these firms already have growth opportunities, but often lack the funds to undertake them (Hadlock and Pierce, 2010). Using Proposition 1, the starting point of our analysis is the following prediction:

Implication 1: *(i) Growth firms with better investment opportunities delay investments less and exhibit less non-precautionary hoarding. (ii) Moreover, delays are shorter and there is less hoarding when there is less disagreement.*

Delaying large investments is more expensive for firms when their growth prospects are better. This explains why for such firms non-precautionary hoarding that attempts to reduce the firm's dependence on external financing plays a smaller role. Combining Implication 1 with our insight that non-precautionary hoarding could help alleviate problems of asymmetric information (Proposition 6), we further predict:

Implication 2: *Growth firms with better investment opportunities will finance new investment opportunities with a higher fraction of external to internal funds. The stock price reaction to public offerings used to finance growth should be more positive when firms fund investment with a higher proportion of external financing.*

One of the innovations of our paper is to develop a theory of non-precautionary cash hoarding and investment in public and private firms. Contrary to precautionary-based theories, which would predict that private firms should hoard more cash as they are more financially constrained, we show that private firms engage in less non-precautionary hoarding and delay investments less (Proposition 3).

Implication 3: *A firm for which the decision to raise private or go public financing is*

endogenous delays investment less and hoards less cash with private than public financing.

Our results apply to firms for which raising private or public financing is an endogenous decision—which is arguably the question of interest for empirical research. These results find strong support in a recent empirical study by Gao et al. (2013) that explicitly takes into account this endogeneity. They show that public firms hoard up to twice as much cash as comparable private firms. Furthermore, Asker et al. (2015) find that private firms not only have more cash, but also react more quickly to new growth opportunities. Our theory could help explain these findings.

Our paper also helps to explain the apparent wish of some firms to gain the best of both world—namely, the stylized fact that public firms choose private financing when their investment opportunities, measured by Tobin’s Q, are better (Gomes and Phillips, 2012). For such cases, Implication 3 would additionally predict that investments financed by private issues will be financed with a larger proportion of external financing than when these firms resort to public issues.

Another novel insight of our model concerns the differential effect of competition on cash hoarding. Specifically, competition drives firms to speed up investment and hoard less when the first-mover advantage is of paramount importance (similar to Grenadier, 2002). However, if the first-mover advantage is less important and the impact of competition on long-term profitability dominates, competition may actually lead to a delay in investments and more hoarding. This prediction could help explain Akdogu and MacKay’s (2008) finding that there is a U-shaped relationship between competition and investment delay—i.e., firms invest more quickly in oligopolistic than in monopolistic industries (pointing at the importance of the first-mover advantage), but more slowly in competitive than oligopolistic industries.²⁰ Our analysis further predicts:

Implication 4: *If retaining a first-mover advantage is not (very) relevant for a growth firm, the effect of product market competition is as follows: the firm engages in more non-precautionary hoarding, raises less external financing, and delays investment more. Growth firms follow the opposite strategy if preserving the first-mover advantage is important.*

The intuition behind Implication 4 is that firms likely to experience a strong erosion of future profits (as in competitive industries) will delay investment and hoard more, while firms perceiving substantial benefits from being a first-mover (as in an oligopoly) will speed up investment relative to the monopoly case (Proposition 4).

Relating these insights to our public vs. private financing results, helps explain why

²⁰Interestingly, using a Compustat panel of industrial firms and Hoberg and Phillips’ (2015) measure of industry concentration, we find a corresponding U-shaped relationship between cash over total assets and competition.

product market competition sometimes leads to more (Chod and Lyandres, 2011) and sometimes to fewer (Chemmanur et al., 2010) firms going public. We predict:

Implication 5: *If retaining a first-mover advantage is not (very) relevant for a growth firm, higher product market competition will make raising public financing more likely. Growth firms are more likely to choose private financing if preserving the first-mover advantage is important.*

The intuition for Implication 5 is that private financing goes hand in hand with (relatively) speedy investment, and this is important when the first-mover advantage is of paramount importance.

Finally, we can relate our analysis to the empirical literature on Tobin’s Q that has found that high Q goes hand in hand with high cash (Opler et al., 1999; Bates et al., 2009), which seems difficult to reconcile with findings that cash-rich firms make worse investments (Harford, 1999). Our analysis sheds light on this. As noted at the end of Section 3.3, if a firm wants to invest at a larger scale (or has more investment opportunities), it would mechanically hoard more cash in our model, explaining why high cash goes hand in hand with high Q. However, we still predict that, among the high Q firms, those that make investments with a lower proportion of internal-to-external financing have better investment opportunities (cf. Implication 1).

6 Conclusion

We develop a theory of non-precautionary cash hoarding that analyzes whether a growth firm will choose to delay investments in order to hoard cash and depend less on outside finance. Entrepreneurs try to avoid external financing in our model because they are reluctant to see their stake diluted. Our starting point is to show that firms with better investment opportunities hoard less cash and finance a higher fraction of new investments with outside financing. The key reason is that they find it more costly to delay a more profitable opportunity. Expanding on this simple insight, we show a number of novel results that question the extent to which standard arguments developed for mature firms (focusing on *precautionary* hoarding) apply to growth firms that seek to satisfy immediate funding needs for investment opportunities at hand (non-precautionary hoarding).

One of our main insights is that growth firms that choose to operate as private firms hoard less cash and invest more quickly than they would if they operated as public firms. This is because firms choose to be private when they value the benefit of a higher alignment with financiers—the benefit of being private—more than the costs associated with

offering less liquid securities. That is, firms choose to be private when their investment opportunities are better, choosing to finance new investments with more external financing and less internally generated cash. We show that this is true even if private financiers have pricing power due to a lack of competition among financiers. In such cases, financiers will extract rents, but in a way that does not affect investment, hoarding, and the choice between public and private financing. This holds because private financiers do not gain from pushing firms to more public financing or more hoarding. These predictions find support in recent empirical work.

Another prediction is that product market competition could lead to longer delays and hoarding. The reason is that delaying investment in our model has two effects. The standard effect, discussed in the literature, is that competition gives firms an incentive to speed up investment not to lose their first-mover advantage. However, there is a countervailing effect, which could easily dominate: competition is likely to reduce future profitability. Investment is then less lucrative making delay less costly. Combining these insights with our results on public versus private financing, we predict that, when product market competition drives firms to hoard more cash and delay investment more, firms will go public. Alternatively, if product market competition leads firms to speed up investment, it will reinforce the benefit of staying private.

Another insight from our model is that asymmetric information actually leads to less hoarding. This is because the hoarding policy conveys a signal about the firm's prospects, which induces firms to choose less hoarding in order to signal a better investment opportunity. Thus, we expect differential announcement effects depending on the internal-to-external financing mix of firms investing in growth opportunities.

Our results also provide new insights on the dynamics of firm evolution and cash holdings. Our analysis focuses on growth firms that are short on cash and operate in an uncertain environment. The ones with the better investment opportunities will choose to grow rapidly using outside funding, and, relative to their lesser peers, will be cash-poor. However, on average, they will be more profitable and successful. This implies that in the follow-up stage after these firms have established themselves, they may start earning cash at a higher rate than needed for investment and growth. High cash holdings are then a sign of past success. This would imply that growth firms striving to become the next Google, Microsoft, or Apple should not try to copy the large cash holdings of these already mature firms; as *growth* firms they should follow a very different cash policy.²¹

²¹Our theory primarily focuses on the 'pre-abundance of cash' stages. In particular, we do not analyze why the accumulated cash, which is arguably a consequence of past success, is not paid out to shareholders. For large multinationals, accumulation in cash holdings could be due to other reasons, such as taxes (Foley

Another implication is that since firms with better opportunities also invest more rapidly, reinforcing effects are present. The result resembles an accelerated Darwinian survival process with “winners taking it all.”

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et al., 2007) or changes in the cost of carrying cash (Azar et al., 2015).

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Appendix A: Omitted Proofs

Proof of Proposition 1. Differentiating (6) with respect to w^* we obtain

$$\frac{\partial}{\partial w^*} U(w_t, w^*, \theta) = \left(-\frac{\beta}{w^*} \left(\left(1 - \frac{K - w^*}{\theta W^F} \right) \theta W^M - w^* \right) + \left(\frac{\theta W^M}{\theta W^F} - 1 \right) \right) \left(\frac{w_t}{w^*} \right)^\beta. \quad (11)$$

The first term shows the time-value-loss of waiting for w to increase, while the second term shows the benefit from obtaining cheaper financing when increasing the co-investment. Note that if $\theta W^F > K$, the right-hand-side (RHS) is negative and hoarding cash is never optimal. Hence, the manager only hoards cash if the disagreement with the financier is sufficiently strong and $\theta W^F < K$. Then, the first order condition (FOC) yields:

$$w^* = \frac{\beta}{\beta - 1} \frac{(K - \theta W^F)}{(\theta W^M - \theta W^F)} \theta W^M$$

where note that $\alpha = \frac{K-w}{\theta W^F} \geq 0$ implies that w^* the upper limit of w^* is K and that the manager chooses $w^* = \min \left[\frac{\beta}{\beta-1} \frac{(K-\theta W^F)}{(\theta W^M-\theta W^F)} \theta W^M, K \right]$.

For completeness, note that the second order condition is

$$\begin{aligned} \frac{\partial^2}{\partial (w^*)^2} U(w_t, w^*, \theta) &= \frac{\beta}{(w^*)^2} \left(\frac{\theta W^F - K}{\theta W^F} \right) \theta W^M \left(\frac{w_t}{w^*} \right)^\beta \\ &\quad - \frac{\beta}{w^*} \left(-\frac{\beta}{w^*} \left(\left(1 - \frac{K - w^*}{\theta W^F} \right) \theta W^M - w^* \right) + \left(\frac{\theta W^M}{\theta W^F} - 1 \right) \right) \left(\frac{w_t}{w^*} \right)^\beta. \end{aligned}$$

At the internal optimum (when the FOC holds), which is the case when $\theta W^F < K$, the second line on the RHS is zero, and the expression is negative. Clearly, if the initial cash at hand is $w_0 > w^*$, the manager invests immediately. Finally, observe that w^* decreases in θ .²² **Q.E.D.**

Proof of Proposition 2. We first show that the set of values θ for which the manager prefers private financing is unchanged by the financier's price setting power (Step 1). We then describe how the financier chooses his pricing schedule $\varepsilon(w)$, and how he internalizes potential financing distortions (Step 2).

Step 1: We argue to contradiction. Suppose that the financier set a pricing schedule $\varepsilon(w) > 0$ for which the manager is better off with public financing. By sticking to this offer, the financier makes zero profit and, thus, has incentives to deviate to offering more favorable financing terms for the manager. This continues to be true as long as the manager's expected payoff with private financing $U^*(w^{priv}, \varepsilon(w))$ continues to be lower than her outside option of public financing $U^*(w^{pub})$. The financier will keep decreasing ε either until $U^*(w^{priv}, \varepsilon(w)) \geq U^*(w^{pub})$ or ε hits zero. Thus, if it is profitable for a firm to raise private financing when the private financier has no bargaining power (i.e., $\varepsilon = 0$),

²²This is true even if we would take a more general functional form for the expected payoff of the firm as a function of θ , $W^{F,M}(\theta)$, as long as it is monotonically increasing in θ .

the private financier's offer will be such that she raises private financing also if he has such power.

Step 2: The private financier chooses a pricing schedule $\varepsilon(w^{priv}) \geq 0$ which sets the markup for any given cash level hoarded by the firm (respectively for any given sum $K - w^{priv}$ that the firm is trying to raise). This pricing schedule maximizes his expected payoff $\varepsilon(w^{priv}) \left(\frac{w}{w^{priv}}\right)^\beta$ subject to the constraints the the manager optimally chooses how much cash to hoard w^{priv} and that the manager is better off raising private than her outside option of raising public financing. In analogy to (6), the manager's expected payoff is

$$U(w) = \left(\left(1 - \frac{K + L + \varepsilon(w^{priv}) - w^{priv}}{\theta W^F} \right) \theta W^M - w^{priv} \right) \left(\frac{w}{w^{priv}} \right)^\beta \quad (12)$$

implying that w^{priv} is pinned down by the first-order-condition

$$0 = -\frac{\beta}{w^{priv}} \left(\left(1 - \frac{K + L + \varepsilon(w^{priv}) - w^{priv}}{\theta W^F} \right) \theta W^M - w^{priv} \right) + \left(-\frac{\frac{\partial \varepsilon(w^{priv})}{\partial w^{priv}} - 1}{\theta W^F} \theta W^M - 1 \right). \quad (13)$$

We can use now that condition (13) defines a differential equation for $\varepsilon(w^{priv})$ of the form

$$\left(\varepsilon(w^{priv}) - \frac{\partial \varepsilon(w^{priv})}{\partial w} \frac{w^{priv}}{\beta} \right) \frac{\theta W^M}{\theta W^F} + \left(\left(1 - \frac{K + L}{\theta W^F} \right) \theta W^M \right) + \frac{(1 - \beta)}{\beta} w^{priv} \left(\frac{\theta W^M}{\theta W^F} - 1 \right) = 0. \quad (14)$$

If the manager's outside option to raise public financing is not binding, this differential equation satisfies the boundary condition $\lim_{w^{priv} \rightarrow K} \varepsilon(w^{priv}) = 0$, which states that the financier cannot expect to make any profits when the manager is close to financing the investment entirely using internal financing. If, using this boundary condition, the manager's outside option is binding, the financier would reduce the mark-up $\varepsilon(w^{priv})$ such that the manager is just indifferent between public and private financing at her optimal hoarding level w^{priv} : $U^*(w^{priv}, \varepsilon(w^{priv})) = U^*(w^{pub})$. This allows the financier to extract as much rent as possible from the manager without driving her to raise public financing. The differential equation (14) together with the appropriate boundary condition pin down the shape of $\varepsilon(w^{priv})$. Using this, it is convenient to restate the financier's problem as that of choosing

$$\max_{w^{priv}} \varepsilon(w^{priv}) \left(\frac{w}{w^{priv}} \right)^\beta. \quad (15)$$

We conclude by formalizing the side-result (which we do not use later) that when the only financing friction is due to differences in vision, financier's bargaining power does not lead to hoarding distortions in our model. The manager's problem (15) gives the first

order condition

$$\left(\frac{\partial \varepsilon(w^{priv})}{\partial w^{priv}} - \varepsilon(w^{priv}) \frac{\beta}{w^{priv}} \right) \left(\frac{w}{w^{priv}} \right)^\beta = 0.$$

Plugging this optimality condition back into the manager's first-order-condition (14), we obtain

$$0 = -\frac{\beta}{w^{priv}} \left(\left(1 - \frac{K + L - w^{priv}}{\theta W^F} \right) \theta W^M - w^{priv} \right) + \left(\frac{\theta W^M}{\theta W^F} - 1 \right),$$

giving the same solution that would obtain if ε were zero for all w . Since this is true at each point in time the manager could approach the financier, we obtain that the financier's pricing schedule does not distort the investment timing (and, thus, cash hoarding) relative to the case when financiers have no bargaining power. In the online appendix, we prove that the same insight characterizes the case in which the financier could lose his price setting power with a positive probability at each point in time. **Q.E.D.**

Proof of Proposition 3. (i) Following steps similar to those of Proposition 1, we can derive that optimal cash hoarding levels for the firm that is just indifferent between public and private financing are

$$w^{priv} = \frac{\beta}{\beta - 1} \frac{(K + L - \theta W^F(\rho^{priv}))}{(W^M - W^F(\rho^{priv}))} W^M \quad (16)$$

$$w^{pub} = \frac{\beta}{\beta - 1} \frac{(K - \theta W^F(\rho^{pub}))}{(W^M - W^F(\rho^{pub}))} W^M \quad (17)$$

where for (16) we use that $\varepsilon = 0$ (Proposition 2), and where $W^F(\rho^{priv, pub})$ makes explicit that there are different levels of alignment with financiers in a public and private firm. If a firm chooses to remain private, then a *necessary* condition for this to be more beneficial

is that

$$\begin{aligned}
0 &< U^{priv}(w_t, w^{nc}, \theta) - U^{pub}(w_t, w^{pub}, \theta) \\
&= \left(\left(1 - \frac{K + \varepsilon(w^{nc}) + L - w^{priv}}{\theta W^F(\rho^{priv})} \right) \theta W^M - w^{nc} \right) \left(\frac{w_t}{w^{priv}} \right)^\beta \\
&\quad - \left(\left(1 - \frac{K - w^{pub}}{\theta W^F(\rho^{pub})} \right) \theta W^M - w^{pub} \right) \left(\frac{w_t}{w^{pub}} \right)^\beta \\
&\leq \left(\left(1 - \frac{K + L - w^{priv}}{\theta W^F(\rho^{priv})} \right) \theta W^M - w^{priv} \right) \left(\frac{w_t}{w^{priv}} \right)^\beta \\
&\quad - \left(\left(1 - \frac{K - w^{pub}}{\theta W^F(\rho^{pub})} \right) \theta W^M - w^{pub} \right) \left(\frac{w_t}{w^{pub}} \right)^\beta
\end{aligned} \tag{18}$$

$$\begin{aligned}
&= \left(\frac{w_t}{w^{priv}} \right)^\beta \frac{\theta W^M}{(\beta - 1)} \frac{K - \theta W^F(\rho^{pub})}{\theta W^F(\rho^{pub})} \left(\frac{w^{priv}}{w^{pub}} \right) \\
&\quad \times \left(\frac{(\theta W^M - \theta W^F(\rho^{priv})) \theta W^F(\rho^{pub})}{(\theta W^M - \theta W^F(\rho^{pub})) \theta W^F(\rho^{priv})} - \left(\frac{w^{priv}}{w^{pub}} \right)^{\beta-1} \right)
\end{aligned} \tag{19}$$

$$< \left(\frac{w_t}{w^{priv}} \right)^\beta \frac{\theta W^M}{(\beta - 1)} \frac{K - \theta W^F(\rho^{pub})}{\theta W^F(\rho^{pub})} \left(\frac{w^{priv}}{w^{pub}} \right) \left(1 - \left(\frac{w^{priv}}{w^{pub}} \right)^{\beta-1} \right) \tag{20}$$

where for the first inequality (18) we use that $\varepsilon \geq 0$ (and that $w^{nc} = w^{priv}$); for the second equality (19) we plug in for w^{priv} and w^{pub} from (16) and (17). The inequality in the last line (20) follows from the fact that $W^F(\rho^{pub}) < W^F(\rho^{priv})$, implying that also the term $\frac{(\theta W^M - \theta W^F(\rho^{priv})) \theta W^F(\rho^{pub})}{(\theta W^M - \theta W^F(\rho^{pub})) \theta W^F(\rho^{priv})}$ in (19) is less than one. Thus, a necessary condition is that the last line (20) is positive, which is true only if the last term $1 - \left(\frac{w^{priv}}{w^{pub}} \right)^{\beta-1}$ is positive, implying that $w^{priv} < w^{pub}$.

(ii) The manager is indifferent between public and private ownership if

$$\Delta_U := U^{priv}(w_t, w^{nc}, \theta) - U^{pub}(w_t, w^{pub}, \theta) = 0.$$

Since $\frac{dU^{priv}(w_t, w^{nc}, \theta)}{dL} < 0$, there is a level for the illiquidity cost L , for which this equality is satisfied. Let \bar{L} denote this threshold level. Since $\frac{dL}{d\theta} = -\frac{\partial \Delta_U}{\partial \theta} / \frac{\partial \Delta_U}{\partial L}$, we only need to sign

$\frac{\partial \Delta_U}{\partial \theta}$. It holds

$$\begin{aligned} \frac{\partial \Delta_U}{\partial \theta} &= \frac{\partial}{\partial \theta} \left(\left((\theta W^F (\rho^{priv}) - (K + \varepsilon(w^{nc}) + L - w^{priv})) \frac{W^M}{W^F(\rho^{priv})} - w^{nc} \right) \left(\frac{w_t}{w^{nc}} \right)^\beta \right) \\ &\quad - \left((\theta W^F (\rho^{pub}) - (K - w^{pub})) \frac{W^M}{W^F(\rho^{pub})} - w^{pub} \right) \left(\frac{w_t}{w^{pub}} \right)^\beta \\ &= W^M \left(\left(\frac{w^{pub}}{w^{nc}} \right)^\beta - 1 \right) \left(\frac{w_t}{w^{pub}} \right)^\beta > 0, \end{aligned}$$

where we use that $w^{pub} > w^{priv} \geq w^{nc}$. Hence, $\frac{\partial \bar{L}}{\partial \theta} > 0$ and higher types are more likely to stay private even for higher level of the illiquidity cost L . Equivalently, this implies that for any given L , there is a cutoff for θ , such that the manager chooses private financing only if the firm's profitability is higher than this threshold. **Q.E.D.**

Proof of Proposition 4. Step 1. We show first that first with a firm that could still enjoy a first-mover advantage hoards less cash than it would hoard as a second-mover. Let w_{SM}^* denote the firm's optimal hoarding level as a second-mover. After a competitor arrives and becomes the first-mover, the manager's expected payoff can be derived analogously to Proposition 1 as

$$\bar{U}(w_t, w^*) = \left(\left(1 - \frac{K - w_{SM}^*}{\xi \pi \theta W^F} \right) \xi \pi \theta W^M - w_{SM}^* \right) \left(\frac{w_t}{w_{SM}^*} \right)^\beta. \quad (21)$$

where for notational simplicity we omit in what follows the dependence of w_{SM}^* , ξ , and π on the competition variable λ . By same arguments as above, we have that $w_{SM}^* = \frac{\beta}{\beta-1} (K - \xi \pi \theta W^F) \frac{W^M}{(W^M - W^F)}$.

Let w_{FM}^* be the manager's optimal cash hoarding level while still being a potential first-mover. Applying Ito's lemma modified for jump processes we have

$$rU(w) = \mu w U_w(w) + \frac{1}{2} \sigma^2 w^2 U_{ww}(w) + \lambda_{priv} (U(w) - \bar{U}(w)).$$

In what follows, we argue to a contradiction that $w_{FM}^* < w_{SM}^*$. Suppose not. If $w_{SM}^* < w_{FM}^*$, we have two cases. If $w_{SM}^* \leq w \leq w_{FM}^*$, the manager's expected payoff takes the

form $A_2w^{\beta_1} + B_2w^{\beta_2} + C_2w + D$ and we have

$$\begin{aligned}
U_{FM_2}(w) &= A_2w^{\beta_1} + B_2w^{\beta_2} + C_2w + D \\
&= \left(\begin{aligned} &\left(1 - \frac{K - w_{FM}^*}{\pi\theta W^F}\right) \pi\theta W^M - w_{FM}^* - B_2(w_{FM}^*)^{\beta_2} \\ &-\frac{\lambda}{r+\lambda-\mu} \left(\frac{W^M}{W^F} - 1\right) w_{FM}^* - \frac{\lambda}{r+\lambda} \left(1 - \frac{K}{\pi\theta W^F}\right) \pi\theta W^M \end{aligned} \right) \left(\frac{w}{w_{FM}^*}\right)^{\beta_1} \\
&\quad + \left(\frac{\lambda}{r+\lambda-\mu} \left(\frac{W^M}{W^F} - 1\right) w + \frac{\lambda}{r+\lambda} \left(1 - \frac{K}{\pi\theta W^F}\right) \pi\theta W^M\right) + B_2w^{\beta_2}
\end{aligned}$$

where β_1 and β_2 are the positive and, respectively, negative root of $(r + \lambda) - \mu y - \frac{1}{2}\sigma^2y(y - 1) = 0$, and where observe that $\frac{\partial}{\partial\lambda}\beta_1 > 0$, implying that $\beta_1 > \beta$.

If, instead, $w \leq w_{SM}^* \leq w_{FM}^*$, then the manager's expected payoff takes the form

$$U_{FM_3}(w) = A_3w^{\beta_1} + \left(\left(1 - \frac{K - w_{SM}^*}{\pi\theta W^F}\right) \pi\theta W^M - w_{SM}^*\right) \left(\frac{w}{w_{SM}^*}\right)^{\beta}$$

where A_3 and B_2 can be obtained from the value matching condition $U_2(w_{SM}^*) = U_3(w_{SM}^*)$, and the smooth pasting condition $\frac{\partial}{\partial w^*}U_{FM_2}(w)|_{w=w_{SM}^*} = \frac{\partial}{\partial w^*}U_{FM_3}(w)|_{w=w_{SM}^*}$. In what follows it is sufficient to note that

$$B_2(w_{SM}^*)^{\beta_2} = \frac{\left(\frac{\beta_1-\beta}{\beta_1} \frac{1}{\beta-1} - \frac{\beta_1-1}{\beta_1} \frac{\beta}{\beta-1} \frac{\lambda}{r+\lambda-\mu} + \frac{\lambda}{r+\lambda}\right) \frac{W^M}{W^F} (K - \pi\theta W^F)}{\left(1 - \frac{\beta_2}{\beta_1}\right)}.$$

Suppose now that $w_{SM}^* \leq w \leq w_{FM}^*$. After some transformations, the manager's first order condition can be stated as

$$\begin{aligned}
0 &= -w_{FM}^*(\beta_1 - 1) \left(\frac{r - \mu}{r + \lambda - \mu}\right) \pi (\theta W^M - \theta W^F) \\
&\quad \beta_1 \left(\left(\frac{r}{r + \lambda}\right) + \left(-\frac{\beta_1-1}{\beta_1} \frac{\beta}{\beta-1} \frac{\lambda}{r+\lambda-\mu} + \frac{\lambda}{r+\lambda} \right) \left(\frac{w_{FM}^*}{w^*}\right)^{\beta_2} \right) (K - \pi\theta W^F) \pi\theta W^M,
\end{aligned} \tag{22}$$

implying that

$$w_{FM}^* = \frac{\beta_1}{(\beta_1 - 1)} \frac{\left(\left(\frac{r}{r+\lambda} \right) + \left(\frac{\beta_1 - \beta}{\beta_1} \frac{1}{\beta - 1} - \frac{\beta_1 - 1}{\beta_1} \frac{\beta}{\beta - 1} \frac{\lambda}{r + \lambda - \mu} + \frac{\lambda}{r + \lambda} \right) \left(\frac{w_{FM}^*}{w^*} \right)^{\beta_2} \right) (K - \pi\theta W^F) W^M}{\left(\frac{r - \mu}{r + \lambda - \mu} \right) (W^M - W^F)} \quad (23)$$

$$< \frac{\beta_1}{(\beta_1 - 1)} \frac{\left(\left(\frac{r}{r+\lambda} \right) + \left(\frac{\beta_1 - \beta}{\beta_1} \frac{1}{\beta - 1} - \frac{\beta_1 - 1}{\beta_1} \frac{\beta}{\beta - 1} \frac{\lambda}{r + \lambda - \mu} + \frac{\lambda}{r + \lambda} \right) \left(\frac{w_{FM}^*}{w^*} \right)^{\beta_2} \right)}{\left(\frac{r - \mu}{r + \lambda - \mu} \right)} \frac{\beta - 1}{\beta} w_{SM}^* \quad (24)$$

$$= \frac{1}{\left(\frac{r - \mu}{r + \lambda - \mu} \right)} \left(+ \left(\frac{\beta_1 - \beta}{(\beta_1 - 1)\beta} - \frac{\lambda}{r + \lambda - \mu} + \frac{\beta_1}{(\beta_1 - 1)} \frac{\beta - 1}{\beta} \frac{\lambda}{r + \lambda} \right) \left(\frac{w_{FM}^*}{w^*} \right)^{\beta_2} \right) w_{SM}^* \quad (25)$$

where the inequality follows from $w_{SM}^* = \frac{\beta}{\beta - 1} (K - \xi\pi\theta W^F) \frac{W^M}{(W^M - W^F)}$. To see that this leads to contradiction, observe that setting $\sigma = 0$ in β and β_1 , the inequality in (24) boils becomes $w_{FM}^* < w_{SM}^*$. This is because for $\sigma = 0$ we have $\beta_1 = \frac{r + \lambda}{\mu}$ and $\beta = \frac{r}{\mu}$. Observe now that the LHS in (25) is maximal for $\beta_1 = \frac{r + \lambda}{\mu}$ and $\beta = \frac{r}{\mu}$, since $\frac{\beta_1}{(\beta_1 - 1)} \frac{\beta - 1}{\beta}$ decreases in σ and, while the second term

$$\left(\frac{\beta_1 - \beta}{(\beta_1 - 1)\beta} - \frac{\lambda}{r + \lambda - \mu} + \frac{\beta_1}{(\beta_1 - 1)} \frac{\beta - 1}{\beta} \frac{\lambda}{r + \lambda} \right)$$

features the same increase in σ , it is multiplied by $\left(\frac{w_{FM}^*}{w^*} \right)^{\beta_2} < 1$ (note: we leave β_2 unchanged all along). Together, this implies that $w_{FM}^* < w_{SM}^*$ for all parameter values, contradicting that $w_{FM}^* \geq w_{SM}^*$.

Step 2. We now analyze the effect of λ on w_{FM}^* . Since $w \leq w_{FM}^* \leq w_{SM}^*$, the manager's expected payoff takes the form $A_1 w^{\beta_1} + C_1 w^\beta$ and it can be verified that

$$U_{FM_1} = \bar{U}(w, w_{SM}^*) + \left(\left(1 - \frac{K - w_{FM}^*}{\pi\theta W^F} \right) \pi\theta W^M - w_{FM}^* - \bar{U}(w_{FM}^*, w_{SM}^*) \right) \left(\frac{w}{w_{FM}^*} \right)^{\beta_1}$$

where, plugging in for (21), w_{FM}^* is the solution to the first-order-condition

$$0 = -\frac{\beta_1}{w_{FM}^*} \left(1 - \frac{K}{\pi\theta W^F} \right) \pi\theta W^M + \left(\frac{W^M}{W^F} - 1 \right) (1 - \beta_1) + \frac{(\beta_1 - \beta)}{w_{FM}^*} \bar{U}(w_{FM}^*, w_{SM}^*).$$

By standard monotone comparative statics arguments, the dependence of w_{FM}^* on λ is

given by the cross partial $\frac{\partial^2 U_{FM_1}}{\partial w_{FM}^* \partial \lambda}$, which after some transformations becomes

$$-\frac{1}{w_{FM}^*} \frac{\partial \beta_1}{\partial \lambda} \left(\left(1 - \frac{K - w_{FM}^*}{\pi \theta W^F} \right) \pi \theta W^M - w_{FM}^* - \bar{U}(w_{FM}^*, w_{SM}^*) \right) \left(\frac{w_{FM}^*}{w_{SM}^*} \right)^{\beta_1} \\ + \frac{\beta_1}{w_{FM}^*} \left(-\frac{\partial}{\partial \lambda} \pi + \frac{\beta_1 - \beta}{\beta_1} \frac{\partial}{\partial \lambda} (\xi \pi) \left(\frac{w_{FM}^*}{w_{SM}^*} \right)^\beta \right) \theta W^F \frac{W^M}{W^F} \left(\frac{w_t}{w_{FM}^*} \right)^{\beta_1}$$

The first line of this expression reflects the firm's cost due to higher competition, reducing the likelihood of being a first-mover. This line is negative as $\frac{\partial \beta_1}{\partial \lambda} > 0$ —i.e., this cost calls for speeding up investment. The second line reflects the decrease in expected payoffs due to higher competition. If $\xi'(\lambda) \geq 0$, this line is positive, as $\frac{\partial \pi}{\partial \lambda} < 0$ and because $\frac{\beta_1 - \beta}{\beta_1}$ and $\left(\frac{w_{FM}^*}{w_{SM}^*} \right)^\beta$ and ξ are all less than one. If $\xi'(\lambda) < 0$, the positive effect remains true as long as $\xi'(\lambda)$ is not too negative. That is, the decrease in profit due to losing the firm's first-mover becomes increasingly strong as λ increases. Thus, overall, cash hoarding decreases if the negative effect of losing the firm's first-mover advantage is strong, and increases otherwise. **Q.E.D.**

Before proving Proposition 6, we start by showing a useful result.

Lemma 2 *Single crossing holds because*

$$\frac{\partial}{\partial \theta} \left(-\frac{\frac{\partial}{\partial w^*} U}{\frac{\partial}{\partial \theta} U} \right) > 0, \quad (26)$$

where $\hat{\theta}$ is the financier's inference about the firm's type θ .

Proof of Lemma 2. Let for this proof $W^M(\theta)$ and $W^F(\theta)$ denote more generically the manager's and the financier's assessment of the firm's value after investment (as a function of θ), where in the main text we have $W^F(\theta) = \theta W^F$ and $W^M(\theta) = \theta W^M$. Single crossing

holds as

$$\begin{aligned}
& \frac{\partial}{\partial \theta} \left(-\frac{\frac{\partial}{\partial w^*} U(w_t, w^*, \hat{\theta}, \theta)}{\frac{\partial}{\partial \theta} U(w_t, w^*, \hat{\theta}, \theta)} \right) \\
&= \frac{\partial}{\partial \theta} \left(-\frac{\left(-\frac{\beta}{w^*} \left(\left(1 - \frac{K-w^*}{W^F(\hat{\theta})} \right) W^M(\theta) - w^* \right) + \frac{W^M(\theta)}{W^F(\hat{\theta})} - 1 \right) \left(\frac{w_t}{w^*} \right)^\beta}{\frac{K-w^*}{(W^F(\hat{\theta}))^2} \frac{\partial}{\partial \theta} W^F(\hat{\theta}) W^M(\theta) \left(\frac{w_t}{w^*} \right)^\beta} \right) \\
&= \frac{1}{\frac{K-w^*}{(W^F(\hat{\theta}))^2} \frac{\partial}{\partial \theta} W^F(\hat{\theta})} \left(\frac{(\beta-1) \frac{\partial}{\partial \theta} W^M(\theta)}{(W^M(\theta))^2} \right) > 0. \tag{27}
\end{aligned}$$

Thus, as claimed in footnote 18, for single crossing it is sufficient that the manager's and the financiers' assessments of firm value are increasing in θ (and not necessarily linear in θ). **Q.E.D.**

Proof of Proposition 6. We show first the existence of a separating equilibrium. Then we show that there is no pooling equilibrium that survives D1.

Claim 1. *There is a unique separating equilibrium*

To show existence of a separating equilibrium, we follow standard arguments.²³ Rewriting (9), we obtain

$$w_\theta^{**} = \arg \max_{\hat{w} \in w^*([\underline{\theta}, \bar{\theta}])} \left(\left(1 - \frac{K - \hat{w}}{w_\theta^{** - 1}(\hat{w}) W^F} \right) \theta W^M - \hat{w} \right) \left(\frac{w_t}{\hat{w}} \right)^\beta$$

Taking the FOC and assuming that a separating equilibrium exists—i.e., $w_\theta^{** - 1}(\hat{w}) = \theta$ —we have

$$\frac{dw_\theta^{**}}{d\hat{\theta}} = \frac{-\frac{\partial}{\partial \theta} U(w_t, w_\theta^*, \hat{\theta}, \theta)|_{\hat{\theta}=\theta}}{-\frac{\beta}{w_\theta^{**}} \left(\left(1 - \frac{K-w_\theta^{**}}{\hat{\theta} W^F} \right) \theta W^M - w_\theta^{**} \right) \left(\frac{w_t}{w_\theta^{**}} \right)^\beta + \left(\frac{\theta W^M}{\hat{\theta} W^F} - 1 \right) \left(\frac{w_t}{w_\theta^{**}} \right)^\beta}. \tag{28}$$

To solve this equation we need the appropriate boundary condition. Since a high type has no incentive to mimic low types, we can set: $w_\theta^* = w_\theta^{VM}$, where w_θ^{**} is given by expression (7). We can now apply Theorems 1-3 from Mailath (1987) to prove the proposition (in Appendix B we verify that the conditions for these theorems are satisfied). From these theorems it follows that there is a unique separating equilibrium in which w_θ^{**} is continuous

²³For a detailed general analysis on this point, see Mailath (1987) and for separation in the context of real options see Grenadier and Malenko (2011) and Morellec and Schürhoff (2011).

and differentiable, satisfies (28), and $\frac{dw_\theta^{**}}{d\theta} < 0$ ($\frac{dw_\theta^{**}}{d\theta}$ has the same sign as $\frac{\partial^2}{\partial \hat{w} \partial \theta} U(w_t, \hat{w}, \hat{\theta}, \theta)$).

We now show that $w_\theta^{**} < w_\theta^*$. To see this, rewrite (28) as

$$\begin{aligned} & -\frac{\beta}{w_\theta^{**}} \left(\left(1 - \frac{K - w_\theta^{**}}{w_\theta^{** - 1}(\hat{w})W^F} \right) \theta W^M - w_\theta^{**} \right) \left(\frac{w_t}{w_\theta^{**}} \right)^\beta + \left(\frac{\theta W^M}{w_\theta^{** - 1}(\hat{w})W^F} - 1 \right) \left(\frac{w_t}{w_\theta^{**}} \right)^\beta \\ = & \frac{-\frac{\partial}{\partial \theta} U(w_t, w_\theta^*, \hat{\theta}, \theta)}{\frac{dw_\theta^{**}}{d\theta}}. \end{aligned} \quad (29)$$

Compare (29) to the optimality condition (11) in Proposition 1. The RHS of (29) is positive, while it is zero absent information asymmetry. Thus, taking into account that the LHS decreases in w_θ^{**} , we must have $w_\theta^{**} < w_\theta^*$.

Claim 2. *There is no pooling equilibrium that survives D1*

Suppose that there is a pooling equilibrium in which all types pool at a cash level $w^P > w_0$. $\hat{\theta}$ is then simply $\hat{\theta} = \int_{\underline{\theta}}^{\bar{\theta}} \theta dF(\theta)$. We start by defining D1 in the context of this game. For use below, note that finding the most expensive financing contract (i.e., financier's response) $\tilde{\alpha}(\theta)$ for which type θ is willing to deviate is equivalent to finding the worst out-of-equilibrium beliefs $\tilde{\theta}(\theta)$ for which the financier still breaks even (i.e., $\tilde{\alpha} = \frac{K-w}{\theta W}$) and for which the manager is willing to deviate.

Definition 1 *For every deviation \tilde{w} , determine for every type the most "expensive" financing contract $\tilde{\alpha}(\theta)$, respectively the worst out-of-equilibrium beliefs $\tilde{\theta}(\theta)$, for which the deviation payoff $\tilde{U}(w_t, \tilde{w}, \tilde{\theta}, \theta)$ is higher than the equilibrium expected payoff $U(w_t, w^P, \hat{\theta}, \theta)$*

$$\tilde{\theta}(\theta) = \arg \min_{\tilde{\theta}} \left\{ \tilde{U}(w_t, \tilde{w}, \tilde{\theta}, \theta) \mid \tilde{U}(w_t, \tilde{w}, \tilde{\theta}, \theta) \geq U(w_t, w^P, \hat{\theta}, \theta) \right\}$$

Then, D1 requires that the financier believe that the deviation comes from the types who find \tilde{w} attractive for the most expensive contract, respectively for the worst out-of-equilibrium beliefs $\Theta \in \arg \min_{\theta} \tilde{\theta}(\theta)$.

Suppose that we observe a downward deviation from w^P . In what follows we show that the type most likely to have deviated is the highest type. Observe, first, that when the financier breaks even, there is a type $\theta' \in (\underline{\theta}, \bar{\theta})$ for whom w^P coincides with w_θ^{VM} ,

implying that

$$\frac{\partial}{\partial w^P} \tilde{U}(w_t, w^P, \tilde{\theta}, \theta) \begin{cases} < 0 \text{ for } \theta > \theta' \\ = 0 \text{ for } \theta = \theta' \\ > 0 \text{ for } \theta < \theta' \end{cases} \implies \frac{d\tilde{\theta}}{dw^P} = - \frac{\frac{\partial}{\partial w^P} \tilde{U}(w_t, w^P, \tilde{\theta}, \theta)}{\frac{\partial}{\partial \tilde{\theta}} \tilde{U}(w_t, w^P, \tilde{\theta}, \theta)} \begin{cases} > 0 \text{ for } \theta > \theta' \\ = 0 \text{ for } \theta = \theta' \\ < 0 \text{ for } \theta < \theta' \end{cases}.$$

Hence, to keep the same utility as on the equilibrium path following a *decrease* from w^P , we have to decrease $\tilde{\theta}$ for $\theta > \theta'$. Moreover, since the marginal rate of substitution $\frac{d\tilde{\theta}}{dw^P}$ increases in θ (analogously to Lemma 2), the change in $\tilde{\theta}$ must be highest for the highest type. Hence, the higher the type, the higher the decrease in $\tilde{\theta}$ (and so the higher $\tilde{\alpha}(\theta)$) that the manager is prepared to tolerate following a deviation to $\tilde{w} < w^P$.

We can, thus, construct a deviation contract $(\tilde{\alpha}, \tilde{w})$ with $\tilde{w} < w^P$, such that only types $(\theta'', \bar{\theta}]$ (where $\theta'' \rightarrow \bar{\theta}$) find it profitable to deviate relative to their expected payoff on the equilibrium path, and such that the financier makes a strictly positive expected profit when accepting for any out-of-equilibrium beliefs that place probability one on the deviation coming from this set of types.²⁴ Since the best response of the investor in this case would be to accept the offer, and the manager's (minimal) payoff from deviating for this best response is higher than on the equilibrium path, this equilibrium candidate does not survive D1, implying that there is no pooling equilibrium with positive cash hoarding. However, there can be also no pooling equilibrium with zero cash hoarding, as by assumption, disagreement is sufficiently strong to prevent investment without cash hoarding. **Q.E.D.**

Proof of Proposition 5. Observe first that the expected value of the investment opportunity upon its arrival is $U(w_{0,\theta}^*, w_\theta^*)$, where U is given by (6) from Section 2 and $w_{0,\theta}^*$ is the cash level that the manager has hoarded before arrival. It is straightforward to verify that $U(w_{0,\theta}^*, w_\theta^*)$ is strictly increasing and convex in $w_{0,\theta}^*$ (cf. footnote 15). Suppose now that it is optimal to stop hoarding before arrival and before the manager has hoarded K —i.e., $w_{0,\theta}^* < K$. We argue to a contradiction that this cannot be the case.

Suppose that before arrival, having reached $w_{0,\theta}^*$, the hoarded amount w_t increases above $w_{0,\theta}^*$. Paying out $w_t - w_{0,\theta}^*$ cannot be optimal if hoarding until $w_{0,\theta}^*$ is optimal. First, the probability of arrival is the same at every instant. Second (given the convexity of U), the marginal increase in the option value U that the manager would have after arrival is increasing in the hoarded amount before arrival. In contrast, paying out a unit of cash

²⁴The latter is feasible, as in a pooling equilibrium types $(\theta'', \bar{\theta}]$ cross subsidize lower types, implying that the financier (who breaks even in expectation) actually makes a profit on these types.

has the same value to the manager regardless of the previously hoarded amount. Hence, if hoarding dominates paying out for $w_t < w_{0,\theta}^*$, it is more beneficial also for $w_t > w_{0,\theta}^*$.

To determine whether the manager should start hoarding, we have to compare the expected payoff from hoarding as prescribed above with paying out w_0 . Clearly, this expected payoff must be increasing in the probability of arrival λ_a . Hence, there is a threshold $\bar{\lambda}_a$, above which setting aside w_0 and hoarding is optimal. In this case, the manager hoards until the arrival of the investment opportunity and, upon arrival, follows Propositions 1. Note that the manager will stop hoarding cash once she becomes independent of external financing.²⁵ **Q.E.D.**

Proof of Proposition 7. We first show that debt financing reduces the need for cash hoarding (part (i)). We then argue that payouts will not arise in equilibrium (part (ii)).

(i) To be able to compare debt and equity financing, we have to specify the cash flow generating process of the new project. Suppose that the good and the bad project are governed by a common cash flows generating process: $dx_t = \mu_x x_t dt + \sigma_x x_t dZ_t$ with $\mu_x, \sigma_x > 0$ and with Z denoting a Brownian motion. Let the scrap value of the project be S . Ex ante, the initial value of this process x_0 is unknown, but the cumulative density function (cdf) over the possible realizations of x_0 for the good projects dominates that for the bad project in terms of FOSD. All of this is common knowledge. Observe that, after the investment is sunk and the initial value has been realized, the financier cannot infer whether the realization of x_0 is due to the project being good or bad.

Before investment, the manager's and the financier's assessments of the project's expected payoff are

$$W^i(\theta) := E^i \left[\frac{x_0}{r - \mu_x} + \frac{1}{1 - \beta_2} S \left(\frac{x_0}{x_d} \right)^{\beta_2} \mid \theta \right] \text{ where } i = F, M, \quad (30)$$

where E^M is conditional on the project being good, and E^F assumes that it is good only with probability ρ . Furthermore, β_2 is the negative root of $\frac{1}{2}\sigma_x^2 y(y-1) + \mu_x y - r = 0$ and (30) takes into account that the project is optimally liquidated if x_t falls below $x_d := \frac{\beta_2}{\beta_2 - 1} S (r - \mu_x)$ (see Morellec and Schürhoff (2011) for a similar derivation).²⁶

Suppose now that the manager promises a small constant debt coupon payment ε in

²⁵To avoid the risk that the cash at hand falls below K , she may hoard slightly more than K before starting to pay out. Furthermore, note that if the manager does not start hoarding, she pays out w_0 and then cannot invest upon arrival.

²⁶Previously, we had $W^i(\theta) = \theta W^i$. However, recall that the results are valid as long as the assessments of firm's value $W^i(\theta)$ are increasing in θ .

addition to an equity share $\tilde{\alpha}$. Furthermore, let the manager's share of the liquidation proceeds be $(1 - \alpha) \left(S - \frac{\varepsilon}{r} \right) - \frac{\varepsilon}{r}$, implying that the financier is guaranteed $\frac{\varepsilon}{r}$ even in liquidation. Clearly, stipulating such a share is feasible for $S > 0$ and ε sufficiently small. It is straightforward to check that it is optimal for the manager to liquidate the project at x_d for such a sharing rule in liquidation (as it is optimal for pure equity financing). The equity share $\tilde{\alpha}$ that satisfies the financier's participation constraint is $\tilde{\alpha} = \frac{K - w - \frac{\varepsilon}{r}}{W^F(\theta)}$. By similar arguments to Proposition 1, we obtain that before investing, the manager hoards:

$$\tilde{w}_\theta = \frac{\beta}{\beta - 1} \left((K - W^F(\theta)) \frac{W^M(\theta)}{W^M(\theta) - W^F(\theta)} - \frac{\varepsilon}{r} \right) < w_\theta^{VM}.$$

(ii) The proof focuses on the case with asymmetric information. Suppose that the manager owns only a fraction η of the firm, and the remaining $1 - \eta$ is owned by external shareholders. Consider a candidate for a separating equilibrium in which the highest type $\bar{\theta}$ repurchases a fraction $\eta - \eta_2$, so that after the repurchase she owns $(1 - \eta_2)$. Clearly, since delay is costly and it is not possible for high types to separate through cash hoarding, it is without loss of generality to focus on the "static" case in which the manager repurchases the shares and raises new financing in the same period. On a competitive market, the price p at which type $\bar{\theta}$ repurchases a fraction $\eta - \eta_2$ of the firm must solve

$$\begin{aligned} \eta (\bar{\theta} W^M - K + w) &= \eta_2 (\bar{\theta} W^M - K + w - p) + p \\ \implies p &= \frac{\eta - \eta_2}{1 - \eta_2} (\bar{\theta} W^M - K + w) \end{aligned}$$

where we use that existing shareholders should be indifferent between selling and not selling their shares at the fair price. Hence, the incentive constraint of type $\underline{\theta}$ not to mimic type $\bar{\theta}$ is

$$(1 - \eta) (\underline{\theta} W^M - K + w) \geq (1 - \eta_2) \left(1 - \frac{K - (w - p)}{\bar{\theta} W^M} \right) \underline{\theta} W^M,$$

which, after plugging for p , boils down to $\frac{(\underline{\theta} - \bar{\theta})}{\bar{\theta}} (K - w) \geq 0$, contradicting that $K > w$. Finally, note that if $K \leq w$, underpricing is irrelevant for the manager, as she can finance the project out of her own funds.

Next, we show by contradiction that there cannot exist an equilibrium in which the firm separates by paying out dividends. First, observe that if the manager does not separate with a dividend payment, she cannot do so through cash hoarding following such a payment. Thus, the only candidate for a separating equilibrium is paying a dividend and then investing immediately. Then, the incentive constraint of any type $\theta_L < \theta_H$ not

to mimic type θ_H is

$$\left(1 - \frac{K - w_L}{\theta_L W^F}\right) \theta_L W^M + (w_t - w_L) \geq \left(1 - \frac{K - w_H}{\theta_H W^F}\right) \theta_L W^M + (w_t - w_H), \quad (31)$$

where $(w_t - w_i)$ is the dividend paid by type θ_i . Using that without disagreement $W^M = W^F$, (31) can be rewritten as $w_H \geq K$, leading to the desired contradiction. **Q.E.D.**

Appendix B: Extensions

Market Timing with Time Varying Disagreement and Profitability

One straightforward way to model change in disagreement is to assume that disagreement could fully disappear at any given instant with some positive probability, and remains otherwise unchanged. Specifically, suppose that the time until such an event follows an exponential distribution with parameter λ_ρ . If disagreement disappears, the manager invests immediately as external financing ceases to be costly, and her expected payoff is $\theta W^M - K$. While such feature creates another motive for delaying investment, our baseline results remain unchanged: Firms with better investment opportunities find it more costly to delay and, hence, hoard less cash.

The other issue is that the expected value of the investment opportunity could vary over time. Delay in investment could, then, occur for two reasons: delaying not only to hoard cash, but also to wait for the value of the investment opportunity to increase. Indeed, assuming that the NPV of the investment opportunity increases on average over time is a standard assumption in the related real options literature (Bolton et al., 2013). Our results remain robust also in such a setting. In particular, let the increase in NPV come from a lower investment outlay K . We now have that at any level of accumulated cash, a lower K implies a lower need for external financing. This reduction in the need for external funding implies that the firm is willing to invest at a lower level of accumulated cash.²⁷

Proof: Time-varying disagreement and profitability. (i) *Time varying disagreement:* Let $\theta \widetilde{W}^F$ be the financier's valuation of the firm given that he knows that, after

²⁷Observe that even though now there are two separate reasons to delay, the firm will not necessarily delay investment longer since a lower investment outlay K implies also a lower need for hoarding cash. Furthermore, note that this insight does not depend on our assumption that the increase of NPV is due to K . The same result would obtain if the NPV would increase because of higher expected cash flows.

investing, disagreement could disappear with probability λ_ρ at any given point in time.²⁸ Applying the modified Ito's lemma for jump processes and following similar steps to Section 3, it is straightforward to show that the manager optimally hoards

$$w_\rho^* = \frac{\gamma}{\gamma - 1} \frac{\left((K - \theta \widetilde{W}^F) W^M + \frac{\lambda_\rho}{\lambda_\rho + r} (\theta W^M - K) \widetilde{W}^F \right)}{(W^M - \widetilde{W}^F)}$$

where γ is the positive root to $\frac{1}{2}\sigma^2 y(y-1) + \mu y - r - \lambda_\rho = 0$. It is straightforward to verify that this leads to the same qualitative insights as in Section 3.²⁹

(ii) *Time-varying profitability*: We illustrate the argument by making a simplifying assumption that allows us to solve the resulting problem analytically. Specifically, suppose that the NPV of the project from the financiers' point of view follows

$$\frac{d(K - \theta W^F)}{(K - \theta W^F)} = \mu_K dt + \sigma_K dZ_K$$

where Z_K is a standard Brownian motion and $\sigma_K > 0$ with a correlation ψ to Z . We assume that $\mu_K < 0$ implying that the NPV increases on average over time. To simplify the analysis, we further assume that the change in NPV is entirely due to a change in the investment cost K . Following similar steps to Proposition 1, the manager's expected payoff is the solution to the following partial differential equation

$$\begin{aligned} rU &= \mu w U_w + \frac{1}{2} \sigma^2 w^2 U_{ww} + \mu_K (K - \theta W^F) U_K \\ &\quad + \frac{1}{2} \sigma_K^2 (K - \theta W^F)^2 U_{KK} + \psi \sigma \sigma_K w (K - \theta W^F) U_{wK} \end{aligned} \quad (32)$$

where the subscripts w and K denote the partials with respect to w and $(K - \theta W^F)$, respectively. Define $\chi = \frac{w}{(K - \theta W^F)}$ so that $U(w, K) = (K - \theta W^F) U(\chi)$, where we use that U is homogenous of degree one in $(w, (K - \theta W^F))$ (doubling w and $(K - \theta W^F)$

²⁸If the disagreement is about the starting value of the flow process in analogy to Proposition 7, then $\theta \widetilde{W}^F = \theta W^F$.

²⁹Furthermore, single crossing holds for λ sufficiently small, which helps to extend also the results from Section 4.1.

would merely double the value of the growth opportunity). We have

$$\begin{aligned} U_w &= U_\chi; U_{ww} = \frac{1}{(K - \theta W^F)} U_{\chi\chi}; U_{wK} = -\frac{w}{(K - \theta W^F)^2} U_{\chi\chi} \\ U_K &= U - \frac{w}{(K - \theta W^F)} U_\chi; U_{KK} = \frac{w^2}{(K - \theta W^F)^3} U_{\chi\chi}. \end{aligned}$$

Plugging into (32), we obtain the simple ordinary differential equation

$$\underbrace{(r - \mu_K)}_{r'} U = \underbrace{(\mu - \mu_K)}_{\mu'} \chi U_\chi + \underbrace{\left(\frac{1}{2} \sigma^2 + \frac{1}{2} \sigma_K^2 - \psi \sigma \sigma_K \right)}_{\sigma'} \chi^2 U_{\chi\chi} \quad (33)$$

with a value matching condition $U(\chi^*) = \left(\frac{1 - \chi^*}{\theta W^F} \right) \theta W^M - \chi^*$. Defining ϕ as the positive root to $\frac{1}{2} \sigma'^2 y(y - 1) + \mu' y = r'$ (where r' , μ' and σ' are defined in (33)), and following the same steps as in Section 3, we obtain

$$\chi^* = \frac{w^*}{(K^* - \theta W^F)} = \frac{\phi}{\phi - 1} \left(\frac{\theta W^M}{\theta W^M - \theta W^F} \right).$$

We see, thus, that the optimal co-investment w and the NPV from the financier's point of view are in a constant proportion at the optimal investment barrier. Along this barrier, the optimal cash level w^* increases with the investment cost K^* , and this level is lower when the investment opportunities are better (high θ). **Q.E.D.**

Proof: Cash Hoarding and Incentives (Section 4.3). We briefly verify the claim that the incentives problem sketched in the main text leads to the same qualitative predictions as differences in vision. Suppose that for some given level of co-investment w by the manager, the financier expects an equilibrium level of effort e^* , prompting him to require a share of the firm $\alpha = \frac{K-w}{e^* \theta W}$. In such a case, it is optimal for the manager to choose

$$\max_{\hat{e}} \left(1 - \frac{K-w}{e^* \theta W} \right) \hat{e} \theta W - w - \frac{\hat{e}^2}{2\nu}$$

implying that $\frac{(e^* \theta W - K + w)}{e^*} = \frac{\hat{e}}{\nu}$. Since in equilibrium $e^* = \hat{e}$, we have $e^* = \frac{1}{2} \theta W \nu + \frac{1}{2} \sqrt{\theta^2 W^2 \nu^2 - 4\nu(K-w)}$ and we see immediately that e^* is increasing in w .

Plugging in for e^* into the manager's expected payoff given in (10) we obtain

$$U^{incentives} := \frac{1}{2} \left(\left(\frac{1}{2} \theta W \nu + \frac{1}{2} \sqrt{\theta^2 W^2 \nu^2 - 4\nu(K-w)} \right) \theta W - K - w \right) \left(\frac{w}{w_\theta^*} \right)^\beta.$$

Thus, w_θ^* , is the solution to the first-order-condition

$$\frac{\nu\theta W}{\sqrt{\theta^2 W^2 \nu^2 - 4\nu(K-w)}} - 1 = \frac{\beta}{w_\theta^*} \left(\left(\frac{1}{2}\theta W \nu + \frac{1}{2}\sqrt{\theta^2 W^2 \nu^2 - 4\nu(K-w)} \right) \theta W - K - w \right).$$

It is straightforward to show that the second-order-condition is satisfied. Furthermore, we also have $\frac{\partial^2 U^{\text{incentives}}|_{w=w_\theta^*}}{\partial w_\theta^* \partial \theta} < 0$, implying by standard arguments that $\frac{dw_\theta^*}{d\theta} < 0$ as claimed in the main text. **Q.E.D.**

Verifying Mailath's Conditions for a Separating Equilibrium

In what follows, we verify that the regularity conditions required by Mailath (1987) are indeed satisfied and that $\frac{\partial^2}{\partial \hat{w} \partial \theta} U(w_t, \hat{w}, \hat{\theta}, \theta) < 0$. Mailath's conditions are:

- 1) Smoothness: $U(\cdot)$ is twice continuously differentiable.
- 2) Belief monotonicity: $\frac{\partial}{\partial \theta} U(\cdot)$ is either strictly positive or strictly negative.
- 3) Type monotonicity: $\frac{\partial^2}{\partial \theta \partial w^{**}} U(\cdot)$ is either strictly positive or strictly negative.
- 4) Strict quasiconcavity: $\frac{\partial}{\partial w^{**}} U(\cdot)|_{\hat{\theta}=\theta} = 0$ has a unique solution in w that maximizes $U(\cdot)|_{\hat{\theta}=\theta}$, and $\frac{\partial^2}{\partial (w^{**})^2} U(\cdot)|_{\hat{\theta}=\theta} < 0$ at this solution.
- 5) Boundedness: There is $k > 0$ such that for all $(\theta, w) \in [\underline{\theta}, \bar{\theta}] \times \mathbb{R}_+$, $\frac{\partial^2}{\partial (w^{**})^2} U(\cdot)|_{\hat{\theta}=\theta} \geq 0$ implies $|\frac{\partial}{\partial w^{**}} U(\cdot)|_{\hat{\theta}=\theta}| > k$.

Conditions 1)-2) are satisfied. Proposition 1 shows that condition 4) is also satisfied. To check for condition 5), observe that if $\frac{\partial^2}{\partial (w^{**})^2} U(\cdot)|_{\hat{\theta}=\theta} \geq 0$, then since the first line on the RHS of

$$\begin{aligned} \frac{\partial^2}{\partial (w^{**})^2} U(w_t, w^*, \hat{\theta}, \theta) &= \frac{\beta}{(w^{**})^2} \left(\frac{\hat{\theta} W^F - K}{\hat{\theta} W^F} \right) \theta W^M \left(\frac{w_t}{w^{**}} \right)^\beta \\ &\quad - \frac{\beta}{w^{**}} \left(-\frac{\beta}{w^{**}} \left(\left(1 - \frac{K-w^*}{\hat{\theta} W^F} \right) \theta W^M - w^{**} \right) + \frac{\theta W^M}{\hat{\theta} W^F} - 1 \right) \left(\frac{w_t}{w^{**}} \right)^\beta \end{aligned}$$

is negative, $\frac{\partial}{\partial w^{**}} U(\cdot)|_{\hat{\theta}=\theta} < 0$ for $\hat{w} \in (0, k)$ where k is bounded away from infinity. w_θ^{**} remains the unique equilibrium even if $k \rightarrow \infty$. To see this, observe that the single crossing property holds for $w^{**} \in (0, \infty)$. Hence, local incentive compatibility of w_θ^{**} guarantees also global incentive compatibility and w_θ^{**} is a separating equilibrium even if $k \rightarrow \infty$. Moreover, it is the unique equilibrium. Otherwise, there must be an alternative equilibrium with a type for whom $w_\theta^{**}(\theta) \rightarrow \infty$. However, for such a trigger, the option value component of this type's expected payoff is zero, whereas it is strictly positive for a positive trigger bounded away from infinity. This makes a deviation profitable, contradicting the

existence of a different separating equilibrium than w_{θ}^{**} .

Finally, we check when $\frac{\partial^2}{\partial w^{**} \partial \theta} U(\cdot) < 0$ holds—i.e., condition 3). U is submodular in w^{**} and θ if

$$\frac{\partial^2}{\partial w^{**} \partial \theta} U(w_t, w^*(\hat{\theta}), \hat{\theta}, \theta) = \left(-\frac{\beta}{\hat{w}} (\hat{\theta} W^F - K) + 1 - \beta \right) \frac{W^M}{\hat{\theta} W^F} \left(\frac{w_t}{\hat{w}} \right)^\beta < 0$$

and so it should hold

$$w^{**}(\hat{\theta}) > \underline{w}_{\hat{\theta}} := \frac{\beta}{\beta - 1} (K - \hat{\theta} W^F). \quad (34)$$

Comparing this condition to (7), we see that submodularity holds as long as signaling does not require a too large distortion away from first best.

Clearly, condition (34) is satisfied for all types close enough to the lowest type, since $w_{\underline{\theta}}^{**} = w_{\underline{\theta}}^* > \underline{w}_{\underline{\theta}}$. A sufficient condition that it is satisfied for all types is that $\theta W^F > \theta W^M - \frac{1}{\beta} K$ —i.e., that disagreement is not excessive.³⁰ Intuitively, if disagreement is excessively large, absent information asymmetry, all types find it optimal to accumulate large cash reserves and raise only little financing from outside financiers. Then, deviating too much from this strategy when there is information asymmetry, which may be needed for high types to separate from low types, could become too costly as the benefit from overcoming information asymmetry does not compensate for the cost of increasing exposure to outside financing and, thus, disagreement.

If condition (34) is violated, denote the lowest type for whom this is the case with θ' . Then, we can construct a separating equilibrium for types $[\underline{\theta}, \theta']$ characterized by (28) and $w_{\underline{\theta}}^{**} = w_{\underline{\theta}}^{VM}$. The remaining types $(\theta', \bar{\theta}]$ then pool at the cash level $w^P < w_{\theta'}^{**}$ for which type θ' is indifferent between separating and pooling with the higher types. It is straightforward to find beliefs that support such an equilibrium.

³⁰This condition can be derived from requiring that $\frac{dw_{\theta}^*}{d\theta} > \frac{d\underline{w}_{\theta}}{d\theta}$ for $w_{\theta}^* = \underline{w}_{\theta}$ —i.e., that w_{θ}^* and \underline{w}_{θ} do not cross.