Creating Intangible Capital

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Abstract

We propose a framework in which intangible capital is created by the joint investment of firm resources and skilled human capital, reducing ex-ante investment spending. Firms must offer deferred compensation to retain employees, creating unhedgeable risk. A human capital retention motive for financial prudence thus arises also absent traditional precautionary motives. Insuring unvested claims requires more net cash in good states, equity rather than debt financing and payouts via repurchases rather than dividends. As intangibles can be easily diverted, firms need more inside equity, especially under high compensation overhang. The model sheds new light on several recent trends in corporate financing.

Keywords. Technological change, intangible assets, cash holdings, human capital, corporate leverage, equity grants, deferred equity, share vesting.

JEL classifications. G32, G35, J24, J33

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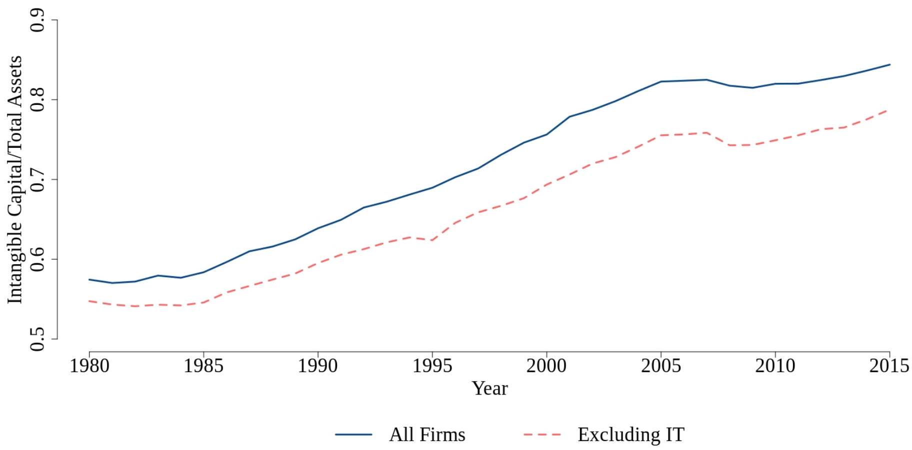
1. Introduction

Technological advances since 1980 have transformed corporate investment, leading to a rising share of intangible assets relative to physical plant and other tangible capital (Corrado and Hulten, 2010). This shift in asset composition (see Figure 1) concurs with some puzzling trends, such as a decline in tangible investment and in its correlation with measures of expected profitability (Gutiérrez and Philippon, 2017).

Figure 1: Growth of Intangibles to Total Capital



Firms with a higher ratio of intangible capital may be more financially constrained because their assets are less pledgeable (e.g. Rampini and Viswanathan, 2013) or they face higher costs of financial distress (Opler et al., 1999). Empirical evidence is consistent with a reduced debt capacity (Bates et al., 2009), pointing to a need for a prudent financial policy. Indeed as intangible assets have risen, net corporate leverage has fallen across a wide range of sectors (Falato et al., 2018; Pinkowitz et al., 2016; Graham and Leary, 2018). Yet there has been no compensating rise in equity flows to firms with the highest growth opportunities (Lee et al., 2018), suggesting a decline in financing needs.

This paper offers a fundamental framework for intangible capital creation, described broadly as a joint investment of firm resources and talented human capital. Successful companies rely on advanced capabilities developed by talented employees for a wide range of modern tasks, such as product design, data analysis, software development, innovative distribution, and brand marketing (Eisfeldt and Papanikolaou, 2013). Building on this insight, the model provides a novel rationale for low measured investment and external financing demand, and predicts that firms adopt a prudent financial policy even in the absence of classic precautionary motives.

While firms directly acquire physical and some intangible assets,[1] they cannot own human capital. Employees are free to leave (Hart and Moore, 1994) once they have developed some intangible capital within the firm for a better outside option (Ashwini and Matsa, 2013; Babina, 2016). Ensuring the commitment of human capital thus requires some form of deferred compensation, such as tenure, career prospects, or time-vesting shares. As a result, while intangible investment is indeed difficult to fund externally, it is largely self-financed as the bulk of compensation for the human capital component is deferred.

These insights are consistent with the evolution of free cashflow and financing over time and across firms. High-intangibles (henceforth HINT) firms generate similar pre-investment cashflows as low-intangibles (LINT) firms, yet since 1980 they have enjoyed considerable free cashflow thanks to lower total investment spending (see Figure 2). While traditional LINT firm outlays historically required external financing, HINT firms spend less than 85% of the cash they generate.

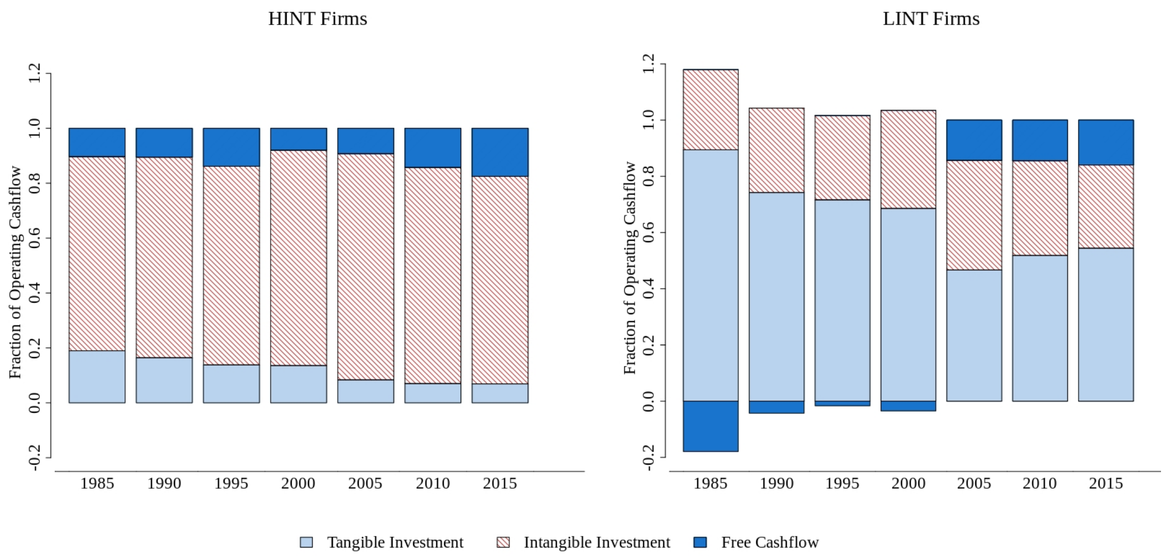
We analyse these insights in a three-period model in which a firm insider with access to a project contracts with risk-neutral outside investors and a risk-averse employee. The firm's investment is characterized by its technological reliance on tangible versus intangible capital. Intangible investment requires less upfront spending by the firm as it is supported by the employee's human capital. While tangible collateral is easily assessed and can be reliably assigned to outsiders, spending on intangibles is hard to observe and may be diverted for private benefit.

At the interim period the firm may face a net financing need for re-investment (Holmstrom and Tirole, 1998), and also must ensure retention of its critical human capital (Oyer, 2004). Precautionary and retention motives shape financial and compensation policies, which in turn affect insider moral hazard on intangible investment.

The baseline model abstracts from external financing. To retain the employee, the firm insider offers the bulk of compensation in the form of deferred equity that fully vests only in the

[1] Firms can directly establish property rights on a few intangible assets, such as patents and licenses.

Figure 2: Cash Flow Use for Across Firms and Over Time



final period after output is realized. While fixed deferred wages provide better insurance to risk-averse employees, they leave high rents in bad states of the world, where outside options are weak. Stock compensation reduces those rents as it is correlated with industry performance and hence the value of outside options (Oyer, 2004). The firm insider chooses the optimal compensation by trading off these two forces.

A key result is that the firm can provide insurance to reduce the cost of human capital by hoarding safe resources (cash) and avoiding risky debt. The employee's stock compensation is a risky claim that cannot be hedged, as personal income cannot be insured. Thus a conservative financial policy increases the utility value of locked-in unvested claims for a risk-averse employee. Hence, the model suggests a *retention motive* for a prudent financial policy, distinct from the traditional *precautionary motive* associated with the lower debt capacity of intangible assets.

Interestingly, the need to retain human capital makes cash particularly valuable for HINT firms in good states. This contrasts with the traditional view of precautionary savings as insuring against spending needs in low states. In fact, the model shows that negative leverage may be optimal even for firms without precautionary needs, and it rationalizes the puzzling observation that highly successful innovative firms appear to hoard the most cash (Begenau and Palazzo, 2017; Pinkowitz et al., 2016; Graham and Leary, 2018). This motive is particularly strong for firms with a lot of intangible investment.

It is well understood that a prudent financial structure may cause moral hazard (Jensen, 1986). In our setup, this can occur even in the absence of external financing. Diversion wastes resources and reduces future project payoffs, but it also encourages skilled employees to depart before their claims vest, thus undoing dilution of the insider's stake. This *compensation overhang* effect is pronounced among firms that rely more on human capital and is binding whenever unvested grants claim a larger share of firm value. In these circumstances insiders need to offer even more stock compensation, which reduces diversion incentives by lowering employees' rents in bad states where moral hazard is binding, but at the cost of paying a larger risk premium.

Corporate governance concerns become pressing when insiders do not have sufficient resources (inside equity) to fund the optimal investment plan. An extension studies the effect of debt and external equity on risk bearing and moral hazard. Debt secured by tangible assets can help financing precautionary needs. However, debt does not support employee retention because it is senior to unvested compensation. In fact, risky debt is counter-productive because it increases the volatility of the employee's equity claim and hence the cost of compensation.

External equity provides insurance to human capital, but a large outside stake may lead insiders to divert resources. Moral hazard concerns are particularly strong if the human capital contribution is large and competition for talent is strong.[2] As a result, HINT firms require deep-pocketed insiders to avoid a conflict between insuring employees and controlling insider moral hazard. This result is consistent with the growing role of venture capitalists and private equity investors in financing innovative firms, and with their active role during a firm's critical growth or transition phases.

In the basic model the firm has full bargaining power in the ex-ante negotiation with human capital. Yet compensation may not be renegotiation proof, since an employee can demand a greater share of surplus once intangible capital has been created. We address this in an extension, recognizing that in reality a firm has an indefinite sequence of projects. In a dynamic

[2] A distinct effect is that risky debt produces worse incentives for inside diversion than outside equity, as it increases compensation overhang. This is particularly true when the value of the human capital contribution is large.

repeated-game setup, the firm typically benefits from maintaining a commitment to refuse renegotiation, even if this leads to occasional employee turnover. The firm can also build a reputation for commitment by choosing a corporate payout policy that respects unvested claims. While dividends reduce the value of deferred compensation, (fairly priced) share repurchases avoid diluting unvested claims. Indeed, HINT firms prefer repurchase over dividends more than LINT firms do (see Figure 5). Thus corporate reputation is a valuable corporate-owned intangible asset, particularly for HINT firms.

Finally we briefly consider a strategic cause for financial caution by HINT firms that are exposed to the risk of disruptive entry, especially since retention relies on deferred equity compensation. Entry may raise competition for talent while causing an incumbent firm's stock price to drop, undermining retention. Incumbents can reduce the risk of talent poaching by preventatively acquiring the entrant, yet this may be difficult to fund externally when the firm's competitive position is under pressure. This creates a strategic motive for holding cash and recasts precautionary savings in the specific context of intangible investment.

The paper contributes to a growing literature on intangible investment and human capital. First, it offers a demand-driven explanation for several recent trends associated with intangibles, such as weak measured investment (Gutiérrez and Philippon, 2017) and the decrease in external financing flows to firms with the highest Tobin's Q values (Lee et al., 2018). In contrast to existing work, the model builds on the noncontractual nature of human capital as well as the displacement of tangible assets, a concept related to work on physical labor substitution (Acemoglu and Autor, 2011). Second, our approach describes a novel dual moral hazard problem by both insiders and employees that is inherent to intangible capital creation. The analysis clarifies why HINT firms require more inside unvested equity, and it identifies a new compensation overhang effect among firms with the most talented employees. A third, broader implication is that the traditional dichotomy between capital and labor is hard to apply to HINT firms. Their financial statements also have reduced accuracy, as common accounting metrics do not properly measure the amount of human capital investment or the value of unvested claims.

Several authors offer related insights on human capital and finance. Berk et al. (2010) show that maintaining low leverage allows a firm to insure its employees against the human cost of bankruptcy, as it reduces the likelihood of financial distress. We complement their work by endogenizing risk exposure and identifying an insurance mechanism outside of distress. Acharya et al. (2011) show that firms must retain internal resources to incentivize future managers, adding an insurance motive and a full analysis of optimal asset financing. A distinctive result of our paper is that HINT firms may face a unique form of overhang, as they need to commit much future value to employees and this may exacerbate insider moral hazard.

Bolton et al. (2019) show that an entrepreneur's ability to hedge idiosyncratic firm risk may be constrained by the inalienability of her human capital, explaining why insider-owned firms hold cash. In Sun and Xiaolan (2018) firms finance investment through delayed compensation, which crowds out future debt capacity and exacerbates precautionary needs. Our model nests many of these papers' results, in a setup with insider moral hazard, risk-averse employees with inalienable human capital, and outside financiers. Importantly, in our view employees are co-investors, explaining lower external financing *demand* as intangible investment substitutes physical assets.

Our setup relates a firm's debt capacity to asset tangibility. In contrast to Falato et al. (2018), we do not impose a collateral constraint that requires debt to be backed by tangible assets. Instead, the firm's ability to raise external financing is limited because insiders can divert intangible spending for their own private benefit, similar to Rampini and Viswanathan (2010) and Rampini and Viswanathan (2013). However, in our model this moral hazard problem can bind even absent any external financing, as the firm promises some future cashflows to employees.

Section 2 presents motivating facts. Section 3 presents the basic model and core results. Section 4 considers external equity and debt financing, the dynamic extension and the strategic motive for cash. Section 5 briefly discusses implications for measuring investment and evaluating firm performance. Proofs and detailed model solutions are in the Appendix.

2. Motivating Evidence

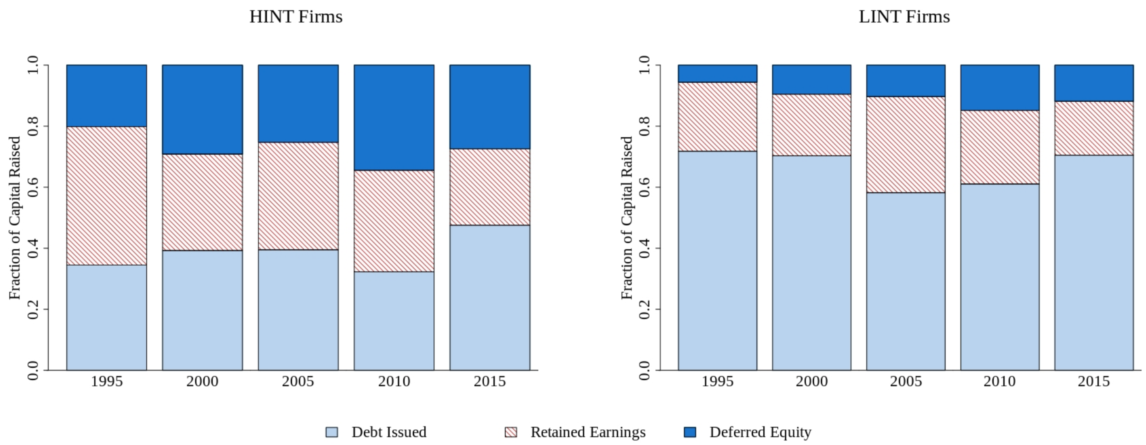
This section presents several new empirical facts about intangibles and their relation to recent corporate finance developments. Data are presented for a sample of listed U.S. firms used by

Bates et al. (2009).[3] Intangible assets are measured following Eisfeldt and Papanikolaou (2013) and Peters and Taylor (2017). Appendix A describes the data in detail.

Fact 1. HINT firms have lower investment outlays. Figure 2 (presented above) plots the median HINT and LINT firms' investment outlays and free cashflows across five-year intervals. Outlays are separated into capital expenditures and firm spending on intangibles. All variables are scaled by operating (pre-investment) cashflows to control for differences in profitability. The figure shows that HINT firms consistently spend less of their incoming cash on investment than LINT firms, but the distinction has become increasingly less marked over time. As reliance on human capital spreads across sectors, capital expenditures and total investment spending have fallen over time across all firms.

Importantly, lower investment spending by HINT firms is not due to lack of profitability. In fact, during the sample period the median HINT firm is slightly more profitable than the median LINT firm on a pre-investment basis. Since 1980 its operating cashflows have ranged from 18 to 26% of total assets, compared to 17 to 20% for LINT firms.

Figure 3: Intangibles Usage and Sources of Financing



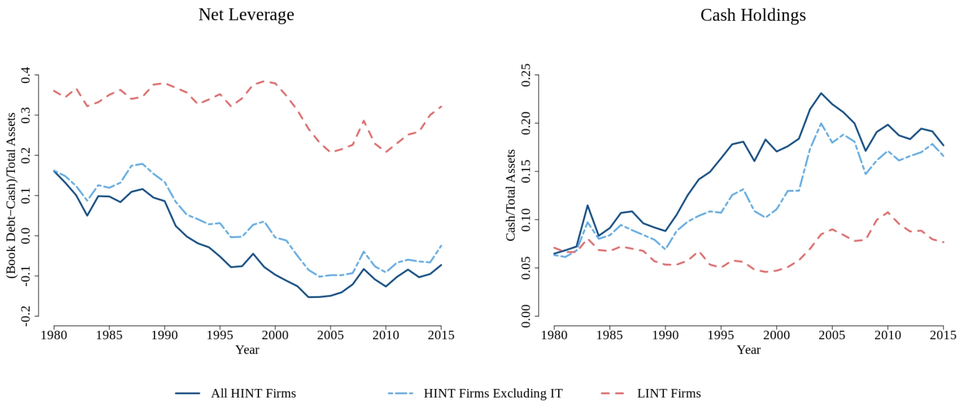
Fact 2. HINT firms use less external financing and more deferred equity. Figure 3 shows that HINT firms raise significantly less debt than LINT firms. In its place,

[3] The sample contains U.S. non-financial and utilities firms in Compustat, excluding those with total assets below $5 million.

innovative firms grant to their employees a significant amount of deferred equity, with expected market value equal to about 30% of total annual financing. In contrast, employee equity grants amount to 12% of capital raised by LINT firms, though this percentage has grown over time.

Retained earnings (a form of capital implicitly raised from external shareholders) are similar across HINT and LINT firms, while net debt issuance is twice as small. This latter fact is consistent with the decline in external financing among high-Q firms (Lee et al. (2018)), many of which also have high intangibles usage.

Figure 4: Intangibles Usage, Net Leverage, and Cash Holdings

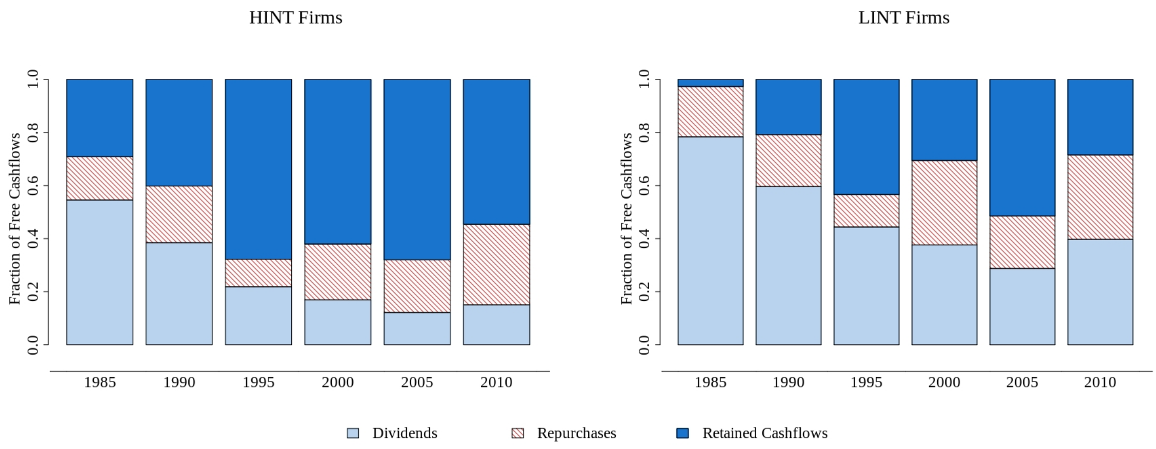


Fact 3. HINT firms maintain lower net leverage. Figure 4 plots the evolution of net leverage over time for the median HINT and LINT firm, and separately for HINT firms outside IT-related sectors. In each year, HINT firms are defined as those with a ratio of intangibles to total assets in the highest tercile, while LINT firms are in the lowest tercile.

HINT firms consistently maintained lower net leverage. Their net leverage has fallen over time, becoming negative in the early 1990s across all sectors (though the IT sector has lower leverage). In contrast, LINT firms' net leverage was fairly stable at 35% of total assets until 2000. It declined moderately since as these firms' intangible capital ratio also rose.

HINT firms' lower net leverage reflects two key trends. First, HINT firms invest less and raise less external financing relative to their capital base. Second, HINT firms retain a much larger share of liquid resources on their balance sheets, as the right panel of Figure 4 shows.

Figure 5: Intangibles Usage and Composition of Free Cashflows



A broad literature has studied various determinants of corporate cash holdings.[4] Remarkably, the growth in cash holdings since 1980 is concentrated among HINT firms, while LINT firms' cash ratios have mostly remained below 10%. This is consistent with recent evidence showing that the aggregate rise in cash holdings is driven by innovative firms (Begenau and Palazzo (2017), Graham and Leary (2018)).

Fact 4. HINT firms retain more resources, and prefer repurchases over dividends. Figure 5 examines how HINT firms allocate their higher free cashflow. The median HINT firm retains about 60% of free cashflow, and pays out the rest mostly through share repurchases. In contrast, LINT firms pay out most of their free cashflow, and until 2000 preferred dividends to share buybacks. Plots exclude repurchases of employee stock following option exercises, using the method of Fama and French (2001).)

Fact 5. Less constrained firms behave similarly. A natural interpretation of the above facts is that HINT firms make more cautious financial choices, as their intangible capital cannot be pledged to raise external financing in times of need. We argue here that some addi-

[4]Explanations include precautionary reserves to avoid financing constraints (Kim et al., 1998; Almeida et al., 2004; Harford et al., 2014); U.S. fiscal rules encouraging cash hoarding abroad (Foley et al., 2007; Harford et al., 2017; Faulkender et al., 2019); a reduction in the opportunity cost of holding cash (Azar et al. (2016)); and agency costs of managerial discretion (Jensen (1986), Pinkowitz et al. (2006), Dittmar and Mahrt-Smith (2007), Harford et al. (2008)).

Table 1: Corporate Policies among Dividend-Paying and S&P 500 Firms Firms

	All Firms			Dividend-Paying Firms			S&P 500 Firms		
	HINT	LINT	Diff.	HINT	LINT	Diff.	HINT	LINT	Diff.
Net Leverage	-0.03	0.32	-0.29	0.06	0.29	-0.23	0.06	0.30	-0.24
Cash Holdings	0.15	0.07	0.08	0.10	0.06	0.04	0.12	0.05	0.07
Free Cashflows	0.11	0.03	0.08	0.22	0.14	0.08	0.27	0.15	0.12
Deferred Equity	0.16	0.04	0.12	0.06	0.03	0.03	0.11	0.04	0.07
Retained Cashflows	1.00	0.86	0.14	0.44	0.41	0.03	0.46	0.35	0.11

tional explanation may be useful, as these patterns hold equally for firms that are unlikely to be financially unconstrained.

Table 1 reports key corporate finance indicators separately for HINT and LINT firms that paid dividends during the year, or were in the S&P 500. Firms that pay dividends typically have large cash buffers, while S&P 500 firms have broad access to financial markets. The table also reports difference between the median HINT and LINT firms in these subsamples, as well as across the entire sample.

The variation in financial choices among all HINT and LINT firms is similar to the differences between large or dividend-paying HINT and LINT firms. This indicates that the previously documented facts are not limited to firms that need to save cash for precautionary reasons.

3. Basic Model

3.1. Setup

The model has three active dates $t = 0, 1, 2$, a firm that is managed by a risk-neutral insider, and a risk-averse skilled employee who is hired by the firm. In the basic model the firm has no outside investors.

Technology. The firm has access to a project that requires fixed investment of I_t in $t = 0, 1$. The project is characterized by its technological intangible intensity η, defined as the fraction of intangible capital used in production, and requires investment of $(1 - \eta)I_t$ into tangible assets and ηI_t into intangibles. The firm must purchase tangible assets, but only spends a fraction α

on intangible investment. Its total investment spending is $I_t^f = [\eta\alpha + (1-\eta)]I_t$. The remaining portion of intangible assets is created over time by the employee, who co-invests her own human capital of $I_t^w = \eta(1-\alpha)I_t$ by exerting effort. Firm intangible investment can include purchases of lab equipment to support R&D or data and advertisements to build marketing capacity, while the employee can use her human capital to accumulate knowledge and develop ideas. This human capital contribution involves no cash outlay, so a significant amount of intangible investment is unrecorded in financial statements, a point we discuss in Section 5.

The project generates a stochastic cashflow $R_t^i(\eta)$ in $t = 1, 2$. Cashflows vary with intangible intensity and the state of the economy i, which can be high or low: $i \in \{h, l\}$. For ease of exposition, we omit the reference to η and express cashflows as R_t^i.

Firm investment spending decreases with η ($\partial I_t^f/\partial\eta = (\alpha - 1)I_t < 0$), as the employee co-invests a larger share of human capital when intangible intensity is higher. This choice of production technology is motivated by our empirical observation that over time, HINT firms have had lower upfront cash outlays and earned higher free cashflows than LINT firms.

Endowments and preferences. The insider has a cash endowment W_0 and chooses to contribute $A_0 \leq W_0$ to fund the project. The endowment can be interpreted as initial insider equity, seed funding provided by venture capitalists, or retained cashflows from previous operations. The baseline model studies a firm that has sufficient resources to cover all investment needs: $W_0 > I_0^f + I_1^f$. Cash can be saved across periods at a risk-free rate normalized to 0.

The insider is indifferent over the timing of consumption c_t, and there is no discounting:

$$U^f = \mathbb{E}[c_0 + c_1 + c_2]$$

The employee is endowed with only human capital, and has mean-variance preferences over consumption with risk-aversion parameter ρ:

$$U^w = \mathbb{E}[c_0^w + c_1^w + c_2^w] - \rho Var[c_0^w + c_1^w + c_2^w],$$

where $\mathbb{E}$ and Var denote expectation and variance. The employee's effort cost is normalized to 0.

Following Hart and Moore (1994), the employee cannot commit up front to stay at the firm through the project's completion. She receives an outside offer at $t = 1$ after the firm has made its investment decision, which reflects the option to move to another firm or start an own venture. The offer provides a state-dependent utility value $s = \eta(1-\alpha)s^i$, where $s^l < s^h$. Human capital is more valuable when the overall economy is strong, as industry peers compete more aggressively and own ventures are more likely to succeed.

Contractability and moral hazard. All agents can verify tangible assets created by the firm and cash held on the balance sheet. These assets are contractible and fully redeployable upon termination or completion of the project, thus the collateral value of tangible assets is $K_2 = (1-\eta)[I_0+I_1]$ at $t = 2$. Outsiders can also verify that the firm has invested into intangibles, but cannot assess the quality of this investment. Therefore at $t = 1$ the insider can choose to divert firm intangible spending $\alpha\eta I_1$ toward a private benefit with the same utility value.[5] In order to mimic a non-diverting firm, the insider still has to make the tangible investment $(1-\eta)I_1$. Diversion causes the project to fail with certainty, undermining future cashflows.

Because firm intangible spending complements human capital investment, the employee can observe whether diversion has occurred and always departs when it does. Insider choices at $t = 1$ cannot be made contingent on employee retention because the employee chooses to leave only after observing the quality of intangible investment.

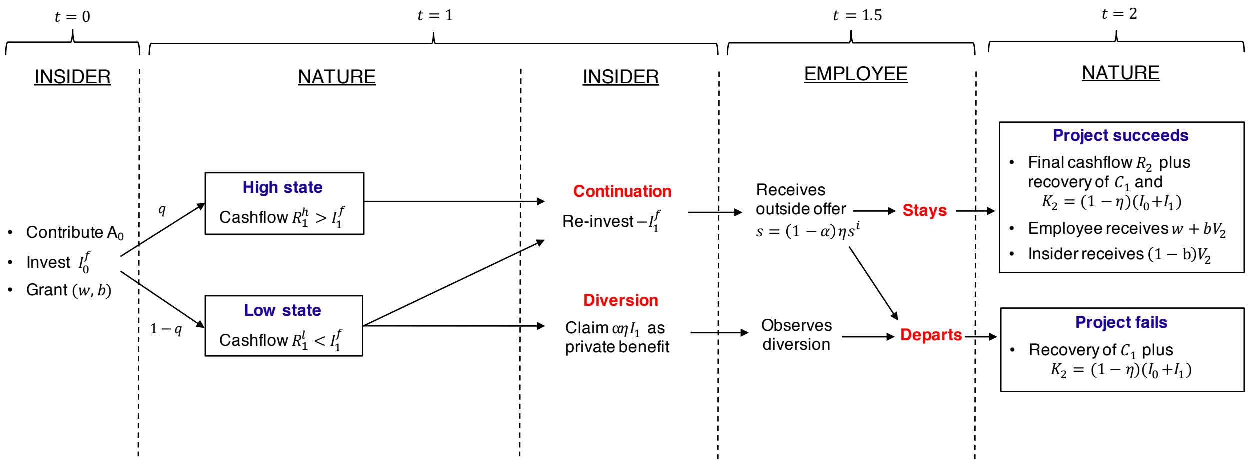
Employee compensation. The firm offers the employee a compensation contract (w, b) at $t = 0$, where w is a fixed deferred wage paid once the final payoff is realized at $t = 2$ and b is a share grant that vests at $t = 2$.[6] The outside option is not contractible, so wages cannot be made contingent on s.

In the baseline model we assume that the firm can hold compensation down to the value of the outside option, and that the compensation contract cannot be re-negotiated at $t = 1$. We relax

[5] We obtain similar results using more general formulations of the utility value of the private benefit, as long as utility increases in the amount of intangible spending diverted. Introducing a loss on redeployed tangible assets also does not affect the results.

[6] The employee's utility function can be modelled to include a preference for smoothing consumption. In this case the firm's remuneration policy may involve a fixed wage at $t = 0$ or $t = 1$. Such payments would increase the upfront cost of hiring the employee, but would not affect retention since the outside offer arrives at the end of $t = 1$.

Figure 6: Timeline of Baseline Model



these assumptions in Section 4, and show that avoiding renegotiation can be an equilibrium outcome in a dynamic repeated-game setting.[7]

Timeline. Figure 6 summarizes the project's evolution and agents' actions and payoffs in different states. At $t = 0$ the insider offers a compensation contract $(w.b)$, chooses her cash contribution A_0 and uses a portion of it to fund the project's initial cost I_0^f, leaving end-of-period cash holdings $C_0 = A_0 - I_0^f$.

At $t = 1$, the state of the economy becomes public knowledge. In the high state (probability q) the project's cashflow exceeds required re-investment: $R_1^h > I_1^f$. In this state, the firm has sufficient resources to continue the project regardless of its cash holdings. In the low state (probability $1 - q$) $R_1^l < I_1^f$, so the firm can only re-invest if it has retained sufficient resources.

After the firm makes its investment decision at $t = 1$, the employee chooses to either remain and contribute human capital $\eta(1 - \alpha)I_1$ to complete the project, or to depart. If she departs, the project fails and the firm recovers only cash and the value of tangible assets K_2. The employee's compensation expires without vesting.

At $t = 2$ the final project payoff R_2 is realized and the employee's share grant vests. All cashflows and asset holdings are sold and the agents consume.

[7]In the extension the firm is exposed to an ex-post holdup problem, in which the employee can demand a significant portion of project surplus through renegotiation. By $t = 1$ the employee has created intangible assets that depend on her human capital. This hold-up problem endogenizes the firm's fixed renegotiation cost in Oyer (2004). By refusing to renegotiate, the firm maintains credibility with future employees.

Assumptions about project payoffs. We decompose each project cashflow into the sum of a random return θ_t^i and the intangible spending associated with its creation: $R_t^i = \theta_t^i + \alpha\eta I_{t-1}$. This assumption ensures that the project's net payoffs are independent of its underlying technology.[8] θ_1 follows a binary distribution, equalling either θ_1^h or θ_1^l. θ_2 has a cumulative distribution function $F(\theta_2)$ on the support $[0, \infty)$ and with variance σ^2. In the high state, $\mathbb{E}[\theta_2] = \bar{\theta}_2^h$, and in the low state $\mathbb{E}[\theta_2] = \bar{\theta}_2^l < \bar{\theta}_2^h$. Hence, in the high state not only are intermediate cashflows higher, but also the outlook for final cashflows: $\bar{R}_2^h \equiv \bar{\theta}_2^h + \alpha\eta I_1 > \bar{R}_2^l \equiv \bar{\theta}_2^l + \alpha\eta I_1$.

We assume that the project has a positive NPV given no diversion, so that a self-funded insider would undertake it at $t = 0$.

Assumption 1. *The project has positive NPV (net of the employee's outside option value) at t=0:*

$$q\left[\theta_1^h + \bar{\theta}_2^h\right] + (1-q)\left[\theta_1^l + \bar{\theta}_2^l\right] \geq (1-\alpha)\eta\left[qs^h + (1-q)s^l\right] \tag{1}$$

The total net payoff of the project on the left-hand side of Eq. (1) is independent of η. The right-hand side is the highest amount the firm must promise to retain the employee in all states.

We also assume that continuation at $t = 1$ is efficient when the employee receives no rents.

Assumption 2. *The project has positive NPV (gross of the employee's outside option value) at $t = 1$ in states h and l:*

$$\bar{\theta}_2^h \geq (1-\alpha)\eta s^h + \rho\sigma^2 \tag{2}$$

$$\bar{\theta}_2^l \geq (1-\alpha)\eta s^l + \rho\sigma^2 \tag{3}$$

3.2. Statement of Problem

The model is solved backwards, starting with the employee's participation decision. We first derive the constraints governing each agent's decision and then the firm's problem.

[8] The project's net payoff is $R_1 + R_2 + K_2 - I_1^f - I_0^f = \theta_1 + \theta_2$. The insider's net payoff from the project may vary with η because she receives the net payoff minus employee compensation, which is endogenous. The formulation ensures that for an entrepreneur contributing her own human capital, the payoff net of her outside option is independent of η.

Employee Participation. The employee remains at the firm as long as the expected utility value of her compensation (w, b) at $t = 1$ matches the outside offer in states h and l:

$$w + b\mathbb{E}_1^h[V_2] - \rho b^2 Var_1^h[V_2] \geq (1-\alpha)\eta s^h, \tag{PC_h}$$

$$w + b\mathbb{E}_1^l[V_2] - \rho b^2 Var_1^l[V_2] \geq (1-\alpha)\eta s^l. \tag{PC_l}$$

In each state, the expectation and variance of final firm value are as of the time that the outside offer is made. Accordingly, $\mathbb{E}_1^i$ and Var_1^i denote the expectation and variance evaluated at $t = 1$ in state i:

$$\begin{aligned}
\mathbb{E}_1^i[V_2] &= \underbrace{A_0 - I_0^f}_{=C_0} \quad + \quad \underbrace{R_1^i - I_1^f}_{\text{Free Cashflow } t=1} \quad + \quad \underbrace{\bar{R}_2^i - w + K_2}_{\text{Final Payoff and Recovery Value}} \\
&= A_0 + \theta_1^i + \bar{\theta}_2^i - w \qquad (4)
\end{aligned}$$

$$Var_1^i[V_2] = \sigma^2 \tag{5}$$

Employee compensation must be deferred until $t = 2$, otherwise (PC_h) and (PC_l) cannot hold.

Insider Re-investment. If the insider diverts at $t = 1$, her payoff is:

$$\underbrace{\alpha\eta I_1}_{\text{Private Benefit}} \quad + \quad \underbrace{C_1 + K_2}_{\text{Firm Value After Diversion}} \quad = A_0 + \theta_1^i,$$

where $C_1 = C_0 + R_1^i - I_1^f$ denotes cash holdings at the end of $t = 1$. In contrast, the expected value of continuing without diversion is:

$$(1-b)\mathbb{E}_1^i[V_2] = (1-b)[A_0 + \theta_1^i + \bar{\theta}_2^i - w].$$

Comparing the two yields the following insider incentive-compatibility constraints for states h

and l:

$$(1-b)[\bar{\theta}_2^h - w] \geq b[A_0 + \theta_1^h], \tag{IC_h}$$

$$(1-b)[\bar{\theta}_2^l - w] \geq b[A_0 + \theta_1^l]. \tag{IC_l}$$

The insider fully funds $\alpha\eta I_1$ herself, so the private benefit's net utility value is zero. The gain from diversion on the right-hand side reflects that the employee departs and forfeits her claim on current assets in place. We refer to this effect as *compensation overhang.* Incentive compatibility requires the insider's share of the final project cashflow (diluted by the employee's claim) to exceed this effect. This occurs only when the project's continuation value at $t = 1$ is high relative to cashflows already earned.

Intangible intensity η does not directly enter into the IC constraints, but it indirectly impacts the insider's gain from diversion through its effect on cash holdings and the employee's equity stake b. With external financing, the gain from diversion directly increases in η (see Section 4.1).

Because the project's expected cashflows at $t = 2$ exceed the value of the employee's outside option, diversion may occur only when the employee receives rents.

Lemma 1. *Under Assumption 2, the insider prefers continuation to diversion for $i = h, l$ if the employee receives no rents in state i. Thus (IC_h) is slack when (PC_h) binds, and (IC_l) is slack when (PC_l) binds.*

Insider Financing Contribution. To ensure project success, the firm's precautionary savings must be sufficient to cover possible re-investment needs at $t = 1$:

$$C_0 \geq I_1^f - R_1^l \equiv C_{PREC} \tag{PREC}$$

This requires the insider to contribute enough to cover investment spending in both periods: $A_0 \geq C_{PREC} + I_0^f \equiv A_{PREC}$. By Assumption 2, the insider prefers holding enough cash to risking project termination in the low state.

Next to the precautionary motive, saving cash also can reduce the cost of hiring human capital. When the employee owns a stake in the project (i.e., $b^* > 0$) she is exposed to its idiosyncratic cashflow risk, but also owns an indirect claim on the firm's cash holdings. Thus carrying $C_0 > C_{PREC}$ reduces the employee's required premium for bearing cashflow risk and increases the utility value of deferred compensation.

Insider Problem. The insider chooses compensation and her cash contribution to maximize her share of firm value, subject to the employee's participation constraints, incentive compatibility constraints, and precautionary needs:[9]

$$\begin{aligned} \max_{A_0,w,b} \quad & U^f = (1-b)\mathbb{E}_0[V_2] - A_0 \\ s.t. \quad & (PC_h), (PC_l), (IC_h), (IC_l), (PREC) \end{aligned} \tag{6}$$

where $\mathbb{E}_0[V_2] = q\ \mathbb{E}_1^h[V_2] + (1-q)\ \mathbb{E}_1^l[V_2]$ is the expected final firm value as of $t = 0$. This problem can be re-formulated as the following Lagrangian function:

$$\begin{aligned} \max_{A_0,w,b} \quad \mathcal{L} = &(1-b)\Big\{A_0 + q(\theta_1^h + \bar{\theta}_2^h) + (1-q)(\theta_1^l + \bar{\theta}_2^l) - w\Big\} - A_0 \\ &+ \mu_h\Big\{w + b[A_0 + \theta_1^h + \bar{\theta}_2^h - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^h\Big\} \\ &+ \mu_l\Big\{w + b[A_0 + \theta_1^l + \bar{\theta}_2^l - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^l\Big\} \\ &+ \phi_h\Big\{(1-b)[\bar{\theta}_2^h - w] - b[A_0 + \theta_1^h]\Big\} \\ &+ \phi_l\Big\{(1-b)[\bar{\theta}_2^l - w] - b[A_0 + \theta_1^l]\Big\} \\ &+ \lambda\Big\{C_0 - C_{PREC}\Big\} \end{aligned} \tag{7}$$

where $\mu_h, \mu_l, \phi_h, \phi_l$ and λ are the Lagrange multipliers for the constraints (PC_h), (PC_l), (IC_h), (IC_l), and (PREC), respectively.[10]

Numerous solutions to Problem (7) are possible depending on which constraints bind. To impose structure, we first note that the insider always matches the employee's outside option

[9]Note that choosing A_0 is analogous to choosing C_0, since investment scales are fixed.

[10]Formally, the Lagrangian should also contain non-negativity constraints for A_0, w and b. We omit these constraints for readability.

in the high state.

Lemma 2. *A_0^*, b^*, and w^* are always set so that the employee's participation constraint (PC_h) binds in the high state ($\mu_h > 0$). It follows that (IC_h) is always slack at the optimum ($\phi_h = 0$).*

The full proof is in Appendix D. The key intuition is that granting the employee more equity is particularly costly for the insider in the high state because cashflows are high. Therefore, if (PC_h) was slack, the insider could reduce the share grant until it binds while still satisfying (PC_l).[11] It further follows from Lemma 1 that (IC_h) is slack, as the insider chooses not to divert in state h when the employee receives no rents.

3.3. Solutions

The model produces two separate solution regions, based on whether the insider's binding constraint is to contribute sufficient resources to retain the employee in all states or to ensure that re-investment at $t = 1$ is feasible in the low state. In the *Retention Motive* (RET) region the firm's traditional precautionary motive is not active, but the firm must provide enough insurance to match the employee's relatively high outside option. This region is characterized by optimal cash holdings $C_0^* \geq C_{PREC}$, and corresponds to $\lambda = 0$ and a slack (PREC) constraint in Problem (7).

In the traditional *Precautionary Motive* (PREC) region, the re-investment need is high relative to the employee's outside option value. In this region the insider chooses $C_0^* = C_{PREC}$, and the employee may receive more insurance than needed to remain at the firm in state l. This corresponds to $\lambda > 0$ and a binding (PREC) constraint.

A general result in both regions is that the insider grants equity to the employee. If not, then she would have to pay a high wage of $(1-\alpha)\eta s^h$ to retain the employee in state h. But because wages are fixed, this would convey rents of $(1-\alpha)\eta(s^h - s^l)$ to the employee in state l, decreasing the insider's payoff and encouraging diversion. The insider could instead write a contract ($b' > 0, w' \geq 0$) that transfers less value to the employee yet still satisfies both participation constraints. The share grant has lower value in the low state, which reduces the rent paid to

[11] Mathematically, the left-hand side of (PC_h) increases more in b than the left-hand side of (PC_l), because $\mathbb{E}_1^h[V_2] > \mathbb{E}_1^l[V_2]$ while $Var_1^h[V_2] = Var_1^l[V_2]$.

the employee (at the cost of exposing her to more risk).[12] Intuitively, because human capital's value is state-contingent, the employee's compensation also should be.

Lemma 3. *Under Assumption 2, the optimal contract contains equity that vests at $t = 2$: $b^* > 0$.*

We first solve the model for cases in which the insider does not divert, i.e., (IC_l) is slack and hence $\phi_l = 0$. Section 3.3.1 studies diversion with $\phi_l > 0$. Analyzing different solution regions sequentially allows us to highlight each of the different economic forces in our model. A general solution is in Appendix B.

Dominant Retention Motive. In the RET region the insider chooses three variables to satisfy two constraints, so the model is underdetermined. We first examinine the solution in which (PC_l) binds ($\mu_l > 0$) in addition to (PC_h), i.e., the employee receives no rents in either state.

The optimal equity grant b^*_{RET} can be derived by combining (PC_l) and (PC_h):

$$b^*_{RET} = \frac{(1-\alpha)\eta\Delta s}{\Delta\theta} \tag{8}$$

where $\Delta s \equiv s^h - s^l$ and $\Delta\theta \equiv [\theta_1^h + \bar{\theta}_2^h] - [\theta_1^l + \bar{\theta}_2^l]$. Eq. (8) shows that b^*_{RET} rises with intangible intensity, and is proportional to the ratio of the employee's incremental retention cost in the high state relative to incremental firm value. Thus when the employee's outside option rises more in state h than does project value, the firm must promise a larger share of the returns on her human capital.

Next we solve for the optimal insurance provided to the risk-averse employee. Both cash holdings and deferred wages convey insurance, since the employee receives a fraction b of each unit of cash that insiders put into the firm and $(1-b)$ of each unit of wages. She thus receives the same utility value from the firm holding $1/b$ units of cash or granting $1/(1-b)$ units of deferred wages. We define overall net insurance as:

$$INS(w, A_0; b) \equiv bA_0 + (1-b)w. \tag{9}$$

[12] Note that Assumption 2 limits employee risk aversion.

The firm's ability to insure the employee with deferred wages is limited, because it cannot safely promise more than the value of cash holdings and minimum realizable project cashflows (which are θ_1^l at $t = 1$ and 0 at $t = 2$). Promising more would expose the employee to idiosyncratic risk, and is suboptimal to saving cash. Thus either cash or wages provide insurance up to a certain wage threshold, beyond which the firm retains cash to meet further insurance needs.

Lemma 4. *In the RET region there is an equivalence between providing insurance via cash $C_0 \geq C_{PREC}$ or deferred wages w, as long as the overall level of insurance satisfies (PC_h):*

$$INS(w, A_0; b) \geq (1-\alpha)\eta s^h + \rho b^2\sigma^2 - b(\theta_1^h + \bar{\theta}_2^h), \tag{10}$$

and wages are sufficiently small to remain safe: $w \leq A_0 + \theta_1^l \equiv \bar{w}$.

This result is shown formally in Appendix B.

From (PC_h), the overall level of insurance needs to match the employee's outside option and risk premium, net of the expected value of cashflows earned by the employee. Optimal insurance INS^*_{RET} is obtained by substituting b^*_{RET} into Eq. (10) and setting the inequality to bind.

The solution and comparative statics are summarized in the proposition below.

Proposition 1. *When (PC_h) and (PC_l) bind, the insider's optimal compensation and financing choices are characterized by:*

$$b^*_{RET} = \frac{(1-\alpha)\eta\Delta s}{\Delta\theta},$$

$$INS^*_{RET} = \left(\frac{\rho(1-\alpha)\eta\Delta s\sigma^2}{\Delta\theta} + \frac{s^h\Delta\theta}{\Delta s} - [\theta_1^h + \bar{\theta}_2^h]\right)\frac{(1-\alpha)\eta\Delta s}{\Delta\theta}.$$

The insider is indifferent between any pair $(w \leq \bar{w}, A_0)$ such that $INS(w, A_0; b^*_{RET}) = INS^*_{RET}$. When insurance needs are sufficiently high, the insider prefers to save cash and her contribution is determined by $INS(\bar{w}, A^*_{0,RET}; b^*_{RET}) = INS^*_{RET}$. Insiders contribute at least $A^*_{0,RET} \geq INS^*_{RET} - (1 - b^*_{RET})\theta_1^l$.

Both the optimal equity grant and overall level of insurance are increasing in intangible intensity:

$$\frac{\partial b^*_{RET}}{\partial \eta} = \frac{(1-\alpha)\Delta s}{\Delta \theta} \geq 0$$

$$\frac{\partial INS^*_{RET}}{\partial \eta} = \frac{\rho(1-\alpha)\Delta s \sigma^2}{\Delta \theta} b^*_{RET} + \frac{INS^*_{RET}}{b^*_{RET}} \frac{(1-\alpha)\Delta s}{\Delta \theta} \geq 0$$

The comparative static results show that the need to provide insurance and deferred stock compensation to the employee is particularly strong for HINT firms. Because human capital plays a bigger role in these firms' investment projects, the employee has better outside options and requires a larger share of the reward.

Interestingly, in the RET region the firm sets aside more liquid resources for the high than low state ($C_0 + \theta_1^h$ versus $C_0 + \theta_1^l$). HINT firms are less likely to experience traditional financial constraints when the economy is strong, yet this is precisely when they face the highest threat and cost from potential turnover of skilled employees. Holding abundant cash in state h is a cost-effective way to retain employees, as the alternative of providing a large share grant is particularly costly when expected firm value is high.

For completeness, we note that an additional interior solution exists in the RET region, in which the insider leaves the employee's low-state participation constraint (PC_l) slack. When the employee is sufficiently risk averse, the insider prefers to offer a lower share grant to limit risk exposure, leaving some rents to the employee in the low state. As long as the rents are not sufficiently large to violate (IC_l), the economic insights and comparative statics are similar to the case studied here. We present this alternative solution in Appendix B.

Traditional Precautionary Motive. In the PREC region optimal cash holdings are directly pinned down by (PREC), implying an initial contribution of $A^*_{0,PREC} \equiv C_{PREC} + I_1^f$. This is more than sufficient to convey optimal insurance, as the threat of becoming constrained requires the insider to set aside more cash for the low state than is needed to retain the employee in either state. By Lemma 2, the insider leaves (PC_l) slack and provides rents to the employee in the low state. Additional insurance via deferred wages is unnecessary.

Lemma 5. *The optimal contract in the PREC region contains only equity and no deferred wages.*

The formal proof is in Appendix B.2. This result highlights an interesting complementarity between the traditional precautionary and retention motives. A prudent financial policy insures the firm's investment needs in bad states of the world, while at the same time providing insurance to employees in good states of the world when outside options are high. As a result, the firm does not need to offer additional insurance via deferred wages.

Plugging C_{PREC} into (PC_h) yields a quadratic equation that implicitly defines the optimal equity grant:

$$b[(1-\eta)(I_0+I_1)+\alpha\eta I_1+\theta_1^h-\theta_1^l+\bar{\theta}_2^h]-\rho b^2\sigma^2-(1-\alpha)\eta s^h=0. \tag{11}$$

The smaller root to this equation, which we denote denote b^*_{PREC}, is optimal as it minimizes compensation cost. It can be expressed in closed form using the quadratic formula.
The following proposition summarizes the solution for the (PREC) region.

Proposition 2. *In the PREC region when (IC_l) is slack, the insider's optimal compensation and financing choice is characterized by:*

b^*_{PREC} *implicitly defined as smaller root of Eq.* (11)

$$w^*_{PREC}=0$$

$$A^*_{0,PREC}=(1-\eta)(I_0+I_1)+\alpha\eta I_1-\theta_1^l$$

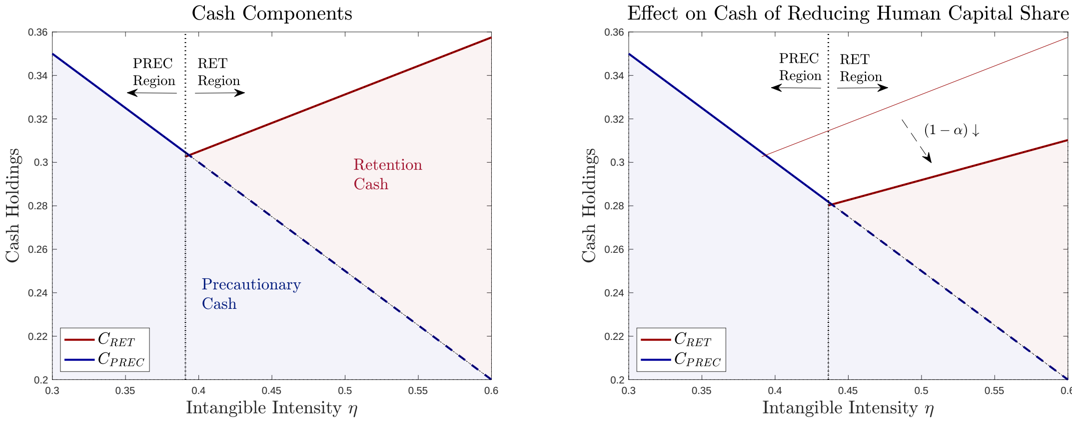
The optimal equity grant is increasing in intangible intensity while cash savings is decreasing:

$$\frac{\partial b^*_{PREC}}{\partial\eta}>0$$

$$\frac{\partial A^*_{0,PREC}}{\partial\eta}=(\alpha-1)I_1-I_0<0$$

The comparative statics for $A^*_{0,PREC}$ result from the fact that HINT firms require a lower

Figure 7: Precautionary versus Retention Cash



upfront funding contribution, as the employee contributes more human capital to create intangibles. This result is qualified once external financing is introduced in Section 4.1. HINT firms have a lower safe debt capacity since intangible assets may be diverted, so while own investment spending is smaller, a larger fraction may need to be funded internally.

Figure 7 uses a numerical example to illustrate how the motives that determine the firm's cash holdings $C_0 = A_0 - I_0^f$ vary with its intangible intensity η.[13] In the left panel, as η increases the retention motive (Prop. 1) becomes stronger relative to the precautionary motive (Prop. 2), leading the firm to hold more cash for insurance purposes. The vertical line indicates where C_{PREC} and C_{RET} cross, with the retention motive dominant to the right and the precautionary motive to the left. In the RET region cash holdings exceed what the firm needs for precautionary reasons alone, and as η rises the retention motive explains an increasingly larger fraction of total cash holdings.

The right panel of Figure 7 highlights the model's prediction that the human capital share of intangible spending $(1-\alpha)$ is an important determinant of cash holdings. When the human capital contribution drops from $(1-\alpha) = 0.5$ to 0.35, the RET region shrinks and the amount of cash needed for insurance decreases.

[13]We set other parameter values to $I_0 = I_1 = 0.5, \theta_1^h = 0.5, \theta_2^h = 1, \theta_1^l = 0, \theta_2^l = 0.9, q = 0.6, \sigma^2 = 0.05, \rho = 1, s^h = 1.1, s^l = 0.8, \alpha = 0.5$.

3.3.1. Compensation Overhang

We now study how the potential for diversion at $t = 1$ affects the firm's problem. In the RET region an interior solution exists in which the insider pays the employee a smaller share grant to reduce risk exposure, thus leaving her rents in the low state (see Appendix B). When these rents are too high, the insider cannot commit to avoid diversion in order to reclaim the deferred compensation.

The insider can prevent this moral hazard problem by reducing the employee's rents in the low state until (IC_l) is just satisfied. In this case, the optimal share grant follows from combining (PC_h) and (IC_l):

$$\bar{\theta}_2^l + b\Delta\theta = \rho b^2\sigma^2 + (1-\alpha)\eta s^h. \tag{12}$$

The optimal grant $b^*_{RET\text{-}IC}$ is the smaller root to this quadratic equation.[14] As before the optimal level of insurance $INS^*_{RET\text{-}IC}$ follows from (PC_h), and an equivalence exists between cash holdings and deferred wages $w \leq \bar{w}$. The following proposition summarizes the solution:

Proposition 3. *If* (IC_l) *binds in the RET region, the optimal share grant* $b^*_{RET\text{-}IC}$ *is the smaller root to Eq.* (12). *The optimal level of insurance is given by*

$$INS^*_{RET\text{-}IC} = \left(\frac{(1-\alpha)\eta s^h}{b^*_{RET\text{-}IC}} + \rho\sigma^2 b^*_{RET\text{-}IC} - [\theta_1^h + \bar{\theta}_2^h]\right) b^*_{RET\text{-}IC}.$$

The optimal equity grant increases and insurance decreases in intangible intensity:

$$\frac{\partial b^*_{RET\text{-}IC}}{\partial \eta} \geq 0$$

$$\frac{\partial INS^*_{RET\text{-}IC}}{\partial \eta} \leq 0$$

Moreover, the optimal equity grant is larger, and the optimal level of insurance is smaller than what the insider would offer if (IC_l) *were slack:*

[14] The solution is $b^*_{RET\text{-}IC} = \frac{\Delta\theta - \left[(\Delta\theta)^2 - 4\rho\sigma^2[(1-\alpha)\eta s^h - \bar{\theta}_2^l]\right]^{1/2}}{2\rho\sigma^2}$ and only exists if $\bar{\theta}_2^l \geq (1-\alpha)\eta s^h$.

$$b^*_{RET\text{-}IC} \geq b^*_{RET},$$
$$INS^*_{RET\text{-}IC} \leq INS^*_{RET}.$$

As in Proposition 1, the optimal equity grant and insurance rise with the firm's intangible intensity. The key difference is that the insider offers a larger share grant and less insurance to the employee than she would if (IC_l) were slack. Shares are relatively less valuable in the low state, so the employee's rents are reduced. This in turn decreases the value of unvested equity that the insider could re-claim by engaging in diversion, alleviating the moral hazard problem. The cost is that the insider must offer more compensation via higher insurance than she would if diversion were not possible. This is shown formally in the general solution in Appendix B.1.

In the PREC region, the firm's precautionary needs may be high enough that diversion becomes unavoidable in the low state. This occurs when the insider must set aside so much cash to fund re-investment in the low state that the rents conveyed to the employee exceed the project's low-state continuation value. In this case, the insider cannot simultaneously guarantee re-investment in the low state and commit to avoiding diversion to re-claim the employee's rents. Re-arranging (IC_l) shows that (b^*_{PREC}, C_{PREC}) are incentive compatible only if:

$$b^*_{PREC} \leq \frac{\bar{\theta}^l_2}{\theta^l_1 + \bar{\theta}^l_2 + A^*_{0,PREC}}.$$

The project is abandoned at $t = 0$ when this condition is not satisfied.

4. Extensions

4.1. External Financing

We extend the baseline model to the case in which the insider must raise external financing to complete the project. The discussion focuses on key differences relative to Section 3, with the full solution presented in Appendix C.

The insider can issue debt D_t at $t = 0$ or 1, which is collateralizable (hence risk-free) up to the value of tangible assets K_2. The insider can also raise equity of E_0 at $t = 0$ by selling a stake e to risk-neutral external shareholders. We assume that the firm pays no dividends at $t = 1$ and that shareholders break even in expectation, i.e., $E_0 = e\mathbb{E}_0[V_2]$.

To start the project and guarantee continuation, the insider's contribution and external financing need to be sufficient to fund the firm's investment. We focus here on the RET solution region by assuming the firm can raise sufficient safe debt to fund investment needs at $t = 0$ and 1 by collateralizing tangible assets (see Appendix C for details).

While debt can help satisfying investment needs, a key insight is that issuance of debt does not insure the employee, because any cash proceeds are re-paid to creditors at $t = 2$ before deferred compensation vests. If the firm needs additional funding to provide insurance to the employee, it prefers to issue external equity instead of debt:

Lemma 6. *In the RET region, the firm never issues risky debt and is indifferent how much safe debt to issue (as long as it can fund investment at $t = 0$ and $t = 1$).*

Equity and debt have the same effect on the insider's incentives for diversion, but risky debt increases the variance of any form of employee compensation and hence raises its required risk premium.[15] External equity can be used to fund intangible investment and insure the employee. The latter occurs as external shareholders agreed to transfer bE_0 to the employee in order to hold down compensation costs.

Yet raising external equity also dilutes the insider's stake. This makes diversion more likely because the insider must share more of the project's expected future surplus. This trade-off between insuring the employee and diluting the insider is the key result of the extension. It can be seen clearly in the modified insider incentive compatibility constraints:

$$(1 - e - b)\left[\bar{\theta}_2^h - w\right] \geq e\alpha\eta I_1 + b\left[A_0 + E_0 + \theta_1^h\right] \tag{IC'_h}$$

$$(1 - e - b)\left[\bar{\theta}_2^l - w\right] \geq e\alpha\eta I_1 + b\left[A_0 + E_0 + \theta_1^l\right]. \tag{IC'_l}$$

In each state the net gain from continuation (left-hand side) must exceed the net gain from diversion (right-hand side). Notably, external equity amplifies the compensation overhang ef-

[15] In practice, employee deferred compensation (including wages) is junior to debt in bankruptcy court, so the employee's claims are worth less in expectation in default than non-default states.

fect (the second term on the right-hand side), as the insider can now divert the cash bE_0 that external shareholders provide to insure the employee. We denote $\bar{e}$ as the maximum stake that the insider can sell while still satisfying incentive compatibility. It is implicitly defined by (IC_l').

4.1.1. Extension Solution

As long as insider incentive-compatibility is satisfied, the optimal equity grant $b^*_{RET'}$ and its associated comparative statics remain the same. This is because the employee's participation constraints are unchanged in the absence of default risk, which the firm avoids by issuing only safe debt.

The optimal insurance level $INS^*_{RET'}$ also remains the same, but it can now be conveyed by three resources: Insider-funded cash A_0, external equity-funded cash E_0, or deferred wages w.

$$INS(w, A_0, E_0; b) \equiv b(A_0 + E_0) + (1 - b)w. \tag{13}$$

Each resource provides insurance only up to a certain threshold. Insider-funded cash holdings cannot exceed the endowment W_0, while deferred wages are safe up to the initial funding contribution plus minimum project cashflows: $w \leq A_0 + E_0 + \theta_1^l \equiv \bar{w}'$. The insider can only sell external equity up to $\bar{e}$ while committing to not divert.

For certain parameter values an equivalence exists between two or even all three sources of insurance. The firm can then achieve the same outcome as in the model without external financing in Section 3. To see this, note the firm can always try to satisfy insider incentive compatibility by providing insurance via deferred wages rather than external equity. With $e = E_0 = 0$ the (IC_l') and (IC_h') collapse to (IC_l) and (IC_h) in Section 3, and insiders can commit not to divert as long as (PC_h) and (PC_l) bind (Lemma 1). An interesting implication is that firms which are less constrained (with slack incentive-compatibility constraints) may hoard *more* cash to insure employees, while constrained firms rely on wages for insurance.

More interesting results obtain when W_0 and $\bar{w}'$ are sufficiently low, so the insider must sell equity to insure the employee. To analyze this case we derive e_{INS^*} as the equity stake needed to achieve optimal insurance, given that the insider contributes all of her endowment and grants

$\bar{w}'$. If $e_{INS^*} \leq \bar{e}$, the insider can convey $INS^*_{RET'}$ while also committing to not divert at $t = 1$.

Proposition 4. *Define $\bar{e}$ as the value of e for which (IC'_l) binds. If*

$$\bar{e} \geq e_{INS^*} \equiv \frac{INS^*_{RET'} - W_0 - (1 - b^*_{RET'})\theta^l_1}{\bar{\theta}_1 + \bar{\theta}_2 - \theta^l_1}$$

the firm can satisfy (IC'_h) and (IC'_l) while offering the same employee compensation as in Proposition 1. To fund employee insurance, insiders are indifferent between any set $(A^*_{0,RET'}, E^*_{0,RET'}, w^*_{RET'})$ such that:

- $b^*_{RET'}(A^*_{0,RET'} + E^*_{0,RET'}) + (1 - b^*_{RET'})w^*_{RET'} = INS^*_{RET'}$
- $E^*_{0,RET'}$ *can be raised by selling an equity stake* $e_{INS^*} \leq \bar{e}$
- $w^*_{RET'} \leq \bar{w}'$.

The comparative statics on $\bar{e}$ are:

$$\frac{d\bar{e}}{d\eta} \leq 0$$
$$\frac{d\bar{e}}{d(1-\alpha)} \leq 0 \quad \textit{if and only if} \quad \frac{b^*_{RET'}}{\bar{e}} \geq \frac{(1-\alpha)\eta I_1}{\bar{\theta}^l_2}.$$

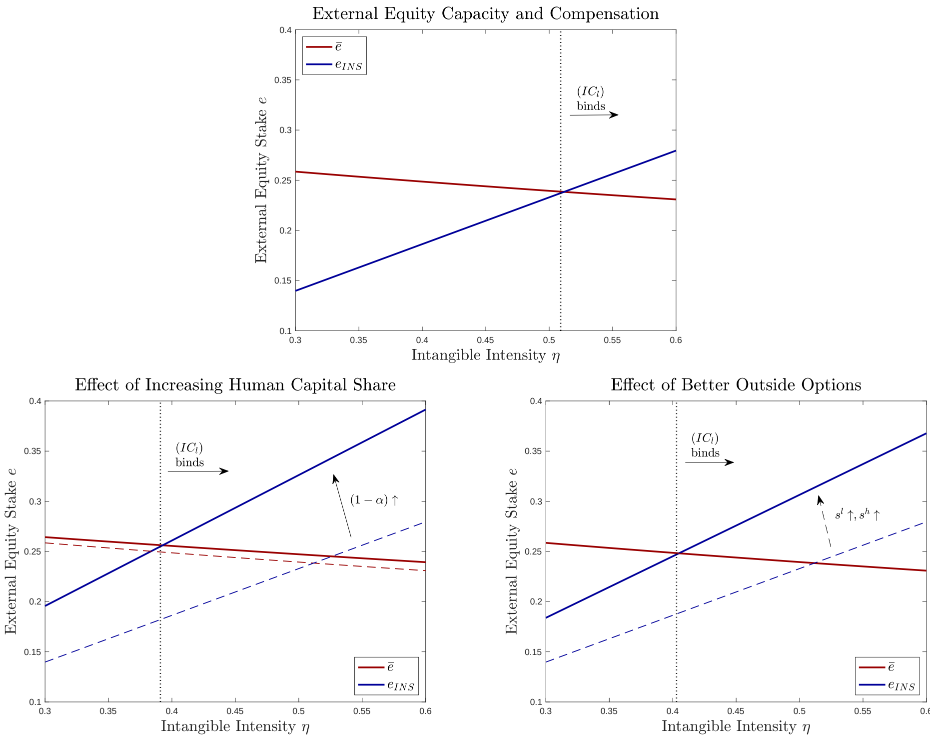
The comparative statics on e_{INS^*} are:

$$\frac{de_{INS^*}}{d\eta} \geq 0$$
$$\frac{de_{INS^*}}{d(1-\alpha)} \geq 0.$$

The comparative statics of Proposition 4 imply that HINT firms have less capacity to raise external equity than LINT firms and at the same time need to raise more funding to insure employees. Moral hazard is exacerbated by greater intangible intensity and reliance on employees' human capital so HINT firms require wealthier insiders to complete investment projects.

More generally, $\bar{e}$ may either increase or decrease with the human capital share $(1 - \alpha)$. A greater $(1-\alpha)$ can lessen moral hazard because employees contribute a larger share of intangible investment, leaving less spending for the insider to divert. On the other hand, when $(1 - \alpha)$ is

Figure 8: Employee Insurance and External Equity Capacity



high, the firm also must offer a high share grant to the employee and this exacerbates moral hazard via a stronger compensation overhang effect.

These results are illustrated in Figure 8, which plots the optimal share grant e_{INS^*} and limit $\bar{e}$ against η.[16] The vertical line indicates the point where $e_{INS^*} = \bar{e}$; to the right, (IC_l') binds for higher values of η. The lower two panels plot the impact of an increasing human capital share $(1-\alpha)$ and employee outside options s^h and s^l, respectively. Both create a greater need to provide insurance to the employee, resulting in a higher level of e_{INS^*} and a binding (IC_l') constraint for a wide range of HINT firms. This illustrates the model's insight that high reliance on human capital can exacerbate insider moral hazard problems.

If $e_{INS^*} > \bar{e}$, the insider cannot convey insurance of INS^*_{RET} to the employee as all parties would anticipate the diversion of project resources. If (PC_l) is slack, the firm can still overcome this problem by offering less insurance than optimal and instead granting $b^*_{RET-IC'} > b^*_{RET'}$, as

[16] We set other parameter values to $I_0 = I_1 = 0.5, \theta_1^h = 0.5, \theta_2^h = 1, \theta_1^l = 0, \theta_2^l = 0.9, q = 0.6, \sigma^2 = 0.05, \rho = 1, s^h = 1.2, s^l = 1, \alpha = 0.5, W_0 = 0$.

discussed in Section 3.3.1. This secures employee participation while avoiding insider diversion, but at a higher overall cost to both parties. If the participation constraint already binds, diversion cannot be avoided. The project is not undertaken at $t = 0$ when diversion renders overall negative NPV, else it is initiated but continuation at $t = 1$ occurs only in the high state.

In summary, the extension with external financing yields two key insights. First, debt financing may be unattractive because cash raised through debt has to be repaid before shares vest and therefore does not add to employee insurance. Instead, HINT firms raise external equity. However, this exacerbates moral hazard problem, especially if investment relies strongly on human capital. As a result, HINT firms ultimately require a larger insider share for innovative projects to succeed.

4.2. Reputation for Contractual Commitment

The model assumes that renegotiation of the employee's compensation contract is not possible at $t = 1$. We discuss here a dynamic repeated-game setup that endogenizes the firm's commitment not to renegotiate, and yields additional implications for payout policy.

The setup makes the following two modifications. First, the firm has an infinite sequence of ex-ante identical investment opportunities with a constant technology η, α, and payoff structure $\{R_1, R_2\}$, all defined as in Section 3. All capital depreciates at the end of each cycle, new employees are hired at the start of the following cycle, and firm insiders have adequate initial resources to finance firm investment. Vested equity owned by the employee is bought back by the insider at the end of each cycle at market value (including cash). Let δ be the discount factor over each cycle.

Second, when an employee receives an outside offer in the interim period of each cycle, she can use her bargaining power to demand a larger share of project surplus. If the firm agrees to renegotiate a symmetric bargaining outcome would result, in which continuation surplus is equally shared with the employee.

The key result of the extension is that the firm may optimally resist renegotiation in order to maintain a reputation for commitment. Absent renegotiation, the insider's expected cashflow (net of firm investment) in each cycle is $(1 - b^*_{RET})\mathbb{E}_0[V_2]$, where the optimal choices

$A^*_{0,RET}, w^*_{RET}, b^*_{RET}$ are the same as in Section 3. The insider's capitalized net profit stream is:

$$\frac{(1-b^*_{RET})\mathbb{E}_0[V_2]}{1-\delta}, \tag{14}$$

provided that cash holdings are adjusted at the start of each cycle to be exactly $A^*_{0,RET}$. This requires the payment of a dividend at the end of each cycle after the employee's shares have been re-purchased.

An infinite-horizon setup admits multiple equilibria, but the literature focuses on an outcome in which the firm maintains a reputation for avoiding renegotiation (Mailath and Samuelson, 2006). The firm can make this commitment as long as it is ready to bear the cost of project failure each time that renegotiation is threatened.

If an the employee attempts to renegotiate and threatens to leave if the firm does not agree, the firm has two choices. It can agree to renegotiate to avoid the employee from leaving. But if the firm makes a concession once, it experiences a complete loss of credibility and is challenged by employees in each cycle to renegotiate and concede half of final net surplus. The payoff from renegotiating is

$$\frac{1}{2}\left((1-b^*_{RET})\mathbb{E}_1[V_2^i] + \delta\frac{(1-b^*_{RET})\mathbb{E}_1[V_2^i]}{1-\delta}\right)$$

Alternatively, the firm can be tough and not renegotiate. The cost of this is that the project fails, but the firm maintains a reputation as never renegotiating so employees will not attempt to renegotiate in the future. The payoff from not renegotiating is thus

$$\delta\frac{(1-b^*)\mathbb{E}_1[V_2^i]}{1-\delta}$$

Comparing the two, it is optimal for the firm not to renegotiate and maintaining a reputation if

$$\delta\frac{(1-b^*_{RET})\mathbb{E}_0[V_2]}{1-\delta} \geq (1-b^*_{RET})\mathbb{E}_1[V_2^i] \tag{15}$$

The highest-deviation payoff for renegotiating the compensation scheme arises in state h, when the continuation surplus is largest.

Condition (15) is satisfied as long as the discount factor δ is sufficiently large, so that the firm accepts to take a loss in one cycle to maintain its credibility. Note that a credible commitment not to renegotiate compensation is a valuable *intangible* asset for the firm, which arises from its persistence over time. This value is lost once the firm goes bankrupt.

4.3. Payout Policy and Reputation as a Fair Employer

Next consider an additional modification to the above setup, which allows end-of-cycle cashflows θ_2^i to be realized before deferred compensation vests with probability ϵ. At this point insiders no longer require the employee's human capital, so a dividend can transfer value that was promised to her to external shareholders.

The maximum gain the firm can capture is $b^*_{RET}V_2 + (1 - b^*_{RET})w$. However, the cost is a loss of all credibility for honouring promised compensation. The firm would no longer be able to attract any talented employee, and hence would lose all future net profits. Thus as long as the discount factor is sufficiently large, the firm refrains from making dividend payouts before employee compensation vests.

Interestingly, this problem can also be overcome by making payouts via repurchases rather than dividends. At the end of each cycle, the firm can use cash of X to repurchase a fraction $x = \frac{X}{V_2^*}$ of shares. The value of the firm drops to $V_2^* - R_2$, but the share price is unaffected because the total number of shares outstanding shrinks. This means that the employee's unvested equity stake effectively rises to $b' = b/(1 - x)$, leaving the claim's value unaffected.

4.4. Disruptive Entry

Our setup allows firms to ensure retention of critical talent using a simple combination of compensation and financial policy, based on a positive correlation between equity pay and outside options. We now consider the (rare) possibility of disruptive new entry that reduces the incumbent's expected cashflows. Entry raises competition for talent just as the incumbent's stock price is falling, leading to a negative correlation between employees' outside options and the expected value of deferred equity compensation.

Specifically, at $t = 1$ let disruptive entry occur with probability ϵ in state h, and label this subset of states h_D. Entry causes skilled employees' outside option to rise from s^h to $s^{h_D} > s^h$. This occurrence cannot be hedged easily using capital markets. It is easy to show that retention can only be ensured by promising the employee extra rents in state h. Because deferred equity compensation may fail in this state, a robust compensation scheme may require a very high cash component.

A cheaper and more robust strategy is for the incumbent firm to acquire the entrant, thus avoiding both the direct competitive effect and the risk of talent poaching. Yet a HINT firm would be challenged to externally fund a large acquisition at a time when its competitive position is under pressure and its success is endogenous to the capital raising itself. Funding an acquisition using equity would require large dilution of the insider's share, exacerbating her incentives to divert. However, a firm can insure against disruption risk by strategic cash holdings, to be used to ensure the success of its bid for a disruptive entrant. Interestingly, strategic cash reflects a precautionary motive recast in the specific context of intangible investment.

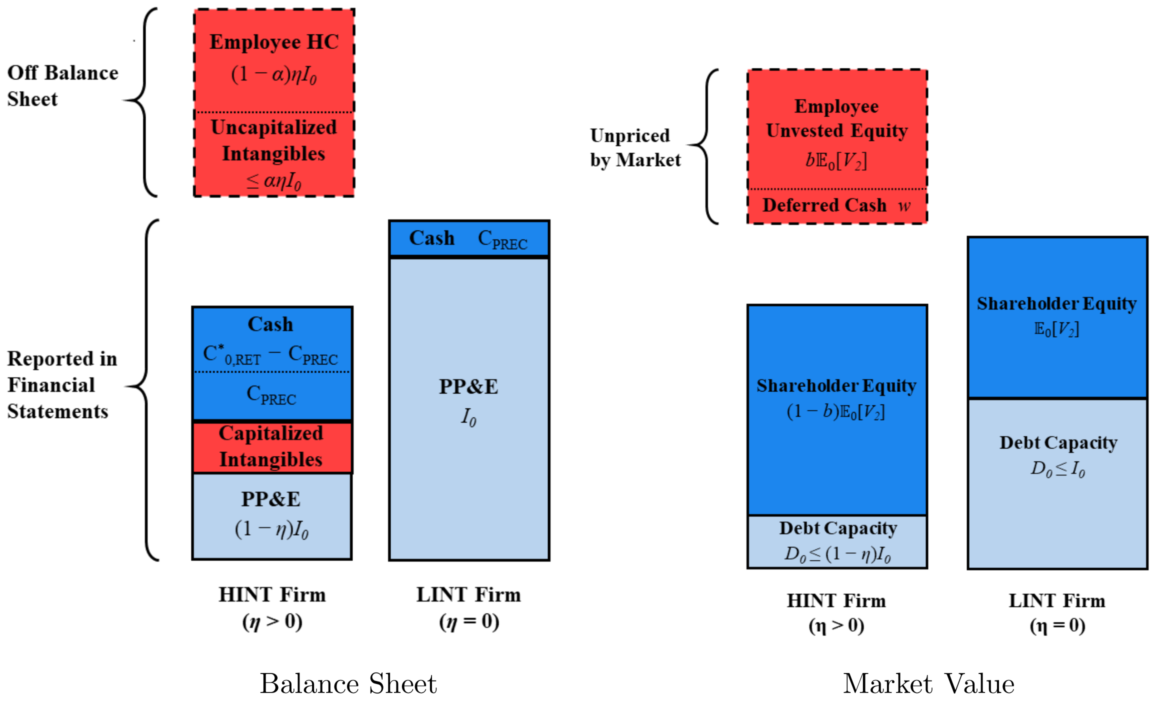
5. Revising Financial Statements

Our framework suggests that a significant amount of HINT firms' investment activity is not recorded in financial statements. Tangible investment $(1-\eta)I_t$ is recorded as Capital Expenditures (CAPEX) in the cash flow statement and capitalized as Property, Plant, and Equipment on the balance sheet. However, intangible investment contributed to the firm by skilled human capital $(1-\alpha)\eta I_t$ is unrecorded. Moreover firms expense deferred compensation grants only as they vest, creating a timing mismatch between intangible investment and the outlays that pay for it.

Furthermore, accounting rules classify observable firm spending on R&D, advertisements, marketing, and organizational capital as ordinary business expenses in the income statement (typically SG&A), and most intangible assets created from such spending are not recorded on the balance sheet.[17] Recent work recognizes some of this spending is an investment in technology and other competences, and adds it to the firm's capital stock (Peters and Taylor, 2017; Bellstam et al., 2017). In our framework this represents only a fraction $\alpha\eta I_t$ of total intangible investment.

[17] Some firm intangible spending is recorded on the balance sheet, such as patent or trademark fees, own software once commercially viable, and purchases of external intangible assets classified as part of goodwill.

Figure 9: Revised View of Corporate Financials



Note: Capitalized and Uncapitalized Intangibles together sum to $\alpha\eta I_0$. Accounting rules permit firms to only capitalize a small portion of intangibles.

Thus increased use of intangible assets implies a growing divergence with traditional financial reporting and valuation. Figure 9 puts forth a revised view of financial statements, by mapping the balance sheets and market values of HINT ($\eta > 0$) and LINT ($\eta = 0$) firms to model parameters at $t = 0$. HINT firms appear to possess fewer book assets than LINT firms, since a standard balance sheet leaves a rising share of firm intangible spending $\alpha\eta I_0$ uncapitalized, and does not record human capital $(1-\alpha)\eta I_0$ contributed by employees. LINT firms' market values can be reasonably approximated as the sum of debt holdings and equity market capitalization. In contrast, a significant share of HINT firms' value is pledged to employees as deferred compensation. This should be added to the market capitalization, which reflects only insider and external shareholders' claims on the firm.

This revised view implies that traditional financial statements are less informative for HINT than LINT firms. Yet corporate valuation relies heavily on reported financials, potentially in-

Figure 10: Classification of Sectors by Capital Composition

Share of intangible capital (η)

Intangible investment composition (α)

	High physical capital	High intangibles
Low human capital	Heavy industry Construction	Consumer brand firms Monopolies
High human capital	Pharmaceuticals Tesla	Software Digital services

creasing the noise and volatility of HINT firms' market prices. For example, the widely used Price/Earnings ratio misvalues HINT firms when the numerator does not incorporate equity grants to employees. Fundamental growth rates are a key input in discounted cashflow models, but they are based on measurable investment spending and hence may be underestimated.

This view implies that while *measurable* investment spending is declining (Gutiérrez and Philippon, 2017), total investment activity is underestimated. Moreover the traditional distinction between returns to labor and capital may be losing relevance, as skilled employees claim a growing share of corporate market value. Next to the classic distinction between intangible and tangible assets, our classification highlights the relative contribution of human capital in intangible capital, which also varies across firms and sectors (see Figure 10). This ratio is objectively difficult to measure, unlike recorded tangible and intangible expenditures.

More fundamentally, in a technological transition towards more valuable intangibles, HINT firms will show rising market valuations and declining CAPEX investment, which will boost their market-to-book ratios. They will also record a declining demand for outside capital, producing a rising negative correlation between Tobin's Q measures and financing as documented in Lee et al. (2018).

6. Conclusions

The paper puts forth a novel view of how intangible capital is created, highlighting the most salient differences from tangible assets as a foundation for a new view of corporate financing needs. It highlights the importance of unvested equity for firm financing and payout policy, and identifies a novel conflict of interest that requires adequate inside equity. By stressing the substitution effect between tangible and intangible capital, it contributes to explain how technological shifts to intangible investment helps explaining recent trends in firm financing, risk management, and payout policy.

The theory builds on two insights about the specific nature of intangible capital. First, while traditional investment involves upfront purchases of physical capital, intangibles are developed jointly by firm resources and creative employees contributing their skills. Second, because human capital cannot be purchased, HINT firms must offer employees a deferred share of the returns to intangible assets. Therefore HINT firms have lower upfront spending needs and less demand for external financing. This contrasts with existing models in which the primary feature of intangibles is a lower debt capacity. Empirically, HINT firms indeed have higher free cashflows, even among subsamples that seem financially unconstrained (such as dividend-paying firms).

Our model generates a rich set of empirical predictions about how financial policies vary with firms' technological reliance on intangibles. First, HINT firms use more inside financing such as employee share grants, while LINT firms raise more external financing. Second, one reason that HINT firms hold more cash than LINT firms is to insure risk-averse employees. Third, HINT firms have lower capacity to raise external equity and require a larger contribution from insiders and early-stage investors to succeed. These predictions apply to unconstrained firms with no precautionary need to conserve resources.

The framework also yields counterintuitive implications that would not emerge from an analysis focused on traditional financial constraints. One is that successful firms may hold the most cash, as this reduces the amount of valuable equity they must share with employees. Another is that insiders who face low growth prospects may encourage key employees to leave, thereby cancelling the dilution from deferred equity pay. Finally, it shows how risky debt may exacerbate diversion risk for high intangible firms.

The modelling framework can easily be applied to additional research questions. Future work can more carefully study how reliance on human capital creates a hold-up problem that makes compensation renegotiation costly. The threat of entry can also be explicitly modelled to derive further implications for employee retention.

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Appendix A Explanation of Motivating Facts Calculations

This appendix contains definitions of the empirical measures used in Section 2, as well as some accompanying notes to the figures and table. Unless otherwise noted, the source of each data item is Compustat.

A.1 Variable definitions

Variable	Definition
Intangibles Ratio	A firm's stock of intangible assets (data item K_INT from the Peters and Taylor Total Q dataset) divided by total assets. The stock of intangible assets is measured as capitalized annual spending on R&D plus capitalized annual spending on organizational capital plus intangible assets reported on the balance sheet (including goodwill). Throughout the paper, total assets are defined as the sum of intangible assets and PP&E (Compustat data item PPENT).
Net Leverage	Long-term debt (data item DLTT) plus short-term debt (DLC) minus cash and marketable securities (CHE), divided by total assets. This variable is winsorized at the 1-99 level.
Cash Holdings	Cash and marketable securities (data item CHE) divided by total assets. This variable is winsorized at the 1-99 level.
Tangible Investment	The annual net change in tangible assets, measured as PP&E in the current year (data item PPENT) plus depreciation of tangible assets (DP minus AM) minus PP&E in the previous year, divided by operating cashflows. Throughout the paper, operating cashflows are operating income before depreciation (OIBDP) plus *Intangible Investment* minus taxes (TXT) minus interest payments (XINT). This variable is set to missing for firms with negative operating cashflows, and is winsorized at the 1-99 level.
Intangible Investment	Annual R&D spending (data item XRD) plus 0.3×SG&A spending (XSGA) plus the annual net change in intangible assets reported on the balance sheet, divided by operating cashflows. The annual net change in reported intangibles is intangible assets reported on the balance sheet in the current year (INTAN) plus amortization (AM) minus intangible assets reported on the balance sheet in the previous year. Missing values of XRD and XSGA are interpolated following Peters and Taylor (2017). Starting in 2006, the fair-value expense of annual stock option grants to employees (OPTFVGR) is deducted from SG&A, as this expense is not a cash outlay. This variable is set to missing for firms with negative operating cashflows, and is winsorized at the 1-99 level.
Free Cashflows	Operating cashflows minus *Tangible Investment* minus *Intangible Investment*, divided by operating cashflows. This variable is set to missing for firms with negative operating cashflows, and is winsorized at the 1-99 level.
Debt Issued	Cash received from issuing long-term debt (data item DLTIS). When DLTIS is missing, the variable equals the long-term debt (DLTT) in the current year minus the difference between the previous year's values of long-term debt and debt scheduled to mature in two years (DD2). This variable is winsorized at the 1-99 level.
Retained Earnings	*Free Cashflows* minus *Dividends* minus *Repurchases*. This variable is set equal to 0 if negative, and is winsorized at the 1-99 level.
Deferred Equity	The annual grant-date fair value of restricted stock (data item STKCO, set to 0 if missing before 2005) plus stock option grants paid to non-executive employees, divided by *Debt Issued* plus *Retained Earnings* plus *Deferred Equity*. Employee option grant values are measured following **?** as the Black-Scholes value of total stock options granted minus the Black-Scholes value of stock options granted to top executives listed in Compustat ExecuComp.
Dividends	Annual payouts of common dividends (data item DVC) divided by *Free Cashflows*. This variable is winsorized at the 1-99 level.
Repurchases	Annual spending on share repurchases divided by *Free Cashflows*. Spending on repurchases is measured following Fama and French (2001) to exclude shares bought back to fulfill employee option exercises. It equals the annual change in number of shares in the corporate treasury (data item TSTKC). For firms with zero or missing values of TSTKC in the two previous years, it equals open-market purchases of common stock (PRSTKC) minus sales of common stock (SSTK). This variable is winsorized at the 1-99 level.
Retained Cashflows	*Free Cashflows* minus *Dividends* minus *Repurchases*, divided by *Free Cashflows*. This variable is winsorized at the 1-99 level.

A.2 Figure and table notes

Figure 1. *Net Leverage* or *Cash Holdings* are plotted for the median HINT firm, LINT firm, and HINT firm that does not operate in an IT sector. IT sectors are the Fama-French 48 industries Computers, Electronic Equipment, Measuring and Control Equipment, and Business Services (SIC codes 7370 to 7379 only).

Figure 2. Plots show *Tangible Investment*, *Intangible Investment*, and *Free Cashflows* for the median HINT and LINT firm. Each variable's median value is calculated over five-year intervals that end in the year shown on the figure.

Figure 3. For each firm, *Debt Issued*, *Retained Earnings*, and *Deferred Equity* are averaged over five-year intervals that end in the year shown on the figure, and then divided by the sum of the averaged values of the three variables. The resulting values are averaged across all HINT or LINT firms in each five-year interval, and then plotted in the figure.

Figure 4. Plots show *Dividends*, *Repurchases*, and *Retained Cashflows* for the median HINT and LINT firm. Plots show the median annual value, averaged over five-year intervals that end in the year shown on the figure.

Table 1. Columns (1) through (3) report variables for the median HINT and LINT firm, as well as the difference in medians. Columns (4) through (6) report values for HINT and LINT firms with positive values of *Dividends* in the year, while columns (7) through (9) report values for HINT and LINT firms in the S&P 500 index during the year.

Appendix B General Solution to Problem 7

The main text in Section 3 focuses on specific solution regions to Problem 7. This appendix presents the general solution to the problem, covering all possible cases. The insider's maximization problem at $t = 0$ can be expressed using the Lagrangian function (7), re-posted here for convenience:[18]

$$\begin{aligned}
\max_{A_0,w,b} \quad \mathcal{L} = {} & (1-b)\Big\{A_0 + q(\theta_1^h + \bar{\theta}_2^h) + (1-q)(\theta_1^l + \bar{\theta}_2^l) - w\Big\} - A_0 \\
& + \mu_h\Big\{w + b[A_0 + \theta_1^h + \bar{\theta}_2^h - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^h\Big\} \\
& + \mu_l\Big\{w + b[A_0 + \theta_1^l + \bar{\theta}_2^l - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^l\Big\} \\
& + \phi_h\Big\{(1-b)[\bar{\theta}_2^h - w] - b[A_0 + \theta_1^h]\Big\} \\
& + \phi_l\Big\{(1-b)[\bar{\theta}_2^l - w] - b[A_0 + \theta_1^l]\Big\} \\
& + \lambda\Big\{C_0 - C_{PREC}\Big\}
\end{aligned} \tag{16}$$

Maximizing Eq. (16) with respect to each choice variable yields:

$$\frac{\partial \mathcal{L}}{\partial A_0} = b(-1 + \mu_h + \mu_l - \phi_h - \phi_l) + \lambda = 0 \tag{17}$$

$$\frac{\partial \mathcal{L}}{\partial w} = (1-b)(-1 + \mu_h + \mu_l - \phi_h - \phi_l) = 0 \tag{18}$$

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial b} = & -\Big\{q(\theta_1^h + \bar{\theta}_2^h) + (1-q)(\theta_1^l + \bar{\theta}_2^l) + A_0 - w\Big\} \\
& + \mu_h\Big\{A_0 + \theta_1^h + \bar{\theta}_2^h - w - 2\rho b\sigma^2\Big\} + \mu_l\Big\{A_0 + \theta_1^l + \bar{\theta}_2^l - w - 2\rho b\sigma^2\Big\} \\
& - \phi_h\Big\{A_0 - w + \theta_1^h + \bar{\theta}_2^h\Big\} - \phi_l\Big\{A_0 - w + \theta_1^l + \bar{\theta}_2^l\Big\} = 0
\end{aligned} \tag{19}$$

[18] Formally, the Lagrangian should also consist of non-negativity constraints for A_0, w, b. We omit these constraints for ease of readibility.

The complementary slackness conditions are:

$$\mu_h \Big\{ w + b[A_0 + \theta_1^h + \bar{\theta}_2^h - w] - \rho b^2 \sigma^2 - (1-\alpha)\eta s^h \Big\} = 0 \tag{20}$$

$$\mu_l \Big\{ w + b[A_0 + \theta_1^l + \bar{\theta}_2^l - w] - \rho b^2 \sigma^2 - (1-\alpha)\eta s^l \Big\} = 0 \tag{21}$$

$$\phi_h \Big\{ (1-b)[\bar{\theta}_2^h - w] - b[A_0 + \theta_1^h] \Big\} = 0 \tag{22}$$

$$\phi_l \Big\{ (1-b)[\bar{\theta}_2^l - w] - b[A_0 + \theta_1^l] \Big\} = 0 \tag{23}$$

$$\lambda \Big\{ A_0 - I_0^f - I_1^f - \theta_1^l \Big\} = 0 \tag{24}$$

Together, conditions (17)–(24) define the optimal choices $(A_0^*, w^*, b^*, \mu_h, \mu_l, \phi_h, \phi_l, \lambda)$.

As in the main text, we split the analysis into the RET Region, defined by a slack (PREC) and $\lambda = 0$, and the PREC Region, defined by a binding (PREC) and $\lambda > 0$. By Lemmas 1 and 2, (PC_h) always binds and (IC_h) is always slack, so $\mu_h > 0$ and $\phi_h = 0$. Table 2 summarizes all remaining cases, categorized into RET and PREC region.

B.1 RET Region

In the RET Region, $\lambda = 0$, and hence the FOCs w.r.t. A_0 and w (Eqs. (17) and (18)) collapse to one single condition:

$$\mu_h + \mu_l = 1 + \phi_l. \tag{25}$$

Hence, in the RET region there is indeterminacy between $w \geq 0$ and $A_0 \geq A_{PREC}$, as long as wages are not so large that they become risky, $w \leq A_0 + \theta_1^l \equiv \bar{w}$ (as discussed in the main text). Instead, the solution determines the optimal level of insurance provided to the employee, defined as

$$INS(w, A_0; b) = bA_0 + (1-b)w.$$

Given the optimal b^*_{RET}, $INS(w, A_0, b)$ follows as the residual from (PC_h):

$$INS(w, A_0; b^*_{RET}) = \rho b^{*2}_{RET} \sigma^2 + (1-\alpha)\eta s^h - b^*_{RET}[\theta_1^h + \bar{\theta}_2^h]$$

Table 2: Possible cases for the solution to Problem 16. "=" indicates a binding constraint, ">" indicates that a constraint is slack.

	RET Region			**PREC Region**	
	RET interior	RET-PCL	RET-IC	PREC	PREC-IC
(PC_h)	=	=	=	=	=
(PC_l)	>	=	>	>	>
(IC_l)	>	>	=	>	=
$(PREC)$	>	>	>	=	=

To determine b^*_{RET}, plug (25) into the firm's FOC w.r.t. b (19):

$$b^*_{RET} = \frac{(1 - q + \phi_l - \mu_l)\Delta\theta}{2(1 + \phi_l)\rho\sigma^2} \tag{26}$$

The optimal share grant depends on parameters, as well as the Lagrangian multipliers μ_l and ϕ_l, associated with the constraints (PC_l) and (IC_l). Within the RET region, there are three cases to consider, as indicated in Table 2.

Case 1: RET interior. In this case, (PC_l) and (IC_l) are both slack, and hence $\mu_l = \phi_l = 0$, and b^*_{RET} directly follows from (26):

$$b^*_{RET} = \frac{(1 - q)\Delta\theta}{2\rho\sigma^2}$$

The cost of providing stock compensation is that it exposes the employee to risk. The benefit is that a share grant is worth less in the low state than a fixed deferred salary, reducing the rents paid in the low state. At this interior solution, the insider optimally trades off these two forces.

Case 2: RET-PCL. In this case, (PC_l) binds and (IC_l) is slack, so that $\mu_l > 0$ and $\phi_l = 0$. Note that b^*_{RET} decreases in μ_l, hence the insider offers a lower level of stock compensation than he would if (PC_l) were slack. In this case, the insider would optimally like to offer so much stock compensation that the employee leaves in the low state. To prevent the employee from leaving, the insider reduces b to the point where (PC_l) is just satisfied. The optimal b follows from combining (PC_h) and (PC_l):

$$b^*_{RET} = \frac{(1-\alpha)\eta\Delta s}{\Delta\theta} \tag{27}$$

The optimal level μ_l^* follows from plugging (27) and $\phi_l = 0$ into (26).

Case 3: RET-IC. In this case, (PC_l) is slack and (IC_l) binds, so that $\mu_l = 0$ and $\phi_l > 0$. Note that b^*_{RET} increases in ϕ_l, hence the insider offers a higher level of stock compensation than she would if (IC_l) were slack. In this case, the insider would optimally like to leave so much rents to the employee in the low state that she cannot commit not to divert resources in the low state. To overcome this moral hazard problem, the insider offers a higher level of b, so as to reduce the rents received by the employee in the low state, up to the point where (IC_l) is just satisfied (at the cost of higher INS, to still satisfy (PC_h)). In this case, the optimal b follows from combining (PC_h) and (IC_l):

$$\rho b^2\sigma^2 - b\Delta\theta + (1-\alpha)\eta s^h - \bar{\theta}_2^l = 0. \tag{28}$$

This equation only has a solution if $(1-\alpha)\eta s^h \leq \bar{\theta}_2^l$ and the optimal b^*_{RET} is defined as the smaller root to this quadratic equation. ϕ_l^* follows from plugging b^*_{RET} into (26).

B.2 PREC Region

In the PREC Region, $\lambda > 0$ and (PREC) binds, such that optimal cash holdings immediately follow as $C_0 = C_{PREC}$, so that $A_0 = A_{PREC}$. From (17), it is clear that with $\lambda > 0$, it must be that $-1 + \mu_h + \mu_l - \theta_h - \theta_l < 0$. But this implies that $\frac{\partial \mathcal{L}}{\partial w} < 0$, by Eq. (18), and hence the firm is at the corner where $w = 0$.

The optimal equity grant can be derived by plugging A_{PREC} into (PC_h) and solving for b^*. This yields a quadratic equation that implicitly defines the optimal equity grant:

$$b[(1-\eta)(I_0 + I_1) + \alpha\eta I_1 + \theta_1^h - \theta_1^l + \bar{\theta}_2^h] - \rho b^2\sigma^2 - (1-\alpha)\eta s^h = 0. \tag{29}$$

The smaller root to this equation, which we denote denote b^*_{PREC}, is optimal as it minimizes compensation cost.

Is it feasible for the firm to offer b^*_{PREC} while holding C_{PREC}? This depends on whether the insider's incentive compatibility constraint (IC_l) is satisfied. Re-arranging (IC_l), it puts an upper bound on the share grant the insider can grant without violating the constraint:

$$b \leq \frac{\bar{\theta}_2^l}{\theta_1^l + \bar{\theta}_2^l + A_{PREC}} = \frac{\bar{\theta}_2^l}{I_0^f + I_1^f + \bar{\theta}_2^l} \equiv \bar{b}$$

Case 4: PREC If $b^*_{PREC} \leq \bar{b}$, (PC_h) and (PREC) bind, while all other constraints remain slack. The insider offers b^*_{PREC} and $w^* = 0$, while holding C_{PREC} to ensure re-investment. Relative to the RET region, the insider offers less stock compensation, because the cash holdings that are needed to ensure re-investment in the low state already provide more than enough insurance to the employee in the high state.

Case 5: PREC-IC If $b^*_{PREC} > \bar{b}$, the insider's moral hazard problem cannot be overcome in the low state, and diversion will occur. The problem is that the high cash savings are simply too attractive for the insider not to divert. Interestingly, it may still be possible to prevent diversion by setting $b = 0$ and $w = (1-\alpha)\eta s^h$. With $b = 0$, the insider does not need to share any cash with the employee, and instead pays a high fixed salary in both states. Plugging these into (IC_l), it is clear that this contract can prevent diversion if

$$\bar{\theta}_2^l \geq (1-\alpha)\eta s^h.$$

If $b^*_{PREC} > \bar{b}$ and $\bar{\theta}_2^l < (1-\alpha)\eta s^h$, there is no contract that prevents the moral hazard problem and at the same time allows to retain the employee. Hence, in this case the project cannot be undertaken.

Appendix C External Financing

This appendix solves the model with external financing from Section 4.1, relaxing the assumption that the insider's initial endowment W_0 is sufficient to fund all investment needs $I_0^f + I_1^f$.

C.1 Firm's Problem with External Financing

Funding Constraints. To start the project, the insider's contribution and external financing must satisfy:

$$A_0 + E_0 + D_0 \geq I_0^f \tag{IFC}$$

Any excess resources at the end of $t = 0$ are held as cash $C_0 = A_0 + E_0 + D_0 - I_0^f$. The firm must also meet its re-investment needs at $t = 1$, using cash or debt. The re-formulated (PREC) constraint is thus given by

$$C_0 + D_1 \geq I_1^f - R_1^l \tag{PREC$'$}$$

We focus here on the RET solution region by assuming the firm can raise sufficient safe debt to fund investment needs at $t = 0$ and 1 by collateralizing tangible assets. For example, this can be guaranteed by assuming that $A_0 \geq \alpha\eta I_0$ and $A_0 + \theta_1^l \geq \alpha\eta I_1$. With these two conditions (IFC) and (PREC$'$) are satisfied if the firm raises $D_t = (1 - \eta)I_t$.

Debt financing allows a firm with small endowment W_0 to fund tangible investment at $t = 0$ and $t = 1$. However, cash obtained from issuing debt does not insure the employee, because her deferred equity claim b is on firm value net of debt repayments at $t = 2$.[19] In contrast, external equity funding can be used to either cover investment needs or convey insurance. The latter occurs because a fraction bE_0 of cash proceeds is transferred to the employee at $t = 2$.

Without loss of generality, the firm's problem can be simplified by setting debt issuance in each period equal to tangible investment: $D_t = (1-\eta)I_t$. In the RET solution region the amount of safe debt issuance does not affect affect the insider's and employee's utilities. While raising debt provides additional cash at $t = 0$, it also reduces the firm's recovery value from selling tangible assets at $t = 2$ by the same amount, and thus has no impact on net cash holdings.

[19] Debt may offer benefits that are outside the scope of the model, such as reduced screening and enforcement costs next to fiscal savings.

To see this, note the employee's participation constraints (PC_h) and (PC_l) are the same as in Section 3, re-posted here for convenience:

$$w + b\mathbb{E}_1^i[V_2] - \rho b^2 Var_1^i[V_2] \geq (1-\alpha)\eta s^i. \tag{PC_i}$$

Importantly, raising safe debt does not alter the firm's final value, as both D_0 and D_1 drop out:

$$\begin{aligned}\mathbb{E}_1^i[V_2] &= \underbrace{A_0 + D_0 + E_0 - I_0^f}_{= C_0} \quad + \quad \underbrace{R_1^i + D_1 - I_1^f}_{\text{Free Cashflow } t=1} + \underbrace{\bar{R}_2^i - w + K_2 - D_0 - D_1}_{\text{Final Payoff and Recovery Value}} \\ &= A_0 + E_0 + \theta_1^i + \bar{\theta}_2^i - w\end{aligned}$$

Therefore, the value of the employee's share grant $b\mathbb{E}_1^i[V_2]$ is not a function of how much safe debt the firm issues. Risky debt even makes matters worse as it increases the volatility of the employee's share grant, reducing its utility value. These considerations show that only outside equity but not debt financing can support employee retention so we can set debt to the value of tangible capital $D_t = (1-\eta)I_t$ as indicated in Lemma 6 in the main text.

In the PREC solution region the firm's optimal choice is to fully fund tangible investment at $t = 1$ using debt. The option to raise debt when state l is realized allows the firm to set aside less precautionary cash savings at $t = 0$. This in turn reduces the amount of rents that the employee receives in state h, when precautionary cash is not used.

Fixing debt issuance allows us to express the firm's initial funding constraint (IFC) and revised precautionary savings constraint (PREC$'$) at $t = 1$ in terms of A_0 and E_0:

$$A_0 + E_0 \geq \alpha\eta I_0 \tag{IFC}$$

$$A_0 + E_0 \geq \alpha\eta I_1 - \theta_1^l \tag{PREC$'$}$$

(IFC) shows that total initial funding contributed by the insider and external shareholders must cover the firm's intangible investment at $t = 0$. (PREC$'$) shows that the initial contribution also must exceed net intangible re-investment needs at $t = 1$. Taken together, the constraints show that the firm must raise external equity if either $W_0 < \alpha\eta I_0$ or $W_0 < \alpha\eta I_1 - \theta_1^l$.[20] It also may optimally choose to raise additional external equity to help insure the employee.

Incentive Compatibility. In the presence of external financing, the insider's payoff from diversion is:

$$\underbrace{\alpha\eta I_1}_{\text{Private Benefit}} \quad + \quad (1-e) \quad \underbrace{[C_1 + K_2]}_{\text{Firm Value After Diversion}} \quad = \quad e\alpha\eta I_1 + (1-e)[A_0 + E_0 + \theta_1^i].$$

The insider's payoff at $t = 1$ from continuation without diversion is:

$$(1-e-b)\mathbb{E}_1[V_2^i] = (1-e-b)[A_0 + E_0 + \theta_1^i + \bar{\theta}_2^i - w] \tag{30}$$

As before, the insider's incentive compatibility constraint in each state is derived by comparing the net gain from continuation (left-hand side) to the net gain from diversion (right-hand side), as also shown in the main text and re-posted here:

$$(1-e-b)\left[\bar{\theta}_2^h - w\right] \geq e\alpha\eta I_1 + b\left[A_0 + E_0 + \theta_1^h\right] \tag{IC'_h}$$

$$(1-e-b)\left[\bar{\theta}_2^l - w\right] \geq e\alpha\eta I_1 + b\left[A_0 + E_0 + \theta_1^l\right]. \tag{IC'_l}$$

The revised constraints differ in two ways from those in Section 3. First, moral hazard is exacerbated by external equity financing. The net gain from continuation decreases in e as well as b, because the project's expected future surplus must be shared with both external shareholders and employees. The insider also does not internalize the full cost of diverting intangible investment, as she claims $e\alpha\eta I_1$ from external shareholders for her own private benefit. Thus, intangible intensity η directly increases the insider's propensity to divert. Second, the compensation overhang effect (the second term on the right-hand side) is larger than in Section 3. Diversion allows the insider to re-claim not only the employee's deferred compensation when she leaves, but also part of the initial funding that external shareholders provided as insurance.

Each constraint can be re-arranged to implicitly define an upper bound $\bar{e}_i$, such that diversion

[20] Specifically, to ensure the project's completion the firm must raise external equity at $t = 0$ of at least $max(0,\ \alpha\eta I_0 - W_0,\ \alpha\eta I_1 - \theta_1^l - W_0)$.

in state $i = h, l$ is avoided if and only if the insider sells a stake $e \leq \bar{e}_i$. We derive $\bar{e}_i$ explicitly for different solution regions below. The main text focuses on the relevant threshold $\bar{e}_l$, which is simply denoted $\bar{e}$.

C.2 Firm Problem

Because equity is fairly priced ($E_0 = e\mathbb{E}_0[V_2]$) the firm's objective function can be written as:

$$U^f = (1 - b - e)\mathbb{E}_0[V_2] - A_0 = (1 - b)\mathbb{E}_0[V_2] - (A_0 + E_0).$$

With e eliminated, the firm's choice variables are A_0, E_0, w, b and the firm problem can be written as the following Lagrangian:

$$\begin{aligned}
\max_{A_0,E_0,w,b} \quad \mathcal{L} = {} & (1-b)\Big\{A_0 + E_0 + \bar{\theta}_1 + \bar{\theta}_2 - w\Big\} - (A_0 + E_0) \\
& + \mu_h\Big\{w + b[A_0 + E_0 + \theta_1^h + \bar{\theta}_2^h - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^h\Big\} \\
& + \mu_l\Big\{w + b[A_0 + E_0 + \theta_1^l + \bar{\theta}_2^l - w] - \rho b^2\sigma^2 - (1-\alpha)\eta s^l\Big\} \\
& + \phi_h\Big\{(1-b)[\bar{\theta}_2^h - w] - b[A_0 + E_0 + \theta_1^h] - \frac{E_0(\bar{\theta}_2^h - w + \alpha\eta I_1)}{A_0 + E_0 + \bar{\theta}_1 + \bar{\theta}_2 - w}\Big\} \\
& + \phi_l\Big\{(1-b)[\bar{\theta}_2^l - w] - b[A_0 + E_0 + \theta_1^l] - \frac{E_0(\bar{\theta}_2^l - w + \alpha\eta I_1)}{A_0 + E_0 + \bar{\theta}_1 + \bar{\theta}_2 - w}\Big\} \\
& + \lambda\Big\{A_0 + E_0 + \theta_1^l - \alpha\eta I_1\Big\} \\
& + \kappa\Big\{A_0 + E_0 - \alpha\eta I_0\Big\}
\end{aligned} \tag{31}$$

The Lagrange multipliers are defined as in Problem 7. The new constraint relative to Problem 7 is the initial funding constraint (IFC), with the Lagrange multiplier κ.

Maximizing Problem. (31) with respect to E_0, w and b yields:

$$\frac{\partial \mathcal{L}}{\partial E_0} = b(-1+\mu_h+\mu_l-\phi_h-\phi_l)+\lambda-\phi_h\frac{(\bar{\theta}_2^h-w+\alpha\eta I_1)(A_0+\bar{\theta}_1+\bar{\theta}_2-w)}{(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w)^2}+\kappa \tag{32}$$
$$-\phi_l\frac{(\bar{\theta}_2^l-w+\alpha\eta I_1)(A_0+\bar{\theta}_1+\bar{\theta}_2-w)}{(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w)^2}=0$$

$$\frac{\partial \mathcal{L}}{\partial w} = (1-b)(-1+\mu_h+\mu_l-\phi_h-\phi_l)+\phi_h\frac{E_0(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-\bar{\theta}_2^h-\alpha\eta I_1)}{(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w)^2} \tag{33}$$
$$+\phi_l\frac{E_0(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-\bar{\theta}_2^l-\alpha\eta I_1)}{(A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w)^2}=0$$

$$\frac{\partial \mathcal{L}}{\partial b} = -\Big\{A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w\Big\} \tag{34}$$
$$+\mu_h\Big\{A_0+E_0+\theta_1^h+\bar{\theta}_2^h-w-2\rho b\sigma^2\Big\}+\mu_l\Big\{A_0+E_0+\theta_1^l+\bar{\theta}_2^l-w-2\rho b\sigma^2\Big\}$$
$$-\phi_h\Big\{A_0+E_0-w+\theta_1^h+\bar{\theta}_2^h\Big\}-\phi_l\Big\{A_0+E_0-w+\theta_1^l+\bar{\theta}_2^l\Big\}=0$$

The complementary slackness conditions are:

$$\mu_h\Big\{w+b[A_0+E_0+\theta_1^h+\bar{\theta}_2^h-w]-\rho b^2\sigma^2-(1-\alpha)\eta s^h\Big\}=0 \tag{35}$$

$$\mu_l\Big\{w+b[A_0+E_0+\theta_1^l+\bar{\theta}_2^l-w]-\rho b^2\sigma^2-(1-\alpha)\eta s^l\Big\}=0 \tag{36}$$

$$\phi_h\Big\{(1-b)[\bar{\theta}_2^h-w]-b[A_0+E_0+\theta_1^h]-\frac{E_0(\bar{\theta}_2^h-w+\alpha\eta I_1)}{A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w}\Big\}=0 \tag{37}$$

$$\phi_l\Big\{(1-b)[\bar{\theta}_2^l-w]-b[A_0+E_0+\theta_1^l]-\frac{E_0(\bar{\theta}_2^l-w+\alpha\eta I_1)}{A_0+E_0+\bar{\theta}_1+\bar{\theta}_2-w}\Big\}=0 \tag{38}$$

$$\lambda\Big\{A_0+E_0+\theta_1^l-\alpha\eta I_1\Big\}=0 \tag{39}$$

Together, conditions (32)–(39) define the optimal choices $(E_0^*, w^*, b^*, \mu_h, \mu_l, \phi_h, \phi_l, \lambda)$.

C.3 Model Solution in RET region

Because our purpose is to study how firms shape policies that encourage human capital investment, the discussion below focuses on the RET solution region in which the funding constraints (IFC) and (PREC$'$) are both satisfied, i.e., when $W_0 \geq \alpha\eta I_0$ and $\theta_1^l \geq \alpha\eta I_1$ and so $\lambda = \kappa = 0$.

We first solve the model for the RET region when both (PC_l) and (PC_h) bind. As in Section 3, the firm's compensation grant includes equity to match the employee's state-contingent outside option. Because the employee's participation constraints are unchanged, $b^*_{RET'}$ and the associated comparative statics remain the same. (This requires the incentive compatibility constraints to be satisfied, a condition we check below.)

Employee insurance can now be conveyed by three resources: Insider-funded cash holdings A_0, external equity-funded cash E_0, and deferred wages w. The overall insurance level is:

$$INS(w, A_0, E_0; b) \equiv b(A_0 + E_0) + (1 - b)w. \tag{40}$$

Optimal insurance $INS^*_{RET'}$ remains the same, and for certain parameter values an equivalence exists between two or even all three sources of insurance.

If optimal insurance can be achieved using only insider-funded cash and deferred wages, then there is no need to raise external equity financing. This occurs when $INS(\bar{w}', W_0; b^*_{RET'}) \geq INS^*_{RET'}$. By setting $e = E_0 = 0$, (IC'_h) and (IC'_l) collapse to (IC_h) and (IC_l) in Section 3. By Lemma 1, insiders can then satisfy the incentive compatibility constraints by offering compensation such that both (PC_h) and (PC_l) bind.

However when W_0 and $\bar{w}'$ are sufficiently low, the insider must sell a stake $e > 0$ to achieve $INS^*_{RET'}$. We derive the required stake when the insider contributes all of her endowment and grants $\bar{w}'$, and then check whether it exceeds $\bar{e}_l$. It is helpful to re-express E_0 in terms of e:

$$\begin{aligned} E_0 &= e\mathbb{E}_0[V_2] \\ &= e[A_0 + E_0 + \bar{\theta}_1 + \bar{\theta}_2 - \bar{w}'] \\ &= e(\bar{\theta}_1 + \bar{\theta}_2 - \theta^l_1) \end{aligned} \tag{41}$$

where $\bar{\theta}_1 \equiv q\theta^h_1 + (1 - q)\theta^l_1$ and $\bar{\theta}_2 \equiv q\bar{\theta}^h_2 + (1 - q)\bar{\theta}^l_2$ are the initial expectations of θ_1 and θ_2.

Denote e_{INS^*} as the equity stake the insider must sell to achieve optimal insurance. This is calculated by plugging $INS^*_{RET'}, b^*_{RET'}, w = \bar{w}', A_0 = W_0$, and E_0 from Eq. (41) into Eq. (40):

$$\begin{aligned} INS^*_{RET'} &= b^*_{RET'}(W_0 + E_0) + (1 - b^*_{RET'})\bar{w}' \\ \Rightarrow e_{INS^*} &= \frac{INS^*_{RET'} - W_0 - (1 - b^*_{RET'})\theta^l_1}{\bar{\theta}_1 + \bar{\theta}_2 - \theta^l_1} \end{aligned} \tag{42}$$

Separately, plugging $\bar{w}'$ and Eq. (41) into (IC'_l) yields an equation that implicitly defines $\bar{e}_l$:

$$(1 - b)\bar{\theta}^l_2 + W_0 + \theta^l_1 \geq e[\alpha\eta I_1 + \bar{\theta}^l_2 + W_0 + \bar{\theta}_1 + \bar{\theta}_2] - e^2[\bar{\theta}_1 + \bar{\theta}_2 - \theta^l_1]. \tag{43}$$

The threshold $\bar{e}_l$ is the smaller root to this quadratic equation.

As long as e_{INS^*} does not exceed this value, the insider can convey optimal insurance while also committing to not divert resources at $t = 1$. This solution is summarized in Proposition 4 in the main text.

Appendix D Proofs

This appendix contains proofs of lemmas and propositions.

D.1 Lemma 1 (Section 3)

Proof. Impose that (PC_i) binds and re-arrange:

$$(1-b)w + bA_0 = \rho b^2\sigma^2 + (1-\alpha)\eta s^i - b[\theta_1^i + \bar{\theta}_2^i].$$

Similarly, re-arranging (IC_i) can be written as

$$(1-b)\bar{\theta}_2^i - b\theta_1^i \geq (1-b)w + bA_0.$$

Combining the two equations yields the condition $\bar{\theta}_2^i \geq (1-\alpha)\eta s^i + \rho b^2\sigma^2$, which is satisfied for $i = h, l$ by Assumption 2. □

D.2 Lemma 2 (Section 3)

Proof. To establish that (PC_h) optimally binds, we first suppose that the constraint is slack and then show that the insider can do better by lowering b to the point where (PC_h) binds.

Formally, if (PC_h) was slack, then $\mu_h = 0$, and hence $\mu_l = 1 + \phi_h + \phi_l - \frac{\lambda}{b}$ by Eq. (17). Plugging this into the first order condition w.r.t. b (19), it is clear that with $\mu_h = 0$:

$$\frac{\partial \mathcal{L}}{\partial b} = -q\Delta\theta - 2\mu_l \rho b\sigma^2 - \frac{\lambda}{b}\left[A_0 - w + \theta_1^l + \bar{\theta}_2^l\right] < 0.$$

The first two terms are clearly negative. To see that the third term is also negative, note that there are two cases to consider. First, if (PREC) is slack, then $\lambda = 0$ and the term drops out. If (PREC) is binding, $\lambda > 0$ but the firm sets the wage optimally at $w = 0$ (Lemma 5), such that the bracket is positive. Therefore, the first order condition is negative if $\mu_h > 0$, and the insider strictly prefers lowering the share grant until $\mu_h = 0$ and (PC_h) binds.

□

D.3 Lemma 3 (Section 3)

Proof. It is easy to see that the employee's compensation must be deferred until $t = 2$. If compensation vested at $t = 1$, in every state the employee would strictly prefer to accept the outside offer and depart the firm.

We next suppose that $b^* = 0$, and then show that it is not possible for conditions (17)–(24) of Problem (16) to all hold.

If $b^* = 0$, then $w = (1 - \alpha)\eta s^h$ to satisfy the participation constraint in state h, so that (PC_l) is slack and $\mu_h > 0$, $\mu_l = 0$. Similarly, (IC_h) is satisfied given that $\bar{\theta}_2^h > (1 - \alpha)\eta s^h$ by Assumption 2.

Plug $b = 0$ and $w = (1 - \alpha)\eta s^h$ into (IC_l), to re-write the constraint as

$$\bar{\theta}_2^l \geq (1 - \alpha)\eta s^h.$$

Now there are two cases to consider. First, if $(1 - \alpha)\eta s^h > \bar{\theta}_2^l$, then the insider is unable to satisfy (IC_l) at $b = 0$, and hence in this case $b = 0$ cannot be optimal.

Second, if $(1-\alpha)\eta s^h \leq \bar{\theta}_2^l$, then ($IC_l$) is slack and hence $\phi_l = 0$. It then follows from (18) that $\mu_h = 1$. Plugging $\mu_h = 1$ and $\mu_l = \phi_l = \phi_h = 0$ into the FOC w.r.t. b in Eq. (19) shows that

$$\frac{\partial \mathcal{L}}{\partial b} = (1 - q)[(A_1^h + \bar{A}_2^h) - (A_1^l + \bar{A}_2^l)] > 0.$$

Hence, in this case the insider would prefer to increase b, inconsistent with $b = 0$ at the optimum. $\square$