Financing Constraints, Performance Manipulation, and Founder Replacement

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Abstract

Granting investors the right to replace founders with professional managers benefits founders ex ante through improved financing terms or access to funding that would otherwise be unavailable. Ex post, however, founders prefer to remain in charge and have incentives to manipulate the performance metrics that trigger their replacement. When founders are financially unconstrained, the optimal contract eliminates manipulation incentives through generous exit packages. When founders are financially constrained, however, such packages leave insufficient pledgeable income to satisfy investors. Constrained founders must therefore offer contracts that induce them to manipulate performance metrics in equilibrium, leading to insufficient founder replacement. The model predicts that lower capital requirements, from technological shifts such as cloud computing, and greater founder wealth lead to larger exit packages, less manipulation, and more frequent turnover. In technologically complex sectors where performance metrics are opaque, exit packages are smaller, manipulation is more prevalent, and replacement is less frequent. The framework extends to staged financing, where founders distort the interim signals that inform follow-on funding decisions, undermining the standard benefit of staging.

Keywords: Financing constraints, Performance manipulation, Founder turnover, Staged financing, Founder exit packages

JEL Classifications: D86, G24, M13

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April 13, 2026

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1 Introduction

One of the most consequential governance mechanisms in venture capital is the replacement of founder-CEOs with professional managers, often driven by concerns regarding managerial competence (Hellmann and Puri 2002; Wasserman 2003; Kaplan et al. 2009). Broughman and Fried (2020) document that approximately 60% of founders are replaced as CEOs by the time of the IPO, and Ewens and Marx (2018) provide causal evidence that replacing founders enhances firm performance. Ex ante, ceding control rights to investors benefits founders through improved financing terms or access to funding that would otherwise be unavailable (Aghion and Bolton 1992; Hellmann 1998).

But control rights are only as useful as the information on which they are exercised. Ex post, founders prefer not to be replaced as they derive private benefits from remaining in charge. This gives them incentives to manipulate the performance metrics that investors rely on for replacement decisions.[1] Manipulation inflates performance signals, making it harder for investors to identify underperforming founders. For example, founders may offer steep discounts to pull forward sales, run promotional campaigns that inflate user engagement, or adopt metric definitions that present existing performance in a more favorable light.

This paper studies how financing constraints shape exit packages, manipulation incentives, and founder replacement.[2] I model manipulation as a costly "window dressing" activity: the founder can take actions that shift the distribution of the performance signal upward without changing actual performance (Cornelli and Yosha 2003; Dutta and Gigler 2002; Demski et al. 2004).

[1] For other implications of the threat of termination, such as distortions to long-term investment decisions, see von Thadden (1995), Edmans (2011), and Laux (2012).

[2] The optimal financial contract is derived without restricting the set of feasible securities.

To isolate the role of financing constraints, I first consider a setting without them. When founders are financially unconstrained, they choose contracts that award them generous exit packages upon removal, effectively eliminating incentives to manipulate the performance signal.[3] These packages can be structured as equity with accelerated vesting triggered by the founder's replacement. Eliminating manipulation incentives has two benefits. First, more informative signals enable investors to identify and replace underperforming founders, and since investors break even, the efficiency gain accrues to the founder. Second, the direct costs of manipulation are saved.

Financially constrained founders cannot afford such generous exit packages because these payments leave insufficient pledgeable income to satisfy investors. Reducing the exit package, however, has competing effects on pledgeable income: it directly frees up income for investors but also increases manipulation and can weaken effort incentives. When the founder's direct cost of manipulation is sufficiently high, the savings from reducing exit packages dominate. Constrained founders can then raise capital, but only by offering contracts that induce some manipulation, making it harder to identify underperforming founders and leading to insufficient replacement. This contrasts with standard financial contracting models, where financing constraints lead to excessive investor intervention: entrepreneurs must cede broad control rights to investors to increase pledgeable income at the cost of inefficient liquidation (Aghion and Bolton 1992; Bolton and Scharfstein 1990; Dewatripont and Tirole 1994; Hart and Moore 1998; Berglöf and von Thadden 1994).[4] Here, ceding

[3] Lambert and Larcker (1985) and Jensen (1988) argue that golden parachutes reduce managers' temptation to resist value-enhancing takeovers. Levitt and Snyder (1997), Laux (2008), Inderst and Mueller (2010), and Mayer (2022) show that termination payments can incentivize managers to reveal unfavorable information that leads to their own replacement or project termination.

[4] In Bolton and Scharfstein (1990), Hart and Moore (1998), and Berglöf and von Thadden (1994), managers can divert cash flow and the threat of termination keeps them honest; in Dewatripont and Tirole (1994), the threat of termination induces effort; in Aghion and Bolton (1992), liquidation increases pledgeable income but destroys the entrepreneur's private benefits.

control rights to investors always leads to the efficient replacement decision given the available information, but the founder has an incentive to distort this information ex post. The resulting information distortion leads to too little replacement rather than too much. Equilibrium manipulation and founder entrenchment are not failures of contract design but the necessary cost of making valuable ventures financeable.

The model generates predictions about the cross-sectional and time-series variation in exit packages, manipulation, and founder replacement. First, the launch of Amazon Web Services in 2006 dramatically reduced capital requirements for internet-based startups (Ewens et al. 2018). Lower capital requirements relax financing constraints, leading to larger exit packages, less manipulation, and more frequent founder replacement among internet-based ventures relative to unaffected sectors. When manipulation declines, early-stage performance metrics become more predictive of eventual outcomes, offering a measurable proxy for manipulation intensity. Second, founder wealth operates through the same channel: founders with more personal assets are less financially constrained, which permits more generous exit packages, reducing manipulation incentives. Wealthier founders are therefore replaced more frequently. Third, technological complexity drives outcomes in the opposite direction. In sectors such as artificial intelligence and biotechnology, performance metrics are difficult for non-specialist investors to evaluate. This opacity gives founders greater scope to manipulate, reducing pledgeable income and forcing founders to accept smaller exit packages, which in turn reinforces manipulation and entrenchment.

The model also distinguishes between voluntary and involuntary founder replacement, a prediction that separates the financing constraint mechanism from alternative explanations based on governance quality (Hermalin and Weisbach 1998; Lerner 1995) or founder heterogeneity. The present model predicts that the same founder, facing the same board, departs voluntarily when financially unconstrained and involuntarily when constrained. The mode of departure is empirically observable through post-departure board retention, the presence of legal disputes, and textual analysis of press releases. The variation comes from the exit package in the contract, not from governance or ability.

The framework extends to staged financing, where investors decide whether to provide follow-on capital rather than whether to replace the founder. The standard argument for staging is that it gives investors the option to terminate underperforming ventures at each funding stage (Admati and Pfleiderer 1994; Gompers 1995). Manipulation undermines this benefit by distorting the interim signals on which termination decisions are based, and the distortion is most severe for financially constrained ventures where staging would be most valuable. A larger follow-on investment makes the termination decision more important but forces contracts that lead to worse decisions by tightening the financing constraint and increasing manipulation. The framework also offers a contracting-based explanation for the findings of Ewens et al. (2018), who document that venture capitalists terminated more startups after cloud computing reduced initial capital requirements. They attribute this to a real options channel: cheaper experiments make it profitable to fund riskier ventures that fail more often. The present model offers a complementary channel: lower capital requirements allow for more generous termination payments, which curb manipulation and improve the accuracy of interim signals, enabling investors to identify and terminate low-quality ventures more frequently.

Cornelli and Yosha (2003) also study manipulation in staged VC financing. In their model, convertible securities eliminate manipulation, and doing so is necessary for financing. In the present model, the opposite holds: constrained founders must accept contracts that induce manipulation because the exit packages that would eliminate it leave insufficient pledgeable income. The difference arises because effort is endogenous. Convertible securities do not work in the present model because they deter manipulation by diluting the founder after a high signal, but this dilution also weakens effort incentives. Exit packages deter manipulation by compensating the founder upon replacement, leaving the founder's long-term reward free to maintain effort incentives.

In the managerial contracting literature, Goldman and Slezak (2006), Crocker and Slemrod (2007), and Beyer et al. (2014) show that inducing effort and eliminating manipulation is not feasible when only short-term signals are available for contracting. In the present model, the contract can condition payments on both the interim signal and long-term cash flows, so these two functions can be separated. In debt contracting, Guttman and Marinovic (2018) and Laux (2022) show that earnings-based covenants induce earnings management. In dynamic compensation settings, Peng and Röell (2014) and Marinovic and Varas (2019) find that long-term pay reduces manipulation but imposes risk on the agent.

2 Model

A founder with personal assets $A \geq 0$ has an investment idea that requires capital $I > 0$ and must raise $I - A$ from outside investors. We begin with the case $A = 0$ and incorporate positive founder wealth in the comparative statics (Section 3.5). While the founder has the vision and idea for the new venture, she may not be the best person to manage the firm in the long run. This is captured by $\omega \in \{\omega_l, \omega_h\}$, representing the founder's managerial skills and expertise.

If the project is financed, its future cash flows depend on whether the founder remains in charge and, if so, on her managerial skills ω. If $\omega = \omega_h$, the project generates high cash flows $x = X_h > I$ with probability $q > 0$ and low cash flows

$x = X_l < I$ with probability $(1-q)$. If $\omega = \omega_l$, the project generates low cash flows X_l with certainty. If the founder is replaced with a professional manager, cash flows are $X_r \in (X_l, X_h)$. The founder reaps private benefits $B > 0$ if and only if she remains in charge.

Building on the moral hazard framework of Holmström and Tirole (1997), the founder's managerial skills depend on her unobservable effort choice. After receiving financing, she chooses an effort level $a \in \{a_l, a_h\}$, where $1 > a_h > a_l > 0$, at cost $c(a)$ with $c(a_h) = C$ and $c(a_l) = 0$. Given effort a, the founder's skills are high, $\omega = \omega_h$, with probability a, and low, $\omega = \omega_l$, with probability $(1-a)$. Neither the founder nor investors observe ω directly.

At an interim stage, the firm produces a performance measure, $s \in \{s_l, s_h\}$, that is informative about managerial ability ω. The founder can affect the distribution of the signal by choosing a level of manipulation m. Manipulation activities are undertaken during the same operating period as the founder's effort to build the firm, so effort and manipulation are chosen simultaneously. Since the founder has no reason to take actions that worsen metrics, the signal structure is $\Pr(s_h|\omega_h, m) = 1$ and $\Pr(s_h|\omega_l, m) = m$.[5]

The unconditional probability of a high signal is $\Pr(s_h) = a + (1-a)m(a)$, where $m(a)$ indicates that the founder's manipulation choice m depends on her effort choice a. Manipulation m costs the founder $0.5km^2$, where k scales the marginal cost of manipulation. Assume that k is sufficiently high that manipulation does not exceed one.

After the signal s is observed, the founder either remains in charge or is replaced

[5] The assumption that high-ability founders always produce a high signal ensures that manipulation is unambiguously inefficient. If high-ability founders sometimes received low signals, manipulation could also protect them from being inappropriately replaced, introducing a beneficial dimension of manipulation.

with a professional manager. I make the following assumptions:

$$X_r > X_l + B, \tag{A1}$$

$$a_h(qX_h + (1-q)X_l) + (1-a_h)X_l > X_r, \tag{A2}$$

$$a_l(qX_h + (1-q)X_l) + (1-a_l)X_r < I. \tag{A3}$$

Assumption A1 implies that replacing the founder is efficient in the low state ($\omega = \omega_l$). Assumption A2 implies that, contingent on high effort, the founder generates a higher expected cash flow than a potential replacement. A2 also implies that retaining the founder is efficient if the signal is high, $s = s_h$, that is,

$$\Pr(\omega_h|s_h)(qX_h + (1-q)X_l) + (1 - \Pr(\omega_h|s_h))X_l > X_r,$$

since $\Pr(\omega_h|s_h) \geq a_h$ for all $m \leq 1$. Finally, A3 implies that the project has a negative net present value if the founder chooses low effort, $a = a_l$. Since $(qX_h+(1-q)X_l) > X_r$ from A2, A3 further implies that $X_r < I$, indicating that investors cannot break even when they replace the founder immediately after financing the project.

Investors are competitive and provide financing if they expect to break even. If investors required a positive profit, the financing constraint would tighten but the qualitative results would be unchanged. The founder offers a contract that determines who has control rights over the replacement decision and specifies a nonnegative payment to the founder $Y(s,d,x) \geq 0$ for each signal s, replacement decision $d \in \{0,1\}$ ($d = 1$ if replaced), and cash flow realization x, subject to limited liability.[6] The investors receive the residual cash flow $x - Y(s,d,x)$. To ensure that monetary

[6] The replacement decision cannot be fully specified in the contract because the details of replacement — such as the identity and qualifications of the successor — are not contractible ex ante. Control rights give investors the authority to implement replacement as they see fit.

incentives are necessary to induce effort, assume that $C > (a_h - a_l)B$.

The timing is as follows: At date 1, the founder and investors sign the financial contract and the founder chooses effort a and the level of manipulation m. At date 2, signal s is realized and the founder is either retained or replaced with a professional manager. At date 3, cash flows are realized and shared according to the contract.

3 Optimal Contract

3.1 Preliminaries

We begin by establishing that the general contract reduces to three payments, that investor control is weakly optimal, and by characterizing equilibrium actions at date 2. To state these results, let Y_h and Y_l denote the founder's pay if she remains in charge and cash flows are high ($x = X_h$) or low ($x = X_l$), and let Y_r denote her exit package if she is replaced. The exit package Y_r can be implemented through equity with accelerated vesting triggered by the founder's removal, or through severance pay.

Lemma 1 *(i) In any optimal contract, the founder is replaced if and only if the signal is low, $s = s_l$.*

(ii) The general contract $Y(s, d, x) \geq 0$ reduces to three payments (Y_h, Y_l, Y_r) without loss of generality.

(iii) Allocating control rights to investors, who replace the founder after s_l, is weakly optimal.

(iv) Under investor control, the founder's optimal manipulation is

$$m(a) = \max\{0, (1 - a)(B + Y_l - Y_r)/k\}, \tag{1}$$

and it is without loss of generality to restrict attention to $Y_r \leq B + Y_l$*.*

Parts (i) and (ii). A low signal reveals $\omega = \omega_l$ with certainty, so replacement is strictly efficient by A1. A high signal implies $\Pr(\omega_h \mid s_h) \geq a_h$ for all $m \leq 1$, so retention is efficient by A2. Since investors are competitive and the founder captures the entire surplus net of I, she designs the contract to implement the efficient replacement rule, regardless of the payment structure or the allocation of control rights.[7] Moreover, replacement after a low signal not only is efficient but also strengthens effort incentives: since high effort reduces the probability of receiving a low signal and being replaced, the threat of losing private benefits B motivates the founder to work. This reduces the monetary incentives required to induce effort and increases pledgeable income. Given this replacement rule, only three (s, d, x) outcomes arise with positive probability under any action profile (a, m): $(s_h, 0, X_h)$, $(s_h, 0, X_l)$, and $(s_l, 1, X_r)$. Payments at all other contingencies affect neither expected payoffs nor incentives, so the contract reduces to three payments (Y_h, Y_l, Y_r) without loss of generality.

Part (iii). Without investor control rights, the founder can only be replaced through voluntary departure. After s_l, the founder knows that her managerial skills are low, $\omega = \omega_l$, and her payoff from remaining in charge is $Y_l + B$. She voluntarily departs only if $Y_r \geq B + Y_l$, so the minimum exit package inducing departure is $Y_r = B$ (with $Y_l = 0$). Since the founder weakly prefers departing, she has no incentive to inflate the signal: $m = 0$. Under investor control rights, setting $Y_r = B$ and $Y_l = 0$ also yields $m = 0$ (from part (iv)) and investors replace only after s_l (from part (i)). Moreover, investor control rights allow investors to set $Y_r < B$ and force replacement, which is not possible without control rights since the founder

[7] Under investor control, investors choose the efficient action directly. Without investor control, the founder can only be replaced through voluntary departure, but since replacement after s_l is efficient and the founder captures the surplus, she designs the exit package to induce her own departure after s_l.

would not voluntarily depart. Investor control rights therefore weakly expand the feasible contract space.[8] In venture capital, for example, investors typically have the authority to remove founders and appoint professional managers, either because they hold a voting majority on the board of directors or because they possess contractual control rights (Kaplan and Strömberg 2003; Ewens and Marx 2018).

Part (iv). Under the investors' optimal replacement rule and given effort a, the founder's expected payoff is

$$U(a) \equiv a(qY_h + (1-q)Y_l + B) + (1-a)(m(a)(B+Y_l) + (1-m(a))Y_r) - 0.5km(a)^2 - c(a). \tag{2}$$

The optimal manipulation follows from the first-order condition of (2) with respect to m. Since $Y_r = B + Y_l$ already eliminates manipulation, any $Y_r > B + Y_l$ yields the same zero manipulation but strictly reduces pledgeable income by increasing the exit package without any offsetting benefit, so the restriction $Y_r \leq B + Y_l$ is without loss.

The founder engages in more manipulation when she chooses low effort rather than high effort, $m(a_l) > m(a_h)$, for any $Y_r < B + Y_l$. Low effort increases the risk of a low signal, making it more attractive to inflate the signal via manipulation. All else equal, higher private benefits B and higher rewards for low cash flows Y_l increase manipulation incentives, while higher exit packages Y_r reduce them. The probability of founder replacement is $\phi(a) \equiv (1-a)(1-m(a))$.

The incentive compatibility constraint, $U(a_h) \geq U(a_l)$, ensures that the founder

[8] Since the replacement decision is efficient given the signal (by Parts (i) and (ii)) and the founder does not observe ω, there is no scope for renegotiation of the replacement decision. Alternatively, the contract may grant investors control rights contingent on a low signal, $s = s_l$, which yields the same outcome as unconditional investor control since investors choose to replace the founder only after a low signal.

exerts high effort and can be written as

$$(a_h - a_l)(qY_h + (1-q)Y_l + B) + \Upsilon(a_h) - \Upsilon(a_l) \geq C, \tag{3}$$

where

$$\Upsilon(a) \equiv (1-a)(m(a)(B + Y_l) + (1 - m(a))Y_r) - 0.5km(a)^2$$

captures the founder's expected benefits and costs of manipulation contingent on effort a. Investors correctly conjecture the founder's effort choice $a = a_h$ and manipulation level $m(a_h)$ and finance the project if their break-even constraint is satisfied:

$$\begin{aligned} V \equiv\ & a_h (q(X_h - Y_h) + (1-q)(X_l - Y_l)) \\ & + (1-a_h)(m(a_h)(X_l - Y_l) + (1 - m(a_h))(X_r - Y_r)) \geq I. \end{aligned} \tag{4}$$

Because investors are competitive, (4) holds as an equality and the founder captures the entire social surplus:

$$\begin{aligned} U(a_h) = W \equiv\ & a_h (qX_h + (1-q)X_l + B) \\ & + (1-a_h)(m(a_h)(X_l + B) + (1 - m(a_h))X_r) - 0.5km(a_h)^2 - C - I. \end{aligned} \tag{5}$$

The Lagrangian of the founder's optimization problem is

$$\begin{aligned} L = & W - \lambda_{IC}\{C - (a_h - a_l)(qY_h + (1-q)Y_l + B) - \Upsilon(a_h) + \Upsilon(a_l)\} \\ & -\lambda_{PC}\{I - V\}, \end{aligned} \tag{6}$$

where $\lambda_{IC} \geq 0$ and $\lambda_{PC} \geq 0$ are the Lagrangian multipliers of (3) and (4), respectively.

3.2 Financially unconstrained founders

When the capital requirement I is sufficiently low, the founder can satisfy investors' participation constraint without reducing total surplus, that is, $\lambda_{PC} = 0$.[9] When $\lambda_{PC} = 0$, we also have $\lambda_{IC} = 0$.[10] Intuitively, the founder can satisfy investors' break-even constraint and still retain a reward Y_h that exceeds the minimum level required for incentive compatibility.

Increasing the exit package Y_r reduces manipulation, which benefits the founder ex ante for two reasons: it improves the efficiency of the replacement decision (investors correctly anticipate manipulation and price protect accordingly), and it eliminates direct manipulation costs. The unconstrained founder therefore sets $Y_r = B$, making herself indifferent between remaining as CEO and departing, which eliminates manipulation incentives.

Proposition 1 *If*

$$\begin{aligned} I \quad \leq \quad & I^U \equiv a_h \left(qX_h + (1-q) X_l \right) + (1-a_h) X_r \\ & - \left(\frac{a_h}{a_h - a_l} C + (1-a_h) B \right), \end{aligned} \tag{7}$$

the founder is financially unconstrained ($\lambda_{PC} = \lambda_{IC} = 0$). In this case,

(i) the optimal exit package is $Y_r^* = B$,

(ii) the founder does not engage in manipulation, $m(a_h) = 0$,

(iii) the cost of manipulation, k, is irrelevant,

(iv) founder replacement is voluntary and efficient, with replacement rate $\phi(a_h) =$

[9]Because investors are competitive, the participation constraint always holds as an equality. Here $\lambda_{PC} = 0$ means that the surplus-maximizing contract generates sufficient pledgeable income, so the constraint does not force a distortion.

[10]Taking the derivative of the Lagrangian with respect to Y_h yields $\frac{dL}{dY_h} = \lambda_{IC}(a_h - a_l) q - \lambda_{PC} a_h q = 0$, which implies that $\lambda_{PC} = 0$ requires $\lambda_{IC} = 0$.

$1 - a_h$.

The threshold I^U is obtained by substituting $Y_l = 0$, $Y_r = B$, $m = 0$, and the binding incentive compatibility constraint (3) into (4) and solving for I. The first line in (7) is the project's expected cash flow and the second line represents the founder's minimum rewards required to induce effort and simultaneously eliminate manipulation incentives.

3.3 Pledgeable income

We now characterize the contract that maximizes pledgeable income, denoting the solution (Y_l^F, Y_h^F, Y_r^F) with the superscript F for financing capacity. This determines the maximum capital a founder can raise and the structure of the constrained-optimal contract.

Proposition 2 *(i) The contract that maximizes pledgeable income sets* $Y_l^F = 0$ *and* Y_h^F *to satisfy the binding incentive compatibility constraint (3).*

(ii) Pledgeable income $\Pi(Y_r)$ *is strictly concave in* Y_r*. The optimal exit package is* $Y_r^F = B$ *when* $k < k_1$*, interior* $Y_r^F \in (0, B)$ *when* $k \in (k_1, k_2)$*, and* $Y_r^F = 0$ *when* $k > k_2$*.*

(iii) Financially-constrained founders $(I > I^U)$ *can attract capital if and only if* $k > k_1$ *and* $I \leq \overline{I} \equiv \Pi(Y_r^F)$*, where* $\overline{I} > I^U$*.*

Proposition 2(i) shows that pledgeable income is maximized by setting the founder's reward for low cash flows to zero, $Y_l^F = 0$. While this may seem obvious, the result is non-trivial. If manipulation were prohibitively costly ($k \to \infty$), the signal s would be a sufficient statistic for effort. Since Y_l and Y_h are paid only when the founder is not replaced, which occurs when the signal s is high, both payments would be equally effective at inducing effort. When manipulation is feasible, $Y_l^F = 0$ is strictly optimal because cash flows are more informative about effort than the manipulated signal and because higher Y_l strengthens manipulation incentives.

The concavity of pledgeable income $\Pi(Y_r)$ reflects three competing channels through which the exit package affects pledgeable income. First, a smaller Y_r increases manipulation, making it harder for investors to identify and replace unsuited founders. This reduces pledgeable income, and the effect is stronger when manipulation is less costly (low k).

Second, holding manipulation constant, a lower Y_r directly increases pledgeable income by reducing the payment to replaced founders. This direct savings effect is stronger when equilibrium manipulation is lower, because replacement occurs more frequently.

Third, the exit package affects pledgeable income indirectly through effort incentives. The direction of this effect depends on $\tau = \phi(a_h) - \phi(a_l)$, the difference in replacement probabilities under high versus low effort. When manipulation incentives are weak—either because manipulation is costly (high k) or the exit package is generous—low-effort founders face higher replacement risk than high-effort founders ($\tau < 0$). In this case, the exit package rewards shirking, and reducing it strengthens effort incentives, lowering the reward Y_h required for incentive compatibility and increasing pledgeable income. When manipulation incentives are strong—due to low k and a small Y_r—low-effort founders manipulate so aggressively that their replacement risk falls below that of high-effort founders ($\tau > 0$). Here, reducing the exit package weakens effort incentives and reduces pledgeable income.

3.4 Financially constrained founders

When $I > I^U$, the exit package that eliminates manipulation incentives $Y_r = B$ leaves insufficient pledgeable income to satisfy investors. By Proposition 2(ii), for $k > k_1$, the founder can free up pledgeable income by reducing Y_r below B. This makes replacement involuntary because founders prefer retaining control, giving them incentives to manipulate performance metrics.

Proposition 3 *(i) When $k < k_1$, financially constrained founders ($I > I^U$) cannot secure funding.*

(ii) When $k > k_1$ and $I \in (I^U, \overline{I})$, the founder can secure funding, but the optimal contract induces equilibrium manipulation ($m(a_h) > 0$), which reduces the replacement rate. Compared to unconstrained founders, exit packages are smaller ($Y_r^* < B$), replacement is less frequent ($\phi(a_h) = (1 - a_h)(1 - m(a_h)) < 1 - a_h$) and involuntary.

When $k < k_1$, manipulation is so easy that reducing the exit package below B triggers a surge in manipulation that more than offsets the direct savings, leaving no way to increase pledgeable income beyond I^U (Proposition 2(ii)). The maximum pledgeable income is achieved at $Y_r = B$, but this is insufficient to satisfy investors, so financially constrained founders cannot secure funding.

When $k > k_1$, starting from $Y_r = B$, reducing the exit package increases manipulation but nevertheless frees up pledgeable income, because the direct savings from a smaller exit package outweigh the cost of increased manipulation. The founder reduces Y_r until investors' break-even constraint is satisfied, yielding $Y_r^* < B$ at the rightmost intersection of the horizontal line I and the concave pledgeable income curve $\Pi(Y_r)$ in Figure 1. The founder chooses the rightmost intersection because it minimizes the distortion from manipulation subject to the financing constraint. This equilibrium represents a second-best solution: some degree of manipulation and

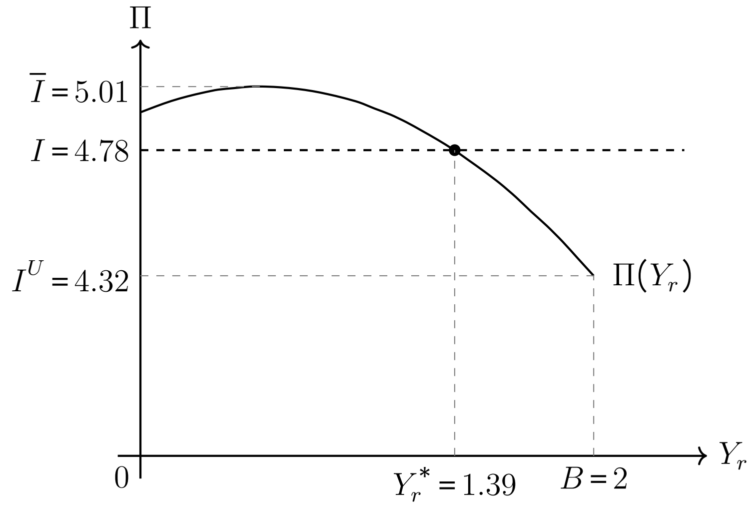

Figure 1: The concave curve $\Pi(Y_r)$ represents the maximum income pledgeable to investors as a function of the exit package. When $I \leq I^U = \Pi(B)$, the founder is unconstrained and sets $Y_r = B$. When $I \in (I^U, \overline{I})$, the founder is constrained and sets Y_r^* at the rightmost intersection of I and $\Pi(Y_r)$. When $I > \overline{I}$, the project cannot be financed. The figure is computed for $a_h = 0.6$, $a_l = 0.2$, $q = 0.7$, $X_h = 12$, $X_l = 1$, $X_r = 3.5$, $B = 2$, $C = 1$, $k = 1.6$, and $I = 4.78$.

inefficient founder retention are induced as the necessary cost of making the project financeable.[11] As in the unconstrained case, $Y_l^* = 0$. The remaining payments Y_h^* and $Y_r^* \in [0, B)$ are determined by the binding incentive compatibility and participation constraints (3) and (4). The founder's turnover rate is $\phi(a_h) = (1 - a_h)(1 - m(a_h))$, which falls below the efficient rate $1 - a_h$ because manipulation shields some unsuited founders from being replaced.

In the standard financial contracting framework, financing constraints lead to excessive project liquidation, as entrepreneurs must cede broad control rights to increase pledgeable income (e.g., Aghion and Bolton 1992). Here, financing constraints have the opposite effect. Ceding control rights to the investor always leads to the efficient replacement decision given the available information, but the optimal contract in-

[11] In Cornelli and Yosha (2003), there are no private benefits of control and no endogenous effort, so eliminating manipulation always increases pledgeable income.

duces manipulation that distorts this information. The financing constraint therefore leads to too little replacement rather than too much. One might ask whether the parties could renegotiate to a higher exit package after the investment is sunk, since eliminating manipulation would increase total surplus. However, the same financing constraint that forces the founder to accept a small exit package also prevents such renegotiation. Raising Y_r to B would reduce the investor's expected return below the amount invested, and the financially constrained founder lacks the resources to make a compensating transfer. Equilibrium manipulation therefore persists not because the parties overlook a joint improvement, but because the financing constraint simultaneously creates the distortion and forecloses its resolution.

3.5 Comparative statics

This subsection characterizes how capital requirements, founder wealth, and technological complexity affect exit packages, manipulation, and replacement patterns.

The severity of the financing constraint depends on how much external capital the founder must raise. Two observable factors determine this: the venture's capital requirement I and the founder's personal assets A. A founder with assets A needs to raise $I - A$ in external capital, so increases in A and decreases in I operate through the same channel.

Proposition 4 *For financially constrained founders ($I - A \in (I^U, \bar{I})$), a reduction in capital requirements I or an increase in founder assets A leads to (i) larger exit packages Y_r, (ii) less manipulation of performance metrics (lower $m(a_h)$), and (iii) more frequent founder replacements (higher ϕ).*

When the founder needs less external capital, the financing constraint relaxes, allowing a more generous exit package. The larger exit package weakens manipu-

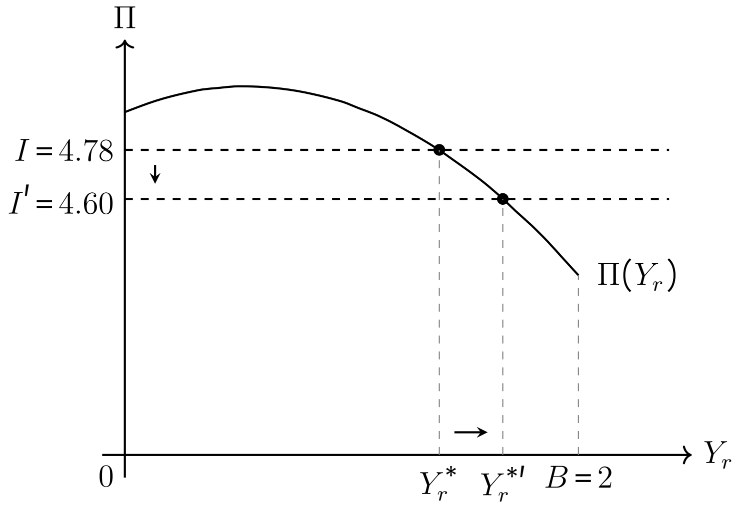

Figure 2: Effect of lower capital requirements on the exit package. When the capital requirement declines from I to $I' < I$, the financing constraint permits a larger exit package ($Y_r^{*\prime} > Y_r^*$). The larger exit package reduces manipulation and increases founder replacement. Same parameters as Figure 1.

lation incentives and improves the informativeness of performance metrics, enabling investors to identify and replace unsuited founders more frequently. This effect is illustrated in Figure 2: a reduction in I shifts the horizontal line downward, moving the intersection with $\Pi(Y_r)$ to the right and increasing Y_r^*.

Technological complexity affects contracting through a different mechanism. Complex technologies make performance metrics more opaque to investors, giving founders greater scope to manipulate. In the model, this corresponds to a lower manipulation cost k. Complex technologies also require founders to integrate expertise across multiple domains, making managerial skill development more challenging, corresponding to a higher effort cost C.

Proposition 5 *For financially constrained founders ($I - A \in (I^U, \overline{I})$), a decline in the manipulation cost k or an increase in the cost C of acquiring managerial skills leads to smaller exit packages Y_r, more manipulation ($m(a_h)$ increases), and less frequent replacement (ϕ decreases).*

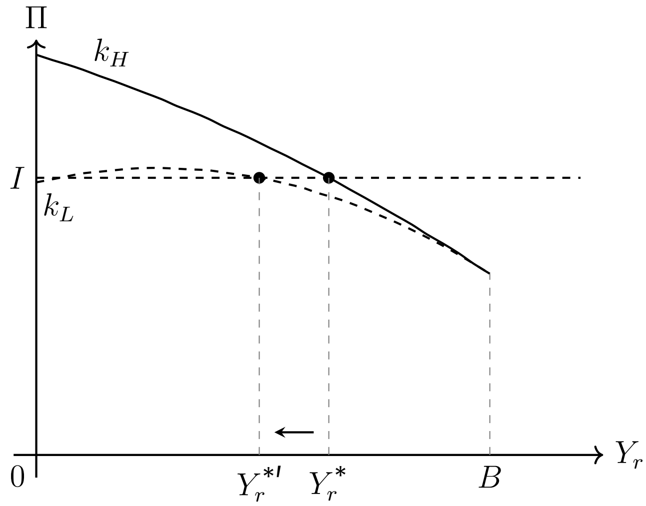

Figure 3: Effect of manipulation costs on pledgeable income and exit packages. When manipulation becomes easier ($k_L < k_H$), pledgeable income declines for any $Y_r < B$, shifting the curve downward. For a given capital requirement I, the exit package declines ($Y_r^{*\prime} < Y_r^*$). Same parameters as Figure 1 except $k_H = 4.0$ and $k_L = 1.6$.

When manipulation is easier (lower k), one might expect the optimal contract to offset this by strengthening incentives against manipulation. The financing constraint, however, prevents this and forces the founder to accept a contract that induces even more manipulation. Figure 3 illustrates that easier manipulation shifts the pledgeable income curve downward, forcing a smaller exit package for any given capital requirement. The smaller exit package in turn amplifies manipulation, further reducing the accuracy of performance signals. When skill development is more costly (higher C), founders must receive a higher reward for long-term success to maintain effort incentives, again reducing pledgeable income.

4 Staged Financing

This section reinterprets the model as a staged financing problem in which the investor decides whether to provide follow-on capital rather than replace the founder. The baseline model maps directly to staged financing with the following modifications. The variable ω represents project quality rather than the founder's managerial skills, and after observing the interim signal s, the investor decides whether to provide follow-on capital $I_2 > 0$ and continue the project, or terminate the venture. Upon termination, the venture generates a liquidation value $X_r \geq 0$ and the founder receives the termination payment $Y_r \geq 0$. Private benefits B accrue only upon continuation.

The new element is the follow-on investment I_2, which must be financed upon continuation. Since I_2 changes the net payoff, assumptions A1–A3 become:

$$X_r + I_2 > X_l + B, \tag{A1$'$}$$

$$a_h(qX_h + (1-q)X_l) + (1-a_h)X_l > X_r + I_2, \tag{A2$'$}$$

$$a_l(qX_h + (1-q)X_l) + (1-a_l)X_r < I + a_l I_2. \tag{A3$'$}$$

A1$'$ ensures that termination is efficient when project quality is low, A2$'$ ensures that continuation is efficient when the signal is high, and A3$'$ ensures that the project has negative net present value under low effort, evaluated at the efficient termination rule with no manipulation.

The left-hand side of the investors' participation constraint (4) is unchanged, but the required financing on the right-hand side increases from I to $I + (a_h + (1 - a_h)m(a_h))I_2$, reflecting the expected follow-on investment. Since the probability of continuation, $a_h + (1 - a_h)m(a_h)$, is increasing in manipulation, the follow-on investment tightens the financing constraint both directly and indirectly through its interaction with manipulation.

The analysis proceeds as in Section 3. Financially unconstrained founders set $Y_r = B$ to eliminate manipulation. Financially constrained founders must reduce Y_r below B to generate sufficient pledgeable income, inducing equilibrium manipulation and raising the probability that low-quality ventures are continued. The comparative statics from Propositions 4 and 5 carry over.

These results have implications for the benefits of staged financing. The standard argument for staging is that it gives investors the option to terminate underperforming ventures at each funding stage (Admati and Pfleiderer 1994; Gompers 1995). The value of this option, however, depends on the quality of the information available at each stage. In the present model, founders strategically distort interim performance metrics, reducing the informativeness of the signals investors use for follow-on financing decisions. This undermines the abandonment benefit that motivates staging in the first place. Moreover, the problem is most severe precisely where staging would be most valuable: financially constrained ventures, where the financing gap is large, face the strongest manipulation incentives and therefore the greatest distortion of interim signals.

The staged financing setting generates an additional comparative static regarding the size of the follow-on investment.

Proposition 6 *For financially constrained ventures, a larger follow-on investment I_2 tightens the financing constraint and leads to (i) smaller termination payments Y_r, (ii) more manipulation $m(a_h)$, and (iii) a higher probability that low-quality ventures receive follow-on funding.*

A higher follow-on cost makes the termination decision more important. However, a larger I_2 also tightens the financing constraint, forcing the founder to accept a smaller termination payment Y_r. This strengthens manipulation incentives, distorting the interim signal. Paradoxically, a larger follow-on investment therefore increases the probability that low-quality ventures are continued.

5 Empirical Predictions

This section translates the model's results into testable predictions. Each prediction identifies the source of variation, the key outcome variables, and an empirical setting suited for testing.

5.1 Capital requirements and cloud computing

The venture capital landscape has undergone a significant transformation over the past two decades. The launch of Amazon Web Services (AWS) in 2006 allowed internet-based startups to rent computing resources on demand rather than making substantial upfront investments in servers and data centers, dramatically reducing their capital requirements (Ewens et al. 2018). The affected sectors include software platforms, SaaS companies, and consumer internet ventures. Sectors such as biotechnology, medical devices, and semiconductors were largely unaffected, providing a natural control group for a difference-in-differences test of Proposition 4.

Prediction 1 *Following the adoption of cloud computing, internet-based ventures should exhibit larger exit packages, higher rates of founder replacement, and stronger predictive accuracy of early-stage metrics relative to sectors where cloud computing had less impact on capital requirements.*

Exit packages can be measured using equity vesting schedules, acceleration clauses triggered by founder removal, and severance provisions in founder employment agreements. Data on contract terms are available from SEC filings for ventures that eventually go public, and deal-level terms can be obtained from databases such as PitchBook. Manipulation intensity is not directly observable but can be proxied by the predictive accuracy of early-stage metrics: if manipulation declines, the correlation between interim performance measures and eventual outcomes should strengthen in the treatment group relative to the control group.

5.2 Founder wealth

At first glance, one might expect wealthier founders to be more entrenched. In the model, the opposite is true: wealthier founders need less external capital, which relaxes the financing constraint and permits more generous exit packages, leading to less manipulation and more frequent replacement (Proposition 4).

Prediction 2 *Within a given sector and time period, founders with greater personal wealth receive larger exit packages, engage in less manipulation, and are replaced more frequently.*

Empirical proxies for founder wealth include prior entrepreneurial exits, accumulated savings, and family resources. A potential concern is that wealthier founders differ systematically on quality—serial entrepreneurs have more experience and better networks. Isolating the financing channel requires controlling for founder quality to ensure that the relationship between wealth and exit packages operates through the pledgeable income mechanism rather than through differences in ability.

5.3 Voluntary versus involuntary departures

The model predicts not only how often founders are replaced but also the nature of their departure. Financially unconstrained founders receive generous exit packages and depart voluntarily; constrained founders receive smaller packages, resist replacement, and are removed involuntarily (Propositions 1 and 3). Unlike models based on governance quality (Hermalin and Weisbach 1998; Lerner 1995) or founder heterogeneity, the present model predicts that the same founder, facing the same board, departs voluntarily when financially unconstrained and involuntarily when constrained. The variation comes from the exit package in the contract, not from governance or ability.

Prediction 3 *Voluntary founder departures are more prevalent in sectors with low capital requirements and among wealthy founders. Involuntary departures concentrate in sectors with high capital requirements and among founders with limited personal resources. Following reductions in capital requirements (e.g., from the adoption of cloud computing), the share of voluntary departures among all founder replacements increases.*

The two modes are empirically distinguishable. Voluntary transitions are characterized by founders retaining advisory roles or board seats, publicly endorsing successors, and negotiating planned transitions over several months. Involuntary transitions involve disputes over exit terms, litigation, and founder disengagement after removal. Researchers can classify transitions using textual analysis of press releases and SEC filings, post-departure board retention, and the presence of legal disputes. Since the introduction of Amazon Web Services in 2006 dramatically reduced capital requirements for internet-based startups, the share of voluntary transitions among these ventures should increase after 2006 relative to sectors where capital requirements were unaffected.

5.4 Technological complexity

Startups in fields such as artificial intelligence and biotechnology operate with technologies whose performance metrics are inherently difficult to evaluate, even for specialist investors. An AI venture's performance on curated benchmarks may not reflect its actual commercial viability, and biotechnology clinical trial outcomes require deep domain expertise to interpret. This opacity gives founders greater scope to manipulate performance metrics. At the same time, these technologies require founders to integrate expertise across multiple domains, making managerial skill development more challenging. From Proposition 5, we obtain the following prediction.

Prediction 4 *Ventures with more opaque performance metrics or more costly managerial skill development exhibit smaller exit packages, more manipulation, and less frequent founder replacement.*

Testing this prediction requires comparing ventures with similar capital requirements but different levels of metric opacity. Among ventures with comparable capital requirements, those in sectors where performance is harder to evaluate—such as AI and drug development—should exhibit smaller exit packages and lower founder replacement rates than ventures in sectors with more transparent metrics.

5.5 Staged financing

The staged financing setting (Section 4) reinterprets the model as a termination problem: instead of replacing the founder, the investor decides whether to continue or shut down the venture.

Prediction 5 *Ventures with higher initial capital requirements, lower internal assets, or larger follow-on investments exhibit greater distortion of interim performance metrics, increasing the likelihood that low-quality ventures receive follow-on funding.*

Guedj and Scharfstein (2004) study clinical trial decisions in the biopharmaceutical industry, a prominent example of staged financing where each phase of clinical trials requires a decision whether to fund the next stage. They find that single-product firms advance drug candidates to the next phase of clinical trials at significantly higher rates than mature firms with diversified drug portfolios, but the candidates they advance are much less likely to succeed in subsequent trials. Single-product firms thus have a higher probability of continuing projects that turn out to be low quality. This pattern is consistent with the model: mature firms generate substantial product revenue, giving them large internal assets (A) and a smaller financing gap. Firms without product revenue must finance clinical trials entirely with external capital, tightening the financing constraint. The tighter constraint leads to contracts that give founders stronger incentives to manipulate performance metrics, distorting the interim signals that investors use to identify low-quality projects.

Ewens et al. (2018) document a related pattern across a broader set of industries. Following the introduction of cloud computing in 2006, which substantially reduced the cost of starting internet-based ventures, VCs shifted toward a "spray and pray" investment strategy: they funded more startups with smaller initial investments, and were more likely to abandon ventures after the initial round of funding. Ewens et al. (2018) attribute this shift to the value of abandonment options. When initial experiments are cheaper, it becomes profitable to fund riskier "long shot" ventures that are more likely to fail at the interim stage, triggering their abandonment. The present model provides an alternative contracting-based channel: lower capital requirements relax the financing constraint, permitting contracts that reduce manipulation incentives. This makes interim signals more informative, enabling VCs to identify and terminate low-quality ventures more frequently. The two channels are complementary but operate through different mechanisms. In the real options channel, VCs fund riskier ventures that fail more often, increasing the frequency of termination; in the contracting channel, less manipulation makes interim signals more informative, improving the termination decision itself.

6 Conclusion

This paper studies how founders' ability to manipulate performance metrics interacts with financing constraints to shape financial contracts, founder replacement, and access to capital. The central insight is that manipulation in equilibrium is not a failure of contract design but a rational response to financing constraints. Unconstrained founders eliminate manipulation incentives through generous exit packages that make them willing to relinquish control. Constrained founders cannot afford such packages because they leave insufficient pledgeable income to satisfy investors. These founders must accept smaller exit packages that strengthen their incentives to manipulate performance metrics, making it harder for investors to identify and replace underperforming founders. As a result, financing constraints lead to too little founder replacement—the necessary cost of making valuable projects financeable. This contrasts with standard financial contracting models, in which financing constraints require the entrepreneur to permit excessive liquidation or termination (Bolton and Scharfstein 1990; Aghion and Bolton 1992; Hart and Moore 1998).

The framework extends to staged financing, where investors decide whether to provide follow-on capital rather than replace the founder. The standard argument for staging is that it gives investors the option to terminate underperforming ventures at each funding stage. The model shows that manipulation undermines this benefit: founders distort the interim signals that investors use for follow-on financing decisions, degrading the information that makes staging valuable. Tighter financing constraints do not improve the refinancing decision but worsen it, because they necessitate contracts that induce more manipulation and further distort interim signals.

The analysis generates several testable predictions. Lower capital requirements—such as those from the adoption of cloud computing—lead to larger exit packages, less manipulation, and more frequent founder replacement. Wealthier founders are also replaced more frequently, not because wealth leads to better governance, but because it relaxes the financing constraint and permits more generous exit packages. The model also predicts that the same founder, facing the same board, departs voluntarily when financially unconstrained and involuntarily when constrained. Finally, the model offers a contracting-based explanation for the findings of Ewens et al. (2018), who document that venture capitalists terminated more startups after cloud computing reduced initial capital requirements. They attribute this to a real options channel: cheaper experiments make it profitable to fund riskier ventures that fail more often. The present paper provides a complementary channel: lower capital requirements allow for contracts that reduce manipulation incentives, improving the interim information on which termination decisions are based.

Appendix

Proof of Proposition 1. When $\lambda_{PC} = 0$ and $\lambda_{IC} = 0$, the founder's utility depends on the contract payments only through the manipulation level $m(a_h)$. Taking the derivative of the Lagrangian with respect to Y_r yields

$$\frac{dL}{dY_r} = \frac{dW}{dm(a_h)}\frac{dm(a_h)}{dY_r} > 0, \tag{8}$$

where

$$\frac{dW}{dm(a_h)} = -(1-a_h)(X_r - X_l - B) - km(a_h) < 0 \tag{9}$$

by A1 and $\frac{dm(a_h)}{dY_r} < 0$. Since L is increasing in Y_r, the founder sets Y_r to its maximum $B + Y_l$ (Lemma 1(iv)), which eliminates manipulation for any $Y_l \geq 0$. This establishes parts (i) and (ii) of the proposition. Since $m = 0$ regardless of k, the cost of manipulation is irrelevant, establishing part (iii). With $m = 0$, the replacement rate is $\phi(a_h) = 1 - a_h$, and since $Y_r = B + Y_l$, the founder is indifferent between remaining and departing, so replacement is voluntary, establishing part (iv). The threshold I^U is obtained by setting $Y_l = 0$—which maximizes pledgeable income (Proposition 2(i))—substituting $Y_r = B$ and $m = 0$ into the binding participation and incentive compatibility constraints, and solving for I. □

Proof of Proposition 2. *Part (i).* To maximize pledgeable income, the payments (Y_h, Y_l, Y_r) solve:

$$\begin{aligned}\underset{Y_h,Y_l,Y_r}{\text{Max}} \quad & \Theta = a_h\left(q\left(X_h - Y_h\right) + (1-q)\left(X_l - Y_l\right)\right) \\ & +(1-a_h)\left(m(a_h)(X_l - Y_l) + (1-m(a_h))(X_r - Y_r)\right) \\ & -\lambda_{IC}\{C - (a_h - a_l)\left(qY_h + (1-q)Y_l + B\right)\end{aligned} \tag{10}$$

$$-(1-a_h)(m(a_h)(B+Y_l)+(1-m(a_h))Y_r)+0.5km(a_h)^2$$
$$+(1-a_l)(m(a_l)(B+Y_l)+(1-m(a_l))Y_r)-0.5km(a_l)^2\},$$

where λ_{IC} is the Lagrangian multiplier associated with the incentive compatibility constraint (3). Taking the first derivatives with respect to Y_h, Y_l, and Y_r yields

$$\begin{aligned} \frac{d\Theta}{dY_h} &= -a_h q + \lambda_{IC}(a_h - a_l)q = 0 \\ &\Rightarrow \quad \lambda_{IC} = \frac{a_h}{a_h - a_l}, \end{aligned} \tag{11}$$

$$\begin{aligned} \frac{d\Theta}{dY_l} &= -a_h(1-q) - (1-a_h)m(a_h) \\ &\quad - (1-a_h)\left((X_r - Y_r) - (X_l - Y_l)\right)\frac{dm(a_h)}{dY_l} \\ &\quad + \lambda_{IC}\{(a_h - a_l)(1-q) + (1-a_h)m(a_h) - (1-a_l)m(a_l)\}, \end{aligned} \tag{12}$$

$$\begin{aligned} \frac{d\Theta}{dY_r} &= -(1-a_h)(1-m(a_h)) + (1-a_h)\left((X_l - Y_l) - (X_r - Y_r)\right)\frac{dm(a_h)}{dY_r} \\ &\quad - \lambda_{IC}\{(1-a_l)(1-m(a_l)) - (1-a_h)(1-m(a_h))\}. \end{aligned} \tag{13}$$

Equation (11) shows that the incentive compatibility constraint (3) cannot be slack because if it was, then $\lambda_{IC} = 0$, and the reward Y_h that maximizes Θ would be zero, which violates (3). Thus, Y_h^F is just high enough to satisfy (3) as an equation.

Substituting $\lambda_{IC} = \frac{a_h}{a_h - a_l}$ from (11) into (12) and (13) yields

$$\begin{aligned} \frac{d\Theta}{dY_l} &= \Omega_l \equiv -(1-a_h)m(a_h) \\ &\quad -(1-a_h)\left((X_r - Y_r) - (X_l - Y_l)\right)\frac{dm(a_h)}{dY_l} \end{aligned} \tag{14}$$

$$-a_h \frac{(1-a_l)m(a_l) - (1-a_h)m(a_h)}{a_h - a_l} < 0,$$

and

$$\begin{aligned} \frac{d\Theta}{dY_r} &= \Omega_r \equiv -(1-a_h)(1-m(a_h)) \\ &\quad -(1-a_h)\left((X_r - Y_r) - (X_l - Y_l)\right) \frac{dm(a_h)}{dY_r} \\ &\quad -a_h \frac{(1-a_l)(1-m(a_l)) - (1-a_h)(1-m(a_h))}{a_h - a_l}, \end{aligned} \tag{15}$$

where the three terms of (14) are each negative: the first because $m(a_h) \geq 0$; the second because $(X_r - Y_r) - (X_l - Y_l) > 0$ by A1 and $Y_r - Y_l \leq B$ and $\frac{dm(a_h)}{dY_l} = (1-a_h)/k > 0$; and the third because $(1-a)m(a) = (1-a)^2(B + Y_l - Y_r)/k$ is decreasing in a, so $(1-a_l)m(a_l) > (1-a_h)m(a_h)$. Therefore $Y_l^F = 0$.

Part (ii). Substituting $Y_l = 0$ and the Y_h that satisfies the binding incentive compatibility constraint (3) into the investors' participation constraint (4) yields the maximum income pledgeable to investors as a function of the exit package Y_r:

$$\begin{aligned} \Pi(Y_r) &= a_h \left(qX_h + (1-q) X_l\right) \\ &\quad +(1-a_h)\left(m(a_h)X_l + (1-m(a_h))(X_r - Y_r)\right) \\ &\quad -a_h \left(\frac{\Upsilon(a_l) - \Upsilon(a_h) + C}{(a_h - a_l)} - B \right). \end{aligned} \tag{16}$$

Taking the first derivative of Π with respect to Y_r yields

$$\begin{aligned} \frac{d\Pi(Y_r)}{dY_r} &= -(1-a_h)\left(X_r - Y_r - X_l\right) \frac{dm(a_h)}{dY_r} \\ &\quad -(1-a_h)(1-m(a_h)) \\ &\quad -a_h \frac{(1-a_l)(1-m(a_l)) - (1-a_h)(1-m(a_h))}{(a_h - a_l)}. \end{aligned} \tag{17}$$

For $Y_l = 0$, Ω_r in (15) leads to $\frac{d\Pi(Y_r)}{dY_r}$ in (17). To show that $\Pi(Y_r)$ is concave in Y_r, take the second derivative, which yields

$$\frac{d^2\Pi(Y_r)}{dY_r^2} = 2(1-a_h)\frac{dm(a_h)}{dY_r} + a_h\left(\frac{(1-a_l)\frac{dm(a_l)}{dY_r} - (1-a_h)\frac{dm(a_h)}{dY_r}}{(a_h - a_l)}\right) < 0. \quad (18)$$

This is negative because $\frac{dm(a_h)}{dY_r} = -(1-a_h)/k < 0$ and $\frac{dm(a_l)}{dY_r} = -(1-a_l)/k < 0$.

Case $k < k_1$. To determine the threshold k_1, suppose that $Y_r = B$, which implements $m(a_h) = m(a_l) = 0$. The derivative in (17) then simplifies to

$$\frac{d\Pi(Y_r)}{dY_r} = -1 + (1-a_h)^2 (X_r - B - X_l)/k. \quad (19)$$

The strength of the manipulation effect (second term in (19)) depends on the cost of manipulation k. If k is small, an increase in the exit package leads to a strong decline in manipulation, which strongly increases Π. There is a threshold k_1 defined by $\frac{d\Pi(Y_r=B)}{dY_r} = 0$, such that for all $k < k_1$, reducing the exit package below $Y_r = B$ reduces pledgeable income. Since Π is concave, if a decline in Y_r decreases Π for $Y_r = B$, then a decline in Y_r decreases Π for all $Y_r \leq B$. As a result, if $k < k_1$, then $Y_r = B$ maximizes pledgeable income.

Case $k > k_2$. Substituting $Y_r = 0$ and $m(a) = (1-a)B/k$ into (17) and simplifying yields

$$\frac{d\Pi(Y_r)}{dY_r} = -1 + m(a_h) + a_h m(a_l) + (1-a_h)^2 (X_r - X_l)/k. \quad (20)$$

There is a threshold k_2 determined by $\frac{d\Pi(Y_r=0,k=k_2)}{dY_r} = 0$, such that $\frac{d\Pi(Y_r=0,k)}{dY_r} < 0$ for all $k > k_2$. Since Π is concave, if Π decreases in Y_r for $Y_r = 0$, then Π decreases in Y_r for all $Y_r > 0$. As a result, for $k > k_2$, $Y_r = 0$ maximizes pledgeable income.

Case $k \in (k_1, k_2)$. From the previous two cases it follows that if $k \in (k_1, k_2)$, the pledgeable income Π is an inverted U-shaped function of Y_r. Thus, the exit package Y_r^F that maximizes Π is an interior value determined by $\frac{d\Pi(Y_r^F)}{dY_r} = 0$, which yields

$$Y_r^F = \frac{-k + (1 - a_l a_h) B + (1 - a_h)^2 (X_r - X_l)}{(1 - a_l a_h) + (1 - a_h)^2} \in (0, B). \tag{21}$$

Substituting Y_r^F into the manipulation function yields

$$m(a_h) = (1 - a_h) \frac{1 - (X_r - B - X_l)(1 - a_h)^2 / k}{(1 - a_h)^2 + 1 - a_h a_l} > 0, \tag{22}$$

$$m(a_l) = (1 - a_l) \frac{1 - (X_r - B - X_l)(1 - a_h)^2 / k}{(1 - a_h)^2 + 1 - a_h a_l} > 0. \tag{23}$$

Part (iii). Since Y_r^F maximizes pledgeable income, the founder can raise capital as long as I does not exceed $\overline{I} \equiv \Pi(Y_r^F)$. Furthermore, given $k > k_1$, the fact that reducing the exit package below B increases pledgeable income Π implies that $\overline{I} > I^U$. $\square$

Proof of Proposition 3. *Part (i).* When $k < k_1$, we know from Proposition 2(ii) that $Y_r = B$ maximizes pledgeable income Π. This immediately implies that financially constrained founders ($I > I^U$) cannot attract capital if $k < k_1$.

Part (ii). I derive the optimal financial contract for $k > k_1$ and $I \in [I^U, \overline{I})$, where $\overline{I}$ is the maximum amount of capital the founder can raise and is determined in Proposition 2. The Lagrangian of the problem is

$$\begin{aligned} L &= W - \lambda_{IC}\{C - (a_h - a_l)(qY_h + (1 - q) Y_l + B) - \Upsilon(a_h) + \Upsilon(a_l)\} \\ &\quad -\lambda_{PC}\{I - a_h (q (X_h - Y_h) + (1 - q)(X_l - Y_l)) \\ &\quad -(1 - a_h)(m(a_h)(X_l - Y_l) + (1 - m(a_h))(X_r - Y_r))\}, \end{aligned} \tag{24}$$

where $\lambda_{IC} \geq 0$ and $\lambda_{PC} \geq 0$ are the Lagrangian multipliers of the founder's incentive compatibility constraint (3) and investors' participation constraint (4), respectively.

Given $I > I^U$, the investors' break-even constraint is binding and has a strictly positive shadow price $\lambda_{PC} > 0$. Taking the first derivative of the Lagrangian in (24) with respect to Y_h yields

$$\frac{dL}{dY_h} = \left(\lambda_{IC}(a_h - a_l) - \lambda_{PC} a_h\right) q = 0,$$

implying that the incentive compatibility constraint is also binding, $\lambda_{IC} = \lambda_{PC} \frac{a_h}{a_h - a_l} > 0$, and hence $Y_h^* = Y_h^F$, where Y_h^F is determined in the proof of Proposition 2.

Using $\lambda_{IC} = \lambda_{PC} \frac{a_h}{a_h - a_l}$, the first derivative of the Lagrangian with respect to Y_r can be written as

$$\frac{dL}{dY_r} = \frac{dW}{dm(a_h)} \frac{dm(a_h)}{dY_r} + \lambda_{PC} \Omega_r = 0, \tag{25}$$

where Ω_r is defined in (15).

Y_r^* is the highest level for which the investors' break-even constraint is satisfied, and solves

$$\Pi(Y_r^*, k) = I. \tag{26}$$

As long as $Y_r < Y_r^*$, the shadow price is zero, $\lambda_{PC} = 0$, which implies that $\frac{dL}{dY_r} > 0$ in (25) and increasing Y_r is optimal. The founder increases Y_r until $Y_r = Y_r^*$. Any further increase in Y_r is not feasible because it would violate the investors' break-even constraint. For $Y_r = Y_r^*$, the equation $\frac{dL}{dY_r} = 0$ in (25) determines the equilibrium shadow price $\lambda_{PC}^* > 0$, which captures the rate with which the founder's ex ante utility increases as the capital requirement I decreases.

There are potentially two values of Y_r that satisfy $\Pi(Y_r^*, k) = I$. One lies below and one above the level that maximizes pledgeable income Y_r^F determined in (21).

Only the higher value is optimal because it causes a lower level of manipulation. Formally, since $\lambda_{PC} > 0$ and $\frac{dW}{dm(a_h)} \frac{dm(a_h)}{dY_r} > 0$ (because $\frac{dW}{dm(a_h)} < 0$ and $\frac{dm(a_h)}{dY_r} < 0$), the equation in (25) implies that $\frac{\partial \Pi(Y_r^*)}{\partial Y_r} < 0$, where $\frac{\partial \Pi(Y_r^*)}{\partial Y_r}$ is given in (17). Because $\Pi(Y_r, k)$ is concave in Y_r (see (18)) and has a maximum at Y_r^F, $\frac{\partial \Pi(Y_r^*)}{\partial Y_r} < 0$ implies $Y_r^* > Y_r^F$.

Using $\lambda_{IC} = \lambda_{PC} \frac{a_h}{a_h - a_l}$, the first derivative of the Lagrangian in (24) with respect to Y_l is

$$\frac{dL}{dY_l} = \frac{dW}{dm(a_h)} \frac{dm(a_h)}{dY_l} + \lambda_{PC} \Omega_l < 0, \tag{27}$$

where Ω_l is defined in (14). Both terms are negative: the first because $\frac{dW}{dm(a_h)} < 0$ and $\frac{dm(a_h)}{dY_l} > 0$, and the second because $\lambda_{PC} > 0$ and $\Omega_l < 0$. Hence the founder's optimal reward in the case of low cash flows is zero, $Y_l^* = 0$. Since $\Pi(B) = I^U < I$, the exit package $Y_r = B$ is infeasible, so $Y_r^* < B$. With $Y_l^* = 0$, the manipulation formula (1) yields $m(a_h) > 0$, and the replacement probability $\phi(a_h) = (1 - a_h)(1 - m(a_h)) < 1 - a_h$, confirming that constrained founders engage in equilibrium manipulation and are replaced less frequently than unconstrained founders. □

Proof of Proposition 4. From Proposition 3, $Y_l^* = 0$ and Y_r^* solves

$$\Phi \equiv \Pi(Y_r^*) - I = 0, \tag{28}$$

with $\frac{\partial \Pi(Y_r^*)}{\partial Y_r} < 0$ (since $Y_r^* > Y_r^F$). Applying the implicit function theorem with respect to I yields

$$\frac{dY_r^*}{dI} = -\frac{\partial \Phi}{\partial I} \Big/ \frac{\partial \Phi}{\partial Y_r} = 1 \Big/ \frac{\partial \Pi(Y_r^*)}{\partial Y_r} < 0,$$

so Y_r^* increases as I declines, establishing part (i). Since $\frac{dm(a_h)}{dY_r} = -(1 - a_h)/k < 0$, a larger Y_r reduces manipulation, establishing part (ii), and raises the replacement frequency $\phi(a_h) = (1 - a_h)(1 - m(a_h))$, establishing part (iii). Since a founder with assets A needs to raise $I - A$ in external capital, an increase in A is equivalent to a decrease in I, so the same comparative statics apply. $\square$

Proof of Proposition 5. From Proposition 3, $Y_l^* = 0$ and $\frac{\partial \Pi(Y_r^*, k)}{\partial Y_r} < 0$. Applying the implicit function theorem on (28) with respect to k and C yields

$$\frac{dY_r^*}{dk} = -\frac{\frac{\partial \Pi(Y_r, k)}{\partial k}}{\frac{\partial \Pi(Y_r, k)}{\partial Y_r}} \tag{29}$$

$$= -\frac{-(1-a_h)\left(X_r - Y_r - X_l\right)\frac{dm(a_h)}{dk} + a_h \frac{0.5m(a_l)^2 - 0.5m(a_h)^2}{(a_h - a_l)}}{\frac{\partial \Pi}{\partial Y_r}} > 0,$$

$$\frac{dY_r^*}{dC} = -\frac{\frac{\partial \Pi}{\partial C}}{\frac{\partial \Pi}{\partial Y_r}} = -\frac{-\frac{a_h}{a_h - a_l}}{\frac{\partial \Pi}{\partial Y_r}} < 0. \tag{30}$$

The numerator of dY_r^*/dk is positive because $\frac{dm(a_h)}{dk} < 0$ and $m(a_l) > m(a_h)$, and the denominator $\frac{\partial \Pi}{\partial Y_r} < 0$, so $dY_r^*/dk > 0$. For dY_r^*/dC, the numerator $\frac{\partial \Pi}{\partial C} = -\frac{a_h}{a_h - a_l} < 0$ and the denominator is negative, so $dY_r^*/dC < 0$.

Using $m(a_h) = (1 - a_h)\frac{B - Y_r^*}{k}$, we obtain

$$\frac{dm(a_h)}{dk} = -(1-a_h)\left(\frac{B - Y_r^*}{k^2} + \frac{dY_r^*}{dk}\frac{1}{k}\right) < 0, \tag{31}$$

$$\frac{dm(a_h)}{dC} = -(1-a_h)\frac{dY_r^*}{dC}\frac{1}{k} > 0, \tag{32}$$

where $dm(a_h)/dk < 0$ because both $\frac{B - Y_r^*}{k^2} > 0$ and $\frac{dY_r^*}{dk}\frac{1}{k} > 0$, and $dm(a_h)/dC > 0$ because $dY_r^*/dC < 0$. Since $\phi(a_h) = (1 - a_h)(1 - m(a_h))$, we have $d\phi/dk = -(1 - a_h)\frac{dm}{dk} > 0$ and $d\phi/dC = -(1 - a_h)\frac{dm}{dC} < 0$. $\square$

Proof of Proposition 6. The staged financing constraint is

$$\Pi(Y_r) \geq I + (a_h + (1 - a_h)m(a_h))I_2, \tag{33}$$

where $\Pi(Y_r)$ is the pledgeable income defined in (16), which is evaluated at $Y_l = 0$ (the argument for $Y_l^F = 0$ in Proposition 2(i) applies unchanged, since the follow-on investment affects the right-hand side of the participation constraint but not the optimization over (Y_h, Y_l, Y_r)). Define net pledgeable income as $\hat{\Pi}(Y_r) \equiv \Pi(Y_r) - (a_h + (1 - a_h)m(a_h))I_2$, so the constraint becomes $\hat{\Pi}(Y_r) \geq I$. Since $m(a_h)$ is linear in Y_r (given $Y_l = 0$), $\hat{\Pi}$ inherits the strict concavity of Π. The optimal Y_r^* is the rightmost solution to $\hat{\Pi}(Y_r^*) = I$, where $\frac{d\hat{\Pi}}{dY_r} < 0$ (by the same argument as in Proposition 3). Applying the implicit function theorem,

$$\frac{dY_r^*}{dI_2} = -\frac{\partial\hat{\Pi}/\partial I_2}{d\hat{\Pi}/dY_r} = -\frac{-(a_h + (1 - a_h)m(a_h))}{d\hat{\Pi}/dY_r} < 0,$$

since $a_h + (1 - a_h)m(a_h) > 0$ and $\frac{d\hat{\Pi}}{dY_r} < 0$. A smaller termination payment increases manipulation, $\frac{dm(a_h)}{dY_r} < 0$, which raises the probability that the venture continues despite $\omega = \omega_l$. □

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