# DISCUSSION PAPER SERIES

DP12618

## THE (SELF-) FUNDING OF INTANGIBLES

Robin Döttling, Tomislav Ladika and Enrico Perotti

**FINANCIAL ECONOMICS**

ISSN 0265-8003

# THE (SELF-) FUNDING OF INTANGIBLES

*Robin Döttling, Tomislav Ladika and Enrico Perotti*

Discussion Paper DP12618
Published 18 January 2018
Submitted 18 January 2018

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

# THE (SELF-) FUNDING OF INTANGIBLES


## Abstract

We model how technological change leads to a shift in corporate investment towards intangible capital, and test its implications for corporate financial policy. While tangible assets can be purchased and funded externally, most intangible capital is created by skilled workers investing their human capital, so it requires lower upfront outlays. Indeed, U.S. high-intangibles firms have larger free cash flows and lower total investment spending, and do not appear more financially constrained. We model and test how these firms optimally retain cash for both a precautionary as well as a retention motive. The optimal reward for risk-averse human capital involves deferred compensation and a commitment to retain cash. High-intangibles firms also should favor a payout policy of repurchases over dividends to avoid penalizing unvested claims. Our empirical evidence supports these predictions.



JEL Classification: G32, G35, J24, J33

Keywords: Technological change, intangible assets, cash holdings, Human Capital, corporate leverage, equity grants, deferred equity, share vesting.



Robin Döttling - r.j.doettling@uva.nl
*Univ Amsterdam*

Tomislav Ladika - t.ladika@uva.nl
*Univ Amsterdam*

Enrico Perotti - e.c.perotti@uva.nl
*University of Amsterdam, Amsterdam Business School and CEPR*



Acknowledgements
*We thank Fernando Anjos, Patrick Bolton, Esther Eiling, Mariassunta Giannetti, Dirk Jenter, Paige Ouimet, Per Str•omberg, Shusen Qi, Luke Taylor, Annette Vissing-J rgensen, David Yermack, and many seminar participants for helpful input. We are grateful to Erasmo Giambona for providing us with data on lines of credit. Send correspondence to Enrico Perotti, ABS-University of Amsterdam, Plantage Muidergracht 12, 1018TV Amsterdam. Email: e.c.perotti@uva.nl.

# The (Self-)Funding of Intangibles

Robin Döttling[1], Tomislav Ladika[2] and Enrico Perotti[3]

[1]University of Amsterdam and Tinbergen Institute
[2]University of Amsterdam
[3]University of Amsterdam, CEPR and Tinbergen Institute

October 10, 2017

**Abstract**

We model how technological change leads to a shift in corporate investment towards intangible capital, and test its implications for corporate financial policy. While tangible assets can be purchased and funded externally, most intangible capital is created by skilled workers investing their human capital, so it requires lower upfront outlays. Indeed, U.S. high-intangibles firms have larger free cashflows and lower total investment spending, and do not appear more financially constrained. We model and test how these firms optimally retain cash for both a precautionary as well as a retention motive. The optimal reward for risk-averse human capital involves deferred compensation and a commitment to retain cash. High-intangibles firms also should favor a payout policy of repurchases over dividends to avoid penalizing unvested claims. Our empirical evidence supports these predictions.

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

**JEL classifications. G32, G35, J24, J33**

*We are grateful to Erasmo Giambona for providing us with data on lines of credit. We thank Fernando Anjos, Patrick Bolton, Esther Eiling, Mariassunta Giannetti, Dirk Jenter, Paige Ouimet, Per Strömberg, Shusen Qi, Luke Taylor, Annette Vissing-Jørgensen, David Yermack, and many seminar participants for helpful input. Send correspondence to Enrico Perotti, ABS-University of Amsterdam, Plantage Muidergracht 12, 1012WB Amsterdam. Email: e.c.perotti@uva.nl.

# The (Self-)Funding of Intangibles

October 10, 2017

**Abstract**

We model how technological change leads to a shift in corporate investment towards intangible capital, and test its implications for corporate financial policy. While tangible assets can be purchased and funded externally, most intangible capital is created by skilled workers investing their human capital, so it requires lower upfront outlays. Indeed, U.S. high-intangibles firms have larger free cashflows and lower total investment spending, and do not appear more financially constrained. We model and test how these firms optimally retain cash for both a precautionary as well as a retention motive. The optimal reward for risk-averse human capital involves deferred compensation and a commitment to retain cash. High-intangibles firms also should favor a payout policy of repurchases over dividends to avoid penalizing unvested claims. Our empirical evidence supports these predictions.

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

**JEL classifications. G32, G35, J24, J33**

# 1. Introduction

Progress in information technology since 1980 has transformed corporate investment. Firms' investment into intangible capital has risen progressively relative to physical plant and other tangible assets (Corrado and Hulten, 2010). Such a major shift in capital asset composition can be expected to alter corporate finance practices, and may help explain falling financial leverage and rising corporate cash holdings (Bates et al., 2009; Falato et al., 2013), (see Figure 1).

A natural interpretation is that more intangible assets imply a reduced debt capacity, as raising external financing depends on the ability to offer collateral. Moreover, innovative firms may face higher costs of financial distress (Opler et al., 1999; Froot et al., 1993). By holding more cash, firms with high intangibles to total assets (henceforth HINT firms) can reduce the risk of becoming financially constrained. This view is supported by evidence that increased corporate cash holdings are highly correlated with R&D investment and cashflow volatility (Bates et al., 2009; Pinkowitz et al., 2016; Graham and Leary, 2016).

This paper models and tests how the composition of investment affects corporate funding and payout policy. While lower asset tangibility necessitates more precautionary savings (e.g., Almeida and Campello, 2007), a careful framing of the process of creating intangible capital yields some novel insights. Since intangible investment relies largely on the commitment of human capital over time, it requires lower upfront cash outlays than the acquisition of tangible assets. Indeed, on average HINT firms have lower investment expenditures for a given level of profitability (see Figure 5). Yet since firms cannot own talented employees' human capital (Hart and Moore, 1994), they need to share the value created so as to match their outside options to move to or start another firm (Eisfeldt and Papanikolaou, 2013). This compensation must be deferred to ensure retention, either explicitly by unvested grants or implicitly via career prospects.

We formalize these insights with a simple model in which firms differ in their technological profile and the composition of their investment. Innovative HINT firms require less upfront cash outlays than traditional firms that operate with more tangible assets. On the other hand, these firms need to reward human capital by promising more future earnings via deferred compensation over time. These rewards are due once revenues are realized.

All firms may face some shock at the interim date that requires additional investment. While low-intangibles (LINT) firms can pledge assets to raise financing, HINT firms need to self-finance more expenditures. On the other hand, some intangible investment is supported by human capital, so it requires lower cash outlays. Overall, innovative firms may or may not face greater financial constraints, depending on the balance between the two effects.

HINT firms' need to reward their human capital creates a conflict quite distinct from the classic agency problem associated with external financing of conventional investment. Because critical employees can leave with the intangible capital created, they must be promised adequate and reliable compensation conditional on their commitment. We show how an efficient reward and retention policy requires pledging future revenues to match the value of employees' external options. Established firms here take advantage of the fact that changing jobs or starting a new firm incurs costs and exposes the employee to more risk.

This insight suggests a second reason for HINT firms' prudent financial policy: They need to retain internal resources until deferred compensation vests (Acharya et al., 2011). Insufficient resource retention can lead to financial distress, which prompts innovative employees to exit and start their own firm (Babina, 2017). Retaining cash has the additional benefit of decreasing future share price volatility, which increases the utility value of deferred pay (whether it comes in the form of share grants or fixed promises), thus reducing the corporate cost of human capital.

For the same reason, firms with more intangibles should choose a payout policy that avoids dividends to vested equity and favors repurchases, in order to protect unvested share values. A generous dividend policy would hurt the firm's reputation for rewarding skilled human capital, thereby increasing future retention costs. Holding more cash and repurchasing shares reduces the deferred equity compensation needed for retention, limiting ex ante dilution for shareholders. Thus the model suggests a retention rationale for HINT firms' prudent financial policy next to the traditional precautionary motive.

Overall, our model makes clear predictions on HINT firms' optimal financing, compensation and payout policies, particularly when employees are exposed to more firm risk.

We test these predictions using a large sample of Compustat firms over the period 1970 through 2010. Following Peters and Taylor (2016), we measure intangible asset values by capi-

talizing annual investment into the production of knowledge, brand quality, and organizational culture. Interestingly, most of these expenditures reflect salaries, illustrating how intangible assets are created and maintained by the human capital investment of highly skilled employees.

We use two empirical approaches to test how intangibles affect firms' financial policies. First, we use pooled OLS regressions to study all of the cross-sectional and time-series variation in intangibles usage. Second, we examine how policies change following large, sectoral shifts from tangible to intangible investment. These technological transitions are staggered across time, reflecting how IT and the Internet have transformed corporate strategies at different speeds across industries.[1] To further highlight the broad adoption of intangibles across sectors and firms' life cycle stages, we report all results separately after excluding young or high-tech firms.

We start our analysis by showing that HINT firms have higher cashflows *and* lower upfront investment outlays than LINT firms. Across all years, HINT firms invest 80% of operating (pre-investment) cashflows, while LINT firms' outlays often exceed their cashflows. We further show that free cashflows rise sharply by 60% after industry-level technological transitions, concurrent with a steep decline in tangible investment.

In part because HINT firms have lower investment needs, they do not appear to have been more frequently financial constrained than LINT firms during our sample period. We find that HINT firms' operating cashflows are more frequently sufficient to fully cover their typical investment outlays, which appear less volatile than those of LINT firms. This suggests that some of HINT firms' large liquidity may be held for reasons other than hedging sudden investment needs.

The data further show that firms use different sources of financing to produce tangible and intangible assets. HINT firms have significantly lower net leverage, and raise larger amounts of internal funding by granting employees more unvested stock options and restricted stock. The value of these grants rises by 40% following technological transitions, and amounts to an annual transfer of 0.7% of firms' market capitalizations to employees.

The evidence indicates that firms retain cash to support the value of these deferred grants, as well as for standard precautionary reasons. First, we find that while HINT firms' payments

[1] We use Andrews (1993)'s procedure to identify major structural breaks in each industries' time-series of investment composition. These breaks range from 1974 to 2002.

to shareholders are similar to LINT firms', they retain a larger fraction of their free cashflows.

Second, HINT firms' cash holdings are larger when their employees are more exposed to firm risk. The positive association between intangibles usage and cash holdings is larger among firms that have higher stock price volatility, and that grant more equity to employees. HINT firms overall hold 3.4% more cash as a fraction of total assets than LINT firms, but high-volatility HINT firms hold 8.7% more cash, and high-equity-grant firms hold 7.4% more cash.[2] These effects are robust to controlling for commonly used measures of financial constraints, which are also positively associated with HINT firms' cash holdings. Thus, the evidence suggests both a precautionary and retention motive for holding cash, as predicted by the model.

To further rule out that financial constraints fully explain the results, we analyze a subset of firms with lines of credit that are partially or fully undrawn. Credit lines provide an ample buffer against future constraints as they cover 144% of typical investment outlays on average, yet they cannot be pledged to unvested employees. Accordingly, we find that HINT firms hold more cash even among this subset of unconstrained firms.

Finally, we show that intangibles usage is also associated with a preference for share repurchases over dividends. The ratio of repurchases to total payouts rises from 0.28 to 0.39 following a technological transition.

## 1.1. Related literature

An extensive literature examines the asset determinants of corporate leverage. Firms tend to fund tangible assets with debt, not least for tax reasons, and often adjust net leverage by their cash holdings.

The classic view is that firms hold cash to buffer against future financing constraints (Kim et al., 1998; Almeida et al., 2004; Harford et al., 2014); see Almeida et al. (2014) for a survey. We include this first-order cause in our model, balanced against associated agency costs of managerial discretion (Jensen, 1986; Pinkowitz et al., 2006; Dittmar and Mahrt-Smith, 2007;

[2]These magnitudes correspond to a 0.31 increase in the ratio of intangible to total assets, which is how much the median firm's intangible usage rose from 1970 to 2010. High-volatility (equity-grant) firms are those with stock volatility (equity grant) values in the top tercile of the sample distribution.

Harford et al., 2008).[3] Our approach is close to Acharya et al. (2011), who show that maintaining resources in the firm is necessary to motivate managerial human capital. More generally, skilled human capital has direct and indirect claims on profits via deferred compensation, career advancement, share and option grants (Eisfeldt and Papanikolaou, 2013). Accordingly, the amount and safety of corporate assets net of leverage are critical determinants to the return to human capital.

Cash holdings by U.S. companies have been on a long-term rise, as documented by Bates et al. (2009).[4] Our explanation is related to the spread of information technology since the early 1980s and its impact on the productivity of skilled human capital. In a closely related paper, Döttling and Perotti (2017) offer a general equilibrium model of technological progress where rising intangible value can account for major financial trends such as declining interest rates and a reallocation of credit from productive to asset finance. Graham and Leary (2016) and Begenau and Palazzo (2017) find that the recent increase in cash is largely associated with listings of high tech firms.

While U.S. tax rules on global profitability encourages firms to retain cash abroad (Foley et al., 2007; Harford et al., 2016), Pinkowitz et al. (2016) find that U.S. Firms' cash holdings are no higher than their foreign counterparts' once properly controlled for their greater R&D intensity. Thus their higher cash holdings appear to reflect more intangible assets, in line with our approach.

Other rationales for high corporate cash holdings reflect transaction costs of raising new funding (Miller and Orr, 1966; Mulligan, 1997) or variations in the opportunity cost of holding cash (Azar et al. (2016)).

One of our contributions is to show that HINT firms simply have lower tangible investment needs, which fits with several recent documented facts. The relationship between external fund flows and growth opportunities has decreased over time (Lee et al., 2016), and capital expenditures of U.S. public firms more than halved from 1980 to 2012 (Fu et al., 2015), while stock prices rose. High-intangibles firms appear to invest less not only in the U.S., but also in Europe

[3]The conflict is less acute when profitability reflects quasi-rents that require investment to be maintained.
[4]Graham and Leary (2016) point out how a similar pattern occurred earlier in the twentieth century.

(Döttling et al., 2017). Philippon and Gutiérrez (2016) also find evidence for a decrease in competition, as well as weakening corporate governance.

Several papers highlight how technological progress has boosted the role of human capital and induced changes in funding and employee compensation choices.[5] Lustig et al. (2011) recognize the impact of technology on the productivity of organizational capital, and are able to explain the rising role and dispersion of managers' pay for performance in large firms.[6] Thakor and Lo (2015) show that cash holdings are essential in a competitive environment where success in R&D is critical.

Our paper also relates to a nascent literature showing that firms choose their leverage ratios in part to offer insurance to risk-averse employees (Berk et al., 2009; Agarwal and Matsa, 2013; Kim et al., 2016). Graham et al. (2016) measure the decline in employees' income following bankruptcy and show that firms grant higher ex-ante wages to compensate for distress risk. We contribute to this literature by showing that even in the absence of bankruptcy or distress costs, innovative firms may hold more cash and use less leverage in order to insure employees with large equity stakes. Our results do not depend on whether deferred compensation takes the form of debt or equity, though in practice firms overwhelmingly grant unvested equity rather than deferred cash, either by individual contracts or through broader employee stock ownership plans (ESOPs). The choice of equity over fixed compensation may be due to fiscal advantages (Babenko and Tserlukevich, 2009; Hanlon and Shevlin, 2002) or the need to index compensation to the ex-post value of the employee's outside option (Oyer and Schaefer, 2005). It may also be due to the greater credibility of a property grant over a nominal contractual promise.

Our work is closely related to two recent papers. Bolton et al. (2016) develop a theory linking corporate liquidity policies to inalienable human capital. In their model, firms retain risk-averse employees by granting them deferred compensation, and hold cash or credit lines to increase the credibility of these claims. Sun and Zhang (2017) also offer a related theory in which firms investing in intangible capital grant deferred compensation to retain innovative employees. Their

[5] This process is believed to account for a drastic rise in the skill premium since 1980 (see, e.g., Katz and Murphy (1992) and Autor et al. (1998)).

[6] Their estimates suggest managers may be able to claim as much as half of total value of organizational capacity they create. As in our approach, employee risk aversion enables firms to retain more of the value created.

model studies under what conditions compensating human capital crowds out external debt financing. Our complementary theory proposes that firms that rely largely on human capital investment also spend less upfront on tangible capital, and hence may have a lower *need* for external funding. Our approach yields unique predictions that associate intangible capital with greater cash holdings and a preference for repurchases over dividends, even in the absence of financial constraints.

The rest of the paper is organized as follows. Section 2 develops a model of intangible investment, generating predictions for capital structure, cash holdings, and payouts. Section 3 describes our sampling procedure, key empirical measures, and regression models. Section 4 presents empirical tests linking intangibles usage to corporate financing policies. Section 5 concludes. Proofs are in Appendix A, and variable definitions are in Appendix B.

## 2. Model

We model how corporate investment strategy affects firm funding and liquidity policy. Besides recognizing that tangible and intangible assets differ in their pledgeability, we add the insight that firms need less upfront investment to produce intangible assets, but must assign some future value to employees who co-invest their human capital. A distinct result is that firms' asset composition affects not only their financial structure but also their liquidity and payout policy even in the absence of any financial constraints.

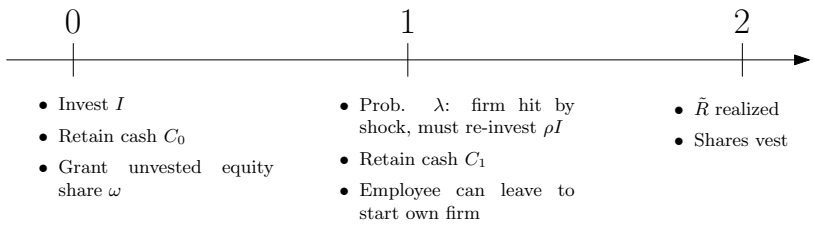
### 2.1. Model setup

Consider a risk-neutral firm with a mandate to maximize shareholder value, and a risk-averse, highly skilled employee. There are three time periods, $t = 0, 1, 2$. All actions are summarized in Figure 2.

At $t = 0$, the firm has access to a project with fixed scale $I$. The project generates a stochastic cashflow $\tilde{R}I$ at $t = 2$, with CDF $F(\tilde{R})$ and support $[0, \bar{R}]$. This cashflow is not verifiable and thus cannot be contracted upon.

In the interim period, the firm experiences a liquidity shock with probability $\lambda$ as in Holm-

Figure 2: Timeline of actions




ström and Tirole (1998). As a result some additional amount (a fraction $\rho$ of the initial investment) is required, else the final output value falls to $\tilde{R} = 0$. Thus the firm has a precautionary motive to retain cash from $t = 0$ to $t = 1$ to avoid the chance of being financially constrained.

The firm has adequate resources at $t = 0$, so it can freely choose how much cash $C_0$ to retain after funding any investment. The firm earns a zero risk-free return on cash holdings in the first period. At $t = 1$ the firm may use some retained cash to re-invest as needed, make payouts to shareholders or retain some remainder $C_1$ until the last period. Holding cash for more than one period however generates a moral hazard deadweight loss of $\chi$ per unit (e.g. associated with managerial discretion in the spirit of Jensen (1986)). This cost creates a trade-off between hoarding cash and providing insurance.

The main comparative static of interest is how much the firm's technology depends on intangible relative to tangible capital, captured by a firm-specific intangible intensity parameter $\eta \in [0, 1]$. Specifically, the firm's total investment of $I$ is composed of an investment $H = \eta I$ into intangible assets and $K = (1 - \eta)I$ into tangible assets.[7]

There are two key differences between tangible and intangible assets. First, intangible capital is not pledgeable, so the firm must fully self-finance any re-investment of intangible assets when the liquidity shock hits at $t = 1$, lest all its value is lost. In contrast, tangible capital retains a liquidation value equal to a share $(1 - \theta)$ of its initial cost, with $\theta \in [0, 1]$.[8] Hence, a fraction $(1-\theta)$ of tangible investment can be collateralized, and the firm must self-finance only a fraction $\theta$. We realistically assume that in liquidation employees have a comparative disadvantage to

[7]The fixed tangible-intangible investment ratio can be motivated by a Leontief production function, where the total return at $t = 2$ is given by $\tilde{R}\mathcal{I}$, with $\mathcal{I} = \min\left\{\frac{H}{\eta}, \frac{K}{1-\eta}, I\right\}$. If the project has positive NPV for the firm, it will always choose $H = \eta I$ and $K = (1 - \eta)I$.

[8]Thus if the firm has to re-invest at $t = 1$, the liquidation value increases to $(1 - \theta)(1 + \rho)K$.

extract value from corporate tangible assets relative to external investors. Consequently, the liquidation value of physical capital is best assigned to financial investors.[9]

Second, the creation of intangible capital depends on joint investment of corporate resources and the contribution over time of human capital by the skilled employee. A fraction $(1-\alpha)$ of intangible investment is created by the employee's effort, assumed costless for simplicity.[10] The firm's contribution requires funding the residual amount $\alpha < 1$ of the investment into intangible assets.

While more intangible investment reduces upfront funding needs, it requires ensuring the commitment of the employee's human capital. The inalienability of the employee's human capital (Hart and Moore, 1994) creates a potential conflict. After observing the firm's re-investment and cash retention decisions at $t = 1$, the employee can leave and use the developed intangible capital to start an own firm, which would produce a stochastic payoff $(1-\alpha)H\tilde{R}$ proportional to the share of intangible capital created. Because the project's cashflows are not verifiable, she cannot sell her stake or insure its underlying risk. For simplicity, we assume that the firm generates no return if the employee departs.

The firm can ensure retention by granting deferred compensation that the employee receives only if she stays at the firm until $t = 2$. Motivated by firms' observed choices, we assume that this compensation takes the form of an unvested equity stake $\omega$ that vests after the project's cashflow is realized at $t = 2$.[11] Importantly, our results also obtain were the firm to offer a deferred cash payment (see Appendix A.2). Unvested equity create an incentive to remain, as employees departing voluntarily forfeit their claim.

We assume that the employee has CRRA preferences over time-2 consumption $x$,

$$U(x) = \frac{x^{1-\gamma}}{1-\gamma}, \tag{1}$$

[9] Under this assumption, the firm realistically uses external funding to finance tangible investments. An alternative rationale for some leverage is a managerial agency conflict over the capture or proper maintenance of tangible assets, which requires posting them as collateral to monitoring creditors. Likewise, a fiscal advantage of debt would induce the firm to take on leverage.

[10] We abstract from incentive issues arising with a continuous effort choice.

[11] The choice of equity over fixed compensation may be due to fiscal advantages (Babenko and Tserlukevich, 2009; Hanlon and Shevlin, 2002) or the need to index compensation to the ex-post value of the employee's outside option (Oyer and Schaefer, 2005).

where $\gamma > 0$ reflects her relative risk aversion. Further, to ensure that the project has positive NPV, we assume

**Assumption 1.** $\mathbb{E}\tilde{R} \geq (1 + \lambda\rho)$.

Thus the firm has two motives for holding cash. The classic precautionary motive suggests that enough liquidity is retained to ensure reinvestment at $t = 1$. Second, some resources need to be retained by the firm to support the value of the deferred reward for human capital (Acharya et al., 2011). Cash is an ideal choice for this retention motive, as it reduces overall payout uncertainty and reduces the volatility of the employee's equity stake $\omega$. This increases the certainty equivalent value of the deferred equity claim at $t = 0$, and reduces the overall cost of compensation. As other claimants are better diversified than the employee, they value risky equity more, and prefer to retain a larger stake at the cost of leaving more cash in the firm.[12]

## 2.2. Precautionary cash holdings

We proceed to solve the firm's decision problem, starting with the demand for precautionary savings.

If the firm is hit by a shock at $t = 1$, the total re-investment need is $\rho I = \rho(H + K)$. In this case, the firm must invest $\rho(\alpha H + K)$, while the employee contributes the remaining $\rho(1-\alpha)H$ using her human capital. The amount $\rho(1-\theta)K$ can be financed externally by pledging tangible assets as collateral, so the firm requires liquidity of $\rho(\alpha H + K) - \rho(1 - \theta)K$ to withstand the shock. These precautionary cash holdings can be expressed as

$$\begin{aligned} C_p &= \rho[\alpha H + \theta K] \\ &= \rho I[\theta + \eta(\alpha - \theta)] \end{aligned} \tag{2}$$

Note how $C_p$ depends on the technology parameter $\eta$. A LINT firm (small $\eta$) incurs a larger expenditure but can obtain external financing, while a HINT firm (large $\eta$) requires a smaller cash outlay but must self-finance all intangible investment.

[12] This might not be the case in a currently financially constrained firm, since retaining cash would reduce investment in some valuable projects.

Whether retained cash increases in $\eta$ therefore depends on whether the fraction of intangible capital that must be self-financed exceeds the fraction of tangible capital that is non-collateralizable ($\alpha > \theta$). While it is not a priori clear whether HINT firms face a greater future funding risk, they may suffer larger losses in distress. The evidence in any case clearly indicates that they engage in greater precautionary savings (Bates et al., 2009; Falato et al., 2013).

### 2.3. Cash holdings and employee compensation

An employee who starts an own firm at $t = 1$ gains $(1-\alpha)H\tilde{R} = (1-\alpha)\eta I\tilde{R}$. Therefore she will choose to remain at the firm if

$$\int U(\omega[RI + (1-\chi)C_1])dF(R) \geq \int U((1-\alpha)\eta RI)dF(R). \tag{IC}$$

Note that (IC) always holds when the firm sets $\omega = (1-\alpha)\eta$ and $C_1 = 0$. In this case the employee's equity stake (and risk exposure) is the same as her outside option, so she will stay even if the firm holds no cash. Retaining cash allows the firm to commit to partially insure the employee, providing higher utility than she could receive from self-employment. As a result, choosing $C_1 > 0$ allows the firm to reduce the optimal equity grant to $\omega^* < (1-\alpha)\eta$. Hence, the firm's choice of cash at $t = 1$ refers only to the retention issue, and we will henceforth use $C_1 = C_R$. This observation yields the following result:

**Lemma 1.** *Under Assumption 1, it is optimal for the firm to invest in the project at $t = 0$, and to retain cash $C_0 \geq C_p$.*

*Proof.* With $C_0 \geq C_p$, the firm will invest if

$$(1-\omega)[\mathbb{E}RI + (1-\chi)C_R] \geq (1+\lambda\rho)(\alpha H + \theta K) + C_R. \tag{3}$$

Since (IC) is always satisfied when $\omega = (1-\alpha)\eta$ and $C_R = 0$, evaluating Eq. (3) at these values yields a necessary condition for firm participation. Using that $H = \eta I$ and $K = (1-\eta)I$, shows that Assumption 1 (Eq. 3) is satisfied for any $\eta \in [0, 1]$. Note that since $\rho \leq 1$, the fact that the firm wants to invest at $t = 0$ also implies that it is optimal to re-invest after the

liquidity shock. Therefore, the firm retains cash $C_0 \geq C_p$. $\square$

Lemma 1 implies that the firm's retained cash at $t = 0$ equals

$$C_0 = C_p + C_R^*,$$

where $C_R^*$ denotes the period-1 level of cash holdings that optimally trades off the moral hazard cost $\chi$ against a reduction in $\omega$.

If the firm is hit by a shock at $t = 1$, it re-invests its precautionary savings $C_p$. Otherwise, the firm can pay out the excess cash $C_p$ as a dividend to its external shareholders. Note that since the employee holds unvested equity she does not receive any dividends, so whether or not a shock occurs the firm can reach its target cash level $C_R^*$ without sharing any of the excess cash with the employee.

It follows that the firm's choice of $C_0$ and $\omega$ can be reduced to choosing $C_R$ and $\omega$. We now consider this optimization problem, which can be written as

$$\begin{aligned} \max_{C_R,\ \omega} \quad & V(\omega, C_R) = (1-\omega)[\mathbb{E}\tilde{R} + (1-\chi)C_R] - (1+\lambda\rho)(\alpha H + \theta K) - C_R, \\ s.t. \quad & (IC), \\ & C_R, \omega \geq 0. \end{aligned}$$

The firm's objective function is decreasing in the employee's equity stake, because higher values of $\omega$ lead to greater dilution of shareholders. Therefore the firm sets $\omega$ to the lowest value that satisfies (IC), i.e., (IC) always binds. Thus we can derive $\omega$ as a function of $C_R$:

$$\omega(C_R) = \eta(1-\alpha)S(C_R), \tag{4}$$

where

$$S(C_R) = \left[\frac{\int (RI)^{1-\gamma} dF(R)}{\int [RI + (1-\chi)C_R]^{1-\gamma} dF(R)}\right]^{\frac{1}{1-\gamma}}.$$

Eq. (4) shows that $\omega$ is proportional to $\eta(1-\alpha)$, scaled down by an insurance premium $S(C_R) \leq 1$. Because $S'(C_R) < 0$, the required equity payment is decreasing in the amount of cash that the firm retains until $t = 2$. Furthermore, the sensitivity of $\omega$ to cash holdings

depends on the employee's risk aversion $\gamma$ and the underlying risk in the distribution of $\tilde{R}$.

Substituting Eq. (4) into the firm's objective function, the first-order condition w.r.t. $C_R$ implicitly defines optimal cash holdings $C_R^*$:

$$(1-\chi)[1-\omega(C_R^*)] - \omega'(C_R^*)[\mathbb{E}R + (1-\chi)C_R^*] = 1. \tag{5}$$

The left-hand side is the firm's marginal benefit from retaining an additional unit of cash. This benefit consists of two terms: 1) the per-unit return on cash net of the moral hazard cost, weighted by the share of cash $1-\omega(C_R^*)$ that accrues to the firm; and 2) the marginal reduction in the share grant $\omega$. The right-hand side is the marginal cost of holding cash, equal to 1.

The following proposition describes how equilibrium cash holdings at $t = 1$ (thus net of precautionary holdings) vary with technology $\eta$.

**Proposition 1.** *The firm's optimal cash holdings for retention purposes are increasing in $\eta$:* $\frac{dC_R^*}{d\eta} \geq 0$.

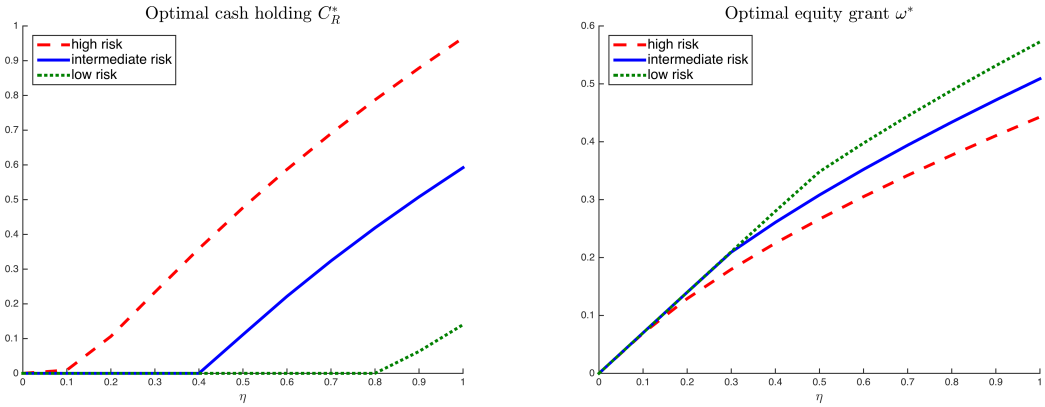
The proof is in Appendix A.1. To interpret the result, note that the employee's human capital contribution increases with $\eta$. To match the value of the employee's outside option, a firm with a higher $\eta$ offers a greater share grant, and holds more cash than what it needs for traditional precautionary reasons.[13]

It is easy to show that retention cash holdings $C_R$ will increase in the employee's risk aversion $\gamma$ and the underlying risk in the distribution of $\tilde{R}$, as both increase the required insurance premium $S(C_R)$. These results are confirmed in the numerical example plotted in Figure 3, where the choice of cash holdings $C_R^*$ as well as the equity stake $\omega^*$ increase with $\eta$. The interesting result is that firms with a more volatile return $\tilde{R}$ will further increase their cash holdings while reducing the equity grant, essentially providing more insurance.

To summarize, the firm's cash holdings at $t = 0$ are composed of a precautionary and a retention component, $C_0 = C_p + C_R^*$. The precautionary motive may induce higher holdings for intangible firms if shocks requires more internal funding, while their retention motive will

[13] In the figure we set $\chi = 0.1$, $I = 1$, $\alpha = 0.3$, $\gamma = 0.9$, while $\tilde{R} \sim U[a, b]$, where $(a, b) = (0, 5), (0.4, 4.6)$ and $(0.8, 4.2)$ describe the high, intermediate and low risk case.

Figure 3: Optimal Cash Holding and Employee Compensation Policies




Numerical solutions for $C_R^*$ and $\omega^*$ for different risk level of $\tilde{R}$.

always induce them to hold more cash holdings to reduce their cost of funding human capital. The setup thus offers a simple rationale for why HINT firms may hold more cash than LINT firms even in the absence of financial constraints. Their greater use of unvested equity grants and other forms of self-financed deferred compensation (e.g., career promises) to employees implies further cash holdings to retain safe resources to insure their employees, all the more so when earnings are more volatile. However, as higher volatility of cash flows also increase precautionary cash holdings, the ability to identify empirically the retention motive depends on the subtler implication that the sensitivity of cash holdings to intangibles should be higher for firms with more human capital and deferred compensation.

## 2.4. Payout policy

We next consider the implications of intangible investment for corporate payout policy. Dividend policy creates a second internal conflict in the firm: As dividends are only paid out to vested shareholders, they reduce the value of the employee's unvested equity.[14]

In our setup, an innovative firm will avoid paying too large a dividend at $t = 1$ as the employee will depart if the value of $\omega^*$ falls below its outside option. Thus dividend payments reduce shareholder value whenever the project's present value exceeds the agency cost of retaining cash

[14]While dividend protected grants may be an option, they are very uncommon, and in any case less safe.

until $t = 2$.

A more interesting possibility arises when the firm can pay a dividend at $t = 2$, just before the employee's shares vest. By this date the employee has contributed her human capital to production and cannot depart to start an own firm. A dividend payment thus transfers value from the employee to shareholders, without affecting the project's return. Anticipating this possibility, highly-skilled employees would leave the firm at $t = 1$.

Thus the creation of intangible assets via the commitment of human capital over time has to resolve a double-sided moral hazard problem. Co-investment at $t = 0$ will occur only if the firm can build a reputation for refraining from large dividends before deferred equity grants vest.

A payout policy that favors repurchases over dividends reduces moral hazard cost while supporting the value of unvested shares. Let the firm's total shares be normalized to 1, and denote the market values of the firm prior to and after a repurchase as $V_{NR}$ and $V_R$, respectively. Repurchasing a fraction $x$ of shares at fair market value requires the firm to spend $xV_{NR}$ of its cash. This reduces the firm's value to $V_R = (1 - x)V_{NR}$, but the employee's unvested equity stake concurrently rises to $\omega' = \omega/(1-x)$. For a risk-neutral agent the value of the stake would remain constant ($\omega' V_R = \omega V_{NR}$). The risk-averse employee however suffers some utility loss from holding a larger claim on a riskier pool of assets. Nevertheless, the negative effect is much smaller than from a dividend payout.

Firms may seek various solutions to the commitment problem. We do not explicitly model how it may be solved by building reputation via an appropriate payout policy in a dynamic setting, and simply note how it would require significant cash retention and a preference for repurchases in payout policy.[15]

## 2.5. Empirical Implications

Our model predicts that relative to firms using few intangible assets, HINT firms:

1. have lower upfront cash outlays and higher free cashflows, for a given level of profitability
2. are not necessarily more frequently financially constrained

[15] Here there is no reason for an innovative firm to prefer dividends, while in reality there are valid reasons (e.g. related to fiscal rules or control issues) to favor them over repurchases.

3. have lower net leverage and pledge a larger fraction of equity to employees
4. retain more cash, increasing in both share price volatility and size of equity grants
5. maintain a payout policy that favors repurchases over dividends

# 3. Empirical Methodology

This section describes our sample, and our measurement of intangible assets and corporate investment, financing, and payout policies. We also describe our pooled regressions and our time-series analysis of industry-level transitions to predominantly intangible investment strategies.

## 3.1. Sampling procedure

We follow the sampling criteria adopted by Bates et al. (2009) and Falato et al. (2013). Starting from all firms in Compustat between 1970 and 2010, we exclude 8,677 financial and utilities firms (SIC codes 6000–6999 and 4900–4999, respectively); 3,815 firms with asset data missing or below $5 million, or with zero or negative sales; 3,695 firms incorporated outside the United States; and 4,800 firms with less than five years of data. Our final sample contains 12,242 firms. Some tests further restrict the sample to 2,435 firms that are in Compustat ExecuComp between 1992 and 2010.

## 3.2. Empirical measures

### 3.2.1. Intangibles

Firms do not report the value of most intangible assets in their financial statements. Instead, U.S. accounting rules require firms to classify spending on intangibles as an ongoing business expense, and to deduct it from operating earnings.[16] As do most other researchers and practitioners, we estimate the value of intangible assets by capitalizing annual investment into intangibles with an appropriate depreciation schedule.

[16] Among the exceptions, the purchase price of externally acquired intangible assets is included in Goodwill. Also, some internally produced intangibles are reported as Other Intangible Assets, including legal and consulting fees incurred when developing a patent, and spending on software that has reached commercial viability.

Our procedure follows Peters and Taylor (2016) by computing the value of knowledge acquired through research, the firm's brand recognition, and the quality of its organizational culture. The creation and maintenance of these assets relies largely on the human capital contribution of highly skilled employees, such as research scientists and marketing professionals. The ideas that creative employees formulate over time matter more for intangible asset values than upfront cash invested by the firm. Prior work measures intangible assets similarly and finds that they are associated with reliance on skilled labor, greater emphasis on employee retention, and usage of information technology (Lev and Radhakrishnan (2005), Eisfeldt and Papanikolaou (2013)).[17]

The procedure capitalizes past years' R&D spending using the perpetual inventory method. Missing R&D values are set to 0 after 1977. R&D depreciation rates are from the Bureau of Economic Analysis, and range across industries from 10% to 40% (see Li (2012)). Similarly, we capitalize a portion of Selling, General, and Administrative expenses (SG&A), as these include investment to enhance organizational capital (e.g., marketing or employee training expenses, see Eisfeldt and Papanikolaou (2013)). We subtract annual R&D spending from SG&A, because Compustat almost always combines the two expenditures. We then capitalize 20% of remaining SG&A as investment into organizational capital. We use a lower weight on SG&A than the 30% in Peters and Taylor (2016), because the data show an economy-wide decrease in SG&A expenditure after 2001 that could be due to cost-cutting efficiency gains rather than reduced investment. We follow the literature by setting the depreciation rate for organizational capital to 20%.

We calculate firms' total intangible assets as the sum of capitalized investments into R&D and organizational capital, plus the book value of Other Intangible Assets. Our measure excludes Goodwill as it partly reflects a market premium paid to acquire tangible assets, but our results are robust to including it and to using a range of different weights on SG&A (see I.A. Table 1). *Intangibles Ratio* equals the stock of intangible assets divided by total assets. Throughout the paper, we measure total assets as the sum of intangible assets and Property, Plant, and Equipment net of depreciation (PP&E).

In addition to using a continuous measure of intangibles, we present some descriptive patterns

[17] Bellstam et al. (2017) propose a different measure of corporate innovation, based on textual analysis of analyst reports, and find that it is associated with growth opportunities and the operation of innovative systems.

separately for HINT and LINT firms. HINT (LINT) firms are those with *Intangibles Ratio* values in the highest (lowest) tercile of the sample distribution. We calculate the distribution across all sample years, but our results do not change when using annual terciles to classify firms.

Table 1 reports a selection of industries that experienced the largest and smallest change in *Intangibles Ratio* during our sample period. While intangibles usage is highest among firms that produce pharmaceuticals (0.96) and computers (0.90), numerous other industries such as Healthcare, Communication, and Apparel have also experienced dramatic increases. At the other end of the spectrum, firms in the Transportation, Agriculture and resource extraction industries use the fewest intangible assets.

Table 1 About Here

### 3.2.2. Investment and Cashflows

To confirm that intangible capital creation requires lower outlays, we measure the amount of cash that firms spend each year on different types of investment. We measure *Tangible Investment* as the annual change in net PP&E. The change in physical plant reflects annual capital expenditures, and also encompasses the cost of acquiring tangible assets as well as purchases recorded under other accounting items. *Intangible Investment*, as described above, is annual spending on R&D and 20% of SG&A, plus external acquisitions of intangible assets. This measures firms' cash outlays—for example, R&D consists mostly of cash wages paid to researchers and the cost of materials—but not the human capital investment of employees.

We scale both variables by operating cashflows, measured as earnings prior to depreciation and investment, minus taxes and interest payments. This is the amount of cash inflows from business operations, which the firm can invest, pay out to shareholders, or retain. Scaling by cashflows is an intuitive way to analyze how much a firm invests out of each dollar of cash that it earns, yet results are robust to scaling by total assets (see I.A. Table 5). Moreover, as Peters and Taylor (2016) explain, operating cashflows more accurately measure the performance of HINT firms than profitability metrics such as EBITDA or ROA, which are calculated after deducting intangible investment.

*Free Cashflows* is the fraction of operating cashflows that remain after total investment outlays. Thus firms with higher free cashflows spend proportionally less upfront on investment. *Retained Cash* measured the fraction of *Free Cashflows* that the firm retains, with the remainder paid out to shareholders. The accumulation of retained free cashflows over time is reflected in a firm's stock of cash. We measure *Cash Holdings* as the sum of cash and marketable securities, divided by total assets.

### 3.2.3. Financing

We use *Net Leverage* to measure firms' reliance on external financing. This variable equals the book value of debt minus cash holdings, divided by total assets.

Our primary measure of inside financing, *Equity Grants*, equals the total dollar value of annual stock option and restricted stock grants to employees, divided by market capitalization. This variable reflects the fraction of total equity value that the firm pledges to employees each year.

One challenge is that firms historically did not report detailed data on inside ownership by employees. Prior work (e.g., Aldatmaz et al. (2017)) commonly uses the procedure developed by Bergman and Jenter (2007). The procedure uses data from ExecuComp on the fraction of stock options granted to top executives each year, and infers the Black-Scholes value of total option grants to all employees. We measure *Equity Grants* as the sum of this number plus the annual value of stock grants to all employees, which firms report in their financial statements. Because the procedure relies on data from ExecuComp, *Equity Grants* is only measured for the firms in that database (which are in the S&P 1500) starting from 1992. We include equity grants to top executives, as their human capital contribution likely supports the value of intangible assets (e.g., some C-Suites include a chief technology or marketing officer); we obtain similar results when excluding them.

We also constructed a second measure, *Reserved Shares*, which equals the number of deferred shares and stock options that firms have granted to employees, divided by this number plus publicly traded shares. This approximates employees' maximum equity stake in the firm, as it equals the amount of shares they would receive if all stock options were exercised and all restricted stock vested. However, Compustat stops reporting this variable after 1995. Because

much of the growth in intangibles usage has come in recent years, we relegate results using *Reserved Shares* to the Internet Appendix.

#### 3.2.4. Payouts

Total payouts are the sum of common dividends and share repurchases. Because our model's implications are for payouts to external shareholders, we measure repurchases following Fama and French's (2001) procedure, which excludes share buybacks that are immediately used to fulfill employees' option exercises. The composition of annual payouts, *Repurchases/Payouts*, is measured as stock repurchases divided by total payouts.

### 3.3. Empirical specifications

#### 3.3.1. Pooled OLS regressions

We use two empirical models throughout the paper. First, we estimate pooled OLS regressions across our entire sample, to analyze all of the cross-sectional and time-series variation in intangibles usage. We use the following model, for firm $i$ and fiscal year $t$:

$$\begin{aligned} Corporate\ Policy_{i,t} = \alpha + \beta Intangibles\ Ratio_{i,t} + \phi Tobin's\ Q_{i,t} + \zeta Log\ Total\ Assets_{i,t} \\ + \delta X_{i,t-1} + \mu_j + \mu_t + \epsilon_{i,t} \end{aligned} \tag{6}$$

The dependent variables in this model are the various corporate policies described in Section 3.2. Our control variables are based on Bates et al. (2009). We use *Tobin's Q* in all regressions to control for investment opportunities, and *Log Total Assets* to control for differences in firm size. We follow Peters and Taylor (2016) by including intangible assets in the denominator of $Q$, as this better explains intangible investment.

Some regressions further include a vector of additional variables $X$ that partly measure financial constraints. These include *Operating Cashflows*, *Cashflow Volatility* measured as the standard deviation of operating cashflows from the previous 10 years, and *Book Leverage*. Firms with higher cash inflows, less risky cashflows, and lower leverage may have a lower need for pre-

cautionary savings.

All regressions include fixed effects $\mu_j$ for the Fama-French 48 industries and $\mu_t$ for the fiscal year. We cluster all standard errors at the firm level, to account for possible serial correlation due to interdependence of firms' observations across time. We obtain similar results when using firm fixed effects in Eq. (6) to analyze how corporate policies change within the same firm as its intangible capital evolves over time (see I.A. Table 2).

We estimate Eq. (6) using all sample firms, and also after excluding firms that produce computers, software, and related products. The tech sector, and startup firms in general, certainly rely largely on employees' human capital contributions and do not need to use many tangible assets. Importantly, however, technological innovation is thought to affect the production process and increase the importance of human capital across a wide range of economic sectors. We test this theoretical view by re-estimating all results without computers firms. We separately report results after excluding any firm that recently completed an IPO (see I.A. Table 3).

### 3.3.2. Staggered technological transitions

Our second model studies how corporate policies evolve across time following large changes in intangibles usage. We analyze rapid, structural shifts from tangible to intangible investment at the industry level. The data show that these transitions were staggered across time, as technological innovation increased the return on human capital earlier in some industries than others. This setting thus provides significant time-series variation that is not fully explained by macroeconomic shocks.

To identify transitions, we first calculate the time series of *Intangible/Total Investment* using the median firm in each Fama-French 48 industry. We then use Andrews (1993)'s procedure to test for a single structural break in each industry's time series.[18] We find structural breaks for 37 of the 48 industries. We omit eight industries whose break dates have a confidence interval wider than five years. We also exclude nine industries with intangible investment rates that

[18] This procedure is commonly applied when the date of a possible break is unknown. We partition each industry's time series into two parts, regress *Intangible/Total Investment* on two separate time trends, and calculate the difference in explanatory power between the time trends. We use 1973 as the first candidate break, and repeat the process for each year through 2007. The break is the year with the largest change in explanatory power.

level off in the 2000s after an earlier period of rapid growth, as our model's implications are for firms that switch from tangible capital-intensive to human capital-intensive production.

We identify that two industries transitioned in the 1970s, seven in the 1980s, four in the 1990s, and seven in the 2000s. Industries that transitioned by the early 1980s include Apparel, Pharmaceuticals, and Business Services (this category includes advertising, software, and data processing). Industries that transitioned after 2000 include Transportation, Wholesale and Entertainment. In our theoretical view, this time-series variation is explained by technological innovations becoming commercially applicable in some industries earlier than in others. Nascent computer systems of the 1980s boosted the productivity of a drug researcher or software developer, while other industries such as wholesale trading were transformed only after the widespread adoption of the Internet.

We estimate the following regression for each firm $i$ in one of the 20 transitioning industries, using a five-year (two-sided) window around each transition:

$$\begin{aligned} \textit{Corporate Policy}_{i,t} = \alpha + \beta \textit{Post Transition}_{i,t} + \phi \textit{Tobin's } Q_{i,t} + \zeta \textit{Log Total Assets}_{i,t} \\ + \delta X_{i,t-1} + \mu_j + \epsilon_{i,t} \end{aligned} \tag{7}$$

In this model, $\textit{Post Transition}_{i,t}$ equals 1 for years that follow a technological transition, and 0 for years that precede it. Other variables are the same as in Eq. (6), except that we do not use year fixed effects; otherwise the analysis would exclude years containing only industries that have already transitioned, such as in the late 2000s. (Results are robust to use fixed effects for five-year periods.) To account for possible changes in the composition of firms within an industry, we estimate Eq. (7) only for firms that were present before and after the transition.

Figure 4 plots intangible and tangible investment rates around the technological transitions. Investment rates are similar before the break. Intangible investment then rises in the year of the break, while tangible investment falls sharply and continues to decrease in subsequent years. As a result, the *Intangible/Total Investment* ratio increases by a third, from 0.51 to 0.69. These plots confirm that these time trend breaks are structural shifts, and correspond to dramatic,

one-time changes in the composition of firms' investment.

FIGURE 4 ABOUT HERE

### 3.4. Summary statistics

Table 2 presents summary statistics for all of the variables used in our analysis, separately for HINT and LINT firms. It also presents the difference in means across the two groups.

TABLE 2 ABOUT HERE

The table shows that HINT firms spend significantly less on tangible investment and have higher free cashflows. Their cash holdings are substantially higher at 21% of assets for the median firm, compared to 7.2% for LINT firms. Furthermore, HINT firms are less levered, pledge more equity to employees, retain more cash, and favor share repurchases over dividends.

Interestingly, Table 2 shows that HINT firms have significantly higher operating cashflows of 30% of assets, compared to 19% for LINT firms. This finding, together with HINT firms' lower total investment outlays, suggests that these firms can cover a greater portion of their investment needs from cash inflows. We study this in more detail in Section 4.3.

## 4. Empirical Tests

This section presents our results on the relation between intangible assets and cashflows, corporate financial policy, employee compensation, and shareholder payouts.

### 4.1. Investment outlays and free cashflows

Our key insight is that the creation of intangible assets requires lower upfront cash outlays than tangible assets, as it relies on the human capital contribution of skilled employees. We start by verifying this critical modeling assumption.

Figure 5, Panel A compares the cash outlays of HINT and LINT firms over time. It plots

the fraction of operating cashflows spent on tangible and intangible investment, as well as the free cashflows left after investment. Across our sample period, the median HINT firm spends less than 20% of operating cashflows on the production of tangible assets. While its intangible investment rate is significantly higher, free cashflows are about 20% of operating cashflows. In contrast, the median LINT firm's free cashflows were frequently negative prior to 2000, reflecting a reliance on external finance for tangible investment. LINT firms' investment outlays decreased in the 2000s, resulting in a free cashflow that was positive yet half as high as that of HINT firms.

FIGURE 5 ABOUT HERE

Panel B plots the evolution of free cashflows around industry-level technological transitions. Free cashflows appear stable in the years preceding a transition, but rise sharply afterward. This increase is concurrent with a large decline in tangible investment (see Figure 4), indicating that firms' outlays fall quickly after a shift to human capital-intensive production, allowing for greater resource retention.

Table 3 analyzes these relationships in a regression framework. Columns (1) through (6) report estimates from pooled OLS regressions based on Eq. (6). They offer further evidence that intangible assets are associated with significantly lower investment outlays and higher free cashflows, as a fraction of operating cashflows. Column (2) indicates that a 0.31 increase in *Intangibles Ratio*—equal to the median firm's rise in intangibles usage from 1970 to 2010—corresponds to a 0.45 ($= -1.44 \times 0.31$) decline in the tangible investment rate. This equals 92% of the variable's interquartile range of 0.49. Column (5) indicates that this rise also leads to 0.11 ($= 0.34 \times 0.31$) higher free cashflows, or 20% of the interquartile range.

The results do not change after excluding computers firms in columns (3) and (6). They are also robust to different variations in the empirical specification, such as measuring tangible investment as the sum of capital expenditures and acquisitions (I.A. Table 4) or scaling investment and free cashflows by total assets (I.A. Table 5).

TABLE 3 ABOUT HERE

Next, columns (7) through (10) present regressions based on Eq. (7), estimated over a five-year window surrounding technological transitions. The estimates indicate that tangible investment indeed declines significantly, from 0.39 prior to the transition to 0.22 afterward, while free cashflows rise from 0.15 to 0.24. The 60% increase in free cashflows shows that large shifts in intangibles production lead to dramatic decreases in investment spending.

## 4.2. Corporate financing

Next we test the model's prediction that firms use different sources of finance to create intangible and tangible assets. LINT firms are able to raise external financing because they can pledge more of their assets as collateral. In contrast, HINT firms grant employees a (deferred) share of the value that their human capital creates, in order to match their outside opportunities. Intangibles usage thus should be associated with lower leverage and larger equity grants to employees.

The results in Table 4 support this prediction. Column (2) indicates that the historical 0.31 rise in *Intangibles Ratio* leads to a 0.17 ($= -0.55 \times 0.31$) decline in net leverage, equal to 28% of the variable's interquartile range. Low leverage is often associated with high tech firms, yet we obtain similar results after excluding all computers firms.

Next, columns (4) through (6) show that firms with more intangibles also grant employees more equity each year, as a fraction of their market capitalization. Column (5) indicates that the historical increase in *Intangibles Ratio* is associated with an annual transfer of 0.4% ($= 0.013 \times 0.31$) of the firm's equity. For comparison, the median *Equity Grants* value across the entire sample is 0.8% of market capitalization. These tests are estimated across the subsample of ExecuComp firms for which compensation data is readily available, yet we obtain similar results using the alternative variable *Reserved Shares* that measures the size of employees' equity stakes across a different set of firms (I.A. Table 6).

Table 4 About Here

Next, columns (7) through (10) examine changes to funding policies around technological transitions. The results imply that the median leverage ratio fell from 0.32 in the five years

preceding a transition to 0.27 in the five years afterward. The median amount of equity pledged annually rose from 0.5% to 0.7% of market capitalization, a 40% increase.

Taken together, these results support our model's prediction that the evolution of investment in recent decades has led to a shift from external to internal financing.

### 4.3. Are HINT firms more financially constrained?

HINT firms' lower investment spending and leverage, as well as their higher cash holdings, could be explained as precautionary steps to avoid the possibility of becoming financially constrained in the future. The model offers an alternative view that HINT firms are not necessarily *more* financially constrained than LINT firms. Instead, their cash holdings consist of two components: 1) precautionary savings $C_p$ that are sufficient to cover future investment outlays in the event of financial constraints; and 2) additional cash $C_R^*$ that supports the value of employees' equity claims. We next document that HINT firms' resources seem to exceed the required precautionary component.

Figure 6 compares HINT and LINT firms' investment coverage. Panel A plots the median firm's cash holdings at the start of the year, divided by annual total investment spending averaged over the three previous years. In the absence of detailed data on anticipated future spending, we examine whether firms' cash holdings are sufficient to maintain recent investment outlays. Naturally, future investment needs may exceed past spending, but it is worth noting that HINT's firms total investment outlays vary less over our sample period than LINT firms' outlays (Table 2 shows a lower standard deviation of *Avg. Total Investment* among HINT firms).

The plots show that in all years, HINT firms' cash covered a larger portion of total investment spending. Moreover, in recent years the median HINT firm's cash has been sufficient to entirely fund annual investment; in contrast, LINT firms' cash equaled less than half of recent expenditures.

Figure 6 About Here

These differences reflect HINT firms' lower investment outlays, yet they also may be due to the cumulative effect of precautionary savings over time. To provide further evidence, Panel

B plots the ratio of current-year operating (pre-investment) cashflows to previous years' total investment. Firms can become financially constrained when they do not earn enough cash to cover annual investment needs. However, the plots show that across time, HINT firms earn similar or higher cashflows relative to recent investment than LINT firms. Additionally, in many years the median HINT firms' cashflows alone were large enough to maintain investment levels.

Next, Panel C analyzes how often each firm's liquid resources are sufficient to preserve investment spending. For each firm, we calculate the fraction of sample years in which current operating cashflows and start-of-year cash holdings exceed previous investment outlays. The plots show that 30% of HINT firms had sufficient investment coverage in all sample years, and another 29% had sufficient coverage at least two-thirds of the time. Only 19% of HINT firms lacked resources in most or all years to cover recent investment levels.

The evidence that HINT firms' cash holdings and cashflows are usually more than sufficient to maintain investment spending offers some perspective to the precautionary savings view. Naturally, some cash retention allows firms to reduce the likelihood of financial constraints. Even if innovative firms are less frequently constrained, their opportunity costs are likely higher. Yet because HINT firms have lower investment outlays, they do not seem to be *more* financially constrained overall than LINT firms. The data suggest they hold cash for reasons other than precautionary savings. We now turn to examining two reasons suggested by our model.

## 4.4. Cash Holdings

### 4.4.1. Resource Retention

HINT firms grant deferred compensation to promote critical employees' retention, thereby ensuring that the capital they create stays within the firm. The model predicts that this compensation has higher value when firms hold more resources until the grants vest. This allows firms to support employees' human capital commitment at a lower cost.

Table 5 presents evidence supporting this prediction, by regressing *Retained Cash* on *Intangibles Ratio*. The results show a positive and highly significant relationship, indicating that intangible firms hold onto more of the free cashflows left after investment, instead of paying

them out to external shareholders. Column (2) shows that a firm with a 0.31 higher *Intangibles Ratio* retains an additional 12.7% (= 0.41 × 0.31) of its free cashflows; the median across the entire sample is 76.8%. Similarly, Column (5) shows that the fraction of free cashflows that firms retain rises from 0.65 to 0.82 (a 26% increase) following a technological transition.

Table 5 About Here

#### 4.4.2. Employee Insurance

Holding significant cash balances offers the additional benefit of reducing future stock price volatility. This boosts the value that risk-averse employees assign to deferred compensation, as large pledged equity grants expose them to idiosyncratic firm risk. The model thus puts forward an insurance benefit of cash holdings, which is increasing in share price volatility and the amount of equity pledged to employees.

We test these predictions using a modified version of our pooled OLS regressions:

$$\begin{aligned} \textit{Cash Holdings}_{i,t} = \alpha &+ \gamma_1 \textit{Intangibles Ratio}_{i,t} + \gamma_2 \textit{High Volatility}_{i,t-1} \\ &+ \gamma_3 \textit{Intangibles Ratio}_{i,t} \times \textit{High Volatility}_{i,t-1} \\ &+ \phi \textit{Tobin's Q}_{i,t} + \zeta \textit{Log Total Assets}_{i,t} + \delta X_{i,t-1} + \mu_j + \mu_t + \epsilon_{i,t} \end{aligned} \tag{8}$$

In Eq. (8), $\gamma_3 > 0$ would indicate that HINT firms hold more cash when their employees are exposed to more stock price risk. *High Volatility* equals 1 for firms with above-median stock volatility, measured as the standard deviation of stock returns from the previous 48 months. It equals 0 for firms with below-median volatility. We use an indicator as the coefficient estimates are easier to interpret, but obtain similar results using continuous volatility (see I.A. Table 7).

We also estimate Eq. (8) by interacting *Intangibles Ratio* with *High Equity Grants*, which equals 1 for firms with above-median values of *Equity Grants*, and 0 for firms with below-median values. In these regressions, a positive $\gamma_3$ would indicate that HINT firms hold more cash when they have pledged a larger equity stake to employees.

Table 6 reports the results. For consistency, we estimate all regressions using the sample of ExecuComp firms over which *Equity Grants* can be measured. Column (1) shows that the

effect of intangibles on cash holdings is 2.5 times stronger at high-volatility firms. The coefficient on *Intangibles Ratio* indicates that among low-volatility firms, a 0.31 rise in intangibles usage leads to a 0.034 ($= 0.11 \times 0.31$) higher cash balance (relative to the sample median of 0.14). For high-volatility firms, the same rise leads to a 0.087 ($= (0.11 + 0.17) \times 0.31$) increase in cash holdings. Column (2) shows that the size of equity grants has a similar impact on the intangibles-cash holdings relationship. Among firms that pledge little equity, the historical rise in intangibles leads to a 0.028 ($= 0.09 \times 0.31$) increase in cash holdings, compared to an increase of 0.074 ($= (0.09 + 0.15) \times 0.31$) at firms that pledge significant equity.

Table 6 About Here

Next, columns (3) and (4) show that both interaction terms have positive and significant coefficients when included together in the same regression. This shows that stock volatility leads to higher cash holdings at both intangible-high equity grant firms and intangible-low equity grant firms. Column (5) further shows that stock volatility and equity grants similarly influence the effect of intangibles usage on cash holdings within the same firm over time.

One possible concern with this analysis is that firms with high stock volatility are at greater risk of financial constraints, and thus hold more cash for precautionary reasons. Similarly, firms with limited free cash may prefer to compensate employees using equity. Table 7 accounts for this possibility in two ways. First, Panel A re-estimates the model from Column (3) of Table 6, with additional controls for the interaction of *Intangibles Ratio* and commonly used measures of financial constraints (see Farre-Mensa and Ljungqvist (2016)). Columns (1) through (3) use the indexes of Hadlock and Pierce (2010), Whited and Wu (2006), and Kaplan and Zingales (1997).[19] Columns (4) and (5) identify constrained firms as those without a credit rating or that do not pay dividends. We omit *Log Total Assets* from these regressions as the constraint

[19] We use the KZ index as measured by Lamont et al. (2001). Following convention, we classify firms with index values in the top tercile as financially constrained, and apply the index estimates directly to our sample without re-estimating the underlying models.

measures are highly correlated with firm size.

Table 7 About Here

Four of the five coefficients on the interaction *Intangibles Ratio* × *High Constraints* are positive and significant, consistent with HINT firms that face a greater risk of becoming constrained holding more cash. (The fifth measure, the Whited-Wu index, shows that firms generally hold more cash when constrained regardless of intangibles usage.) Yet alongside this precautionary motive, stock volatility and the amount of equity pledged to employees continue to explain intangible firms' cash holdings. The magnitudes of these effects are just slightly smaller than those from Table 6.

Next, Panel B re-estimates results using a subset of ExecuComp firms that do not appear to be financially constrained. Column (6) contains only firms with lines of credit that are partially or fully undrawn.[20] The average (median) undrawn credit line covers 144% (109%) of annual average total investment spending from the past three years. This provides firms with a precautionary buffer against future constraints, yet firms cannot pledge credit lines to unvested employees and must still hold cash to reward them. The results indeed show that riskier HINT firms or those with larger equity grants hold more cash. Column (7) reports similar results among firms that pay out cash to shareholders; firms that have sufficient cash to buy back stock or pay dividends are likely unconstrained.

Overall, these results support the model's prediction that firms have a retention motive for holding cash, next to a need to maintain precautionary liquidity.

### 4.5. Payouts to external shareholders

Finally, we examine the model's prediction that HINT firms favor paying out cash using share repurchases rather than dividends, as this better supports the value of employees' deferred equity grants. Table 8 regresses *Repurchases/Payouts* on *Intangibles Ratio*, among the firms that pay out some amount of cash to shareholders. The results shows that firms with more

[20] Data on the amount of undrawn credit lines is provided by Erasmo Giambona, and were hand-collected from firm financial statements.

intangibles indeed pay out cash primarily by repurchasing shares. Column (2) indicates that a 0.31 increase in *Intangibles Ratio* is associated with a 0.08 ($= 0.25 \times 0.31$) higher payout ratio, compared to the sample mean of 0.31. Columns (4) and (5) further show that firms shift the composition of payouts toward more repurchases after their industries experience technological transitions; the payout ratio rises from 0.28 to 0.39 after a transition.

Table 8 About Here

## 5. Conclusions

The paper has studied empirically the effect of evolving technology on funding and payout policy through the lens of a simple model of corporate investment.

Our main contribution is an analysis of the impact of human capital on corporate financing, risk management and payout policy. Our simple investment model distinguishes firms in terms of their adoption of intangible investment. We show that the specific nature of intangible capital implies two key differences.

First, while traditional firms rely on upfront purchases of physical capital, intangible capital needs to be developed and innovated by creative employees contributing their human capital, which cannot be purchased. As a result, HINT firms have lower investment and financing needs. Empirically, innovating firms indeed tend to have higher free cashflows and pledge more equity to skilled employees. They are on average less likely to be ex-post constrained, although some of their cash is likely held for precautionary reasons, reflecting a higher opportunity cost of financial constraints and distress.

Moreover, the setup suggests a second motive for prudent financial policy next to this classic precautionary motive. As intangible investment requires cooperation of skilled labor in developing intangible capital, it needs to be rewarded by deferred compensation. Reducing the cost of skilled human capital requires lower leverage, higher cash holdings and a preference for share repurchases over dividends in the corporate payout policy. This strategy supports the commitment of risk-averse human capital to the development of corporate intangible assets, and

reduces the cost of skilled human capital. Our empirical analysis confirms the importance of such a complementary motive for prudent corporate financing and payout policies. Firms with more intangibles appear to hold even more cash, in particular when their stock volatility is high or their employees hold large equity stakes, and favor repurchases over dividends.

In conclusion, this paper contributes to an emerging literature that extends classic insights on corporate financial structure to the growing use of a special class of assets. The traditional motives of risk management and minimization of the cost of capital are here restated in a world where innovation is paired with skilled human capital, and where innovators and top talent have improved outside options. Much work needs to be still done to fully appreciate the implication of this transformation.

## References


Acharya, Viral V., Stewart C. Myers, and Raghuram G. Rajan, 2011, The internal governance of firms, *The Journal of Finance* 66, 689–720.

Agarwal, Ashwini, and David Matsa, 2013, Labor unemployment risk and corporate financing decisions, *Journal of Financial Economics* 108, 449–470.

Aldatmaz, Serdar, Paige Ouimet, and Edward D. Van Wesep, 2017, The option to quit: The effect of employee stock options, *Journal of Financial Economics* forthcoming.

Almeida, Heitor, and Murillo Campello, 2007, Financial constraints, asset tangibility, and corporate investment, *Review of Financial Studies* 20, 1429–1460.

Almeida, Heitor, Murillo Campello, Igor Cunha, and Michael S. Weisbach, 2014, Corporate liquidity management: A conceptual framework and survey, *Annu. Rev. Financ. Econ.* 6, 135–162.

Almeida, Heitor, Murillo Campello, and Michael S. Weisbach, 2004, The cash flow sensitivity of cash, *Journal of Finance* 59, 1777–1804.

Andrews, Donald, 1993, Tests for parameter instability and structural change with unknown change point, *Econometrica* 61, 821–856.

Autor, David H., Lawrence F. Katz, and Alan B. Krueger, 1998, Computing inequality: Have computers changed the labor market?, *The Quarterly Journal of Economics* 113, 1169–1213.

Azar, José A, Jean-François Kagy, and Martin C Schmalz, 2016, Can changes in the cost of carry explain the dynamics of corporate "cash" holdings?, *Review of Financial Studies* 29, 2194–2240.

Babenko, Ilona, and Yuri Tserlukevich, 2009, Analyzing the tax benefits from employee stock options, *Journal of Finance* 64, 1797–1825.

Babina, Tania, 2017, Destructive creation at work: How financial distress spurs entrepreneurship, Columbia University Working Paper.

Bates, Thomas W., Kathleen M. Kahle, and Ren M. Stulz, 2009, Why do U.S. firms hold so much more cash than they used to?, *Journal of Finance* 64, 1985–2021.

Begenau, Juliane, and Berardino Palazzo, 2017, Firm selection and corporate cash holdings, Harvard Business School Working Paper.

Bellstam, Gustaf, Sanjai Bhagat, and J. Anthony Cookson, 2017, A text-based analysis of corporate innovation, University of Colorado Working Paper.

Bergman, Nittai K., and Dirk Jenter, 2007, Employee sentiment and stock option compensation, *Journal of Financial Economics* 84, 677–712.

Berk, Jonathan, Richard Stanton, and Josef Zechner, 2009, Human capital, bankruptcy and capital structure, *Journal of Finance* 65, 891–925.

Bolton, Patrick, Neng Wang, and Jinqiang Yang, 2016, Liquidity and risk management: Coordinating investment and compensation policies, Columbia University and NBER Working Paper.

Corrado, Carol A., and Charles R. Hulten, 2010, How do you measure a "technological revolution"?, *American Economic Review* 100, 99–104.

Dittmar, Amy, and Jan Mahrt-Smith, 2007, Corporate governance and the value of cash holdings, *Journal of Financial Economics* 83, 599–634.

Döttling, Robin, Germán Gutiérrez, and Thomas Philippon, 2017, Is there an investment gap in advanced economies? If so, why?, Prepared for the ECB Forum on Central Banking.

Döttling, Robin, and Enrico C. Perotti, 2017, Secular trends and technological progress .

Eisfeldt, Andrea L, and Dimitris Papanikolaou, 2013, Organization capital and the cross-section of expected returns, *The Journal of Finance* 68, 1365–1406.

Falato, Antonio, Dalida Kadyrzhanova, and Jae W. Sim, 2013, Rising intangible capital, shrinking debt capacity, and the US corporate savings glut, Finance and Economics Discussion Series Working Paper 2013-67.

Farre-Mensa, Joan, and Alexander Ljungqvist, 2016, Do measures of financial constraints measure financial constraints?, *Review of Financial Studies* 29, 271–308.

Foley, C. Fritz, Jay C. Hartzell, Sheridan Titman, and Garry Twite, 2007, Why do firms hold so much cash? A tax-based explanation, *Journal of Financial Economics* 86, 579–607.

Froot, Kenneth A., David S. Scharfstein, and Jeremy C. Stein, 1993, Risk management: Coordinating corporate investment and financing policies, *The Journal of Finance* 48, 1629–1658.

Fu, Fangjian, Sheng Huang, and Rong Wang, 2015, Why do US firms invest less over time?, Singapore Management University Working Paper.

Graham, John, Hyunseob Kim, Si Li, and Jiaping Qiu, 2016, Employee costs of corporate bankruptcy, Duke University Working Paper.

Graham, John, and Mark Leary, 2016, The evolution of corporate cash, Duke University Working Paper.

Hadlock, Charles J., and Joshua R. Pierce, 2010, New evidence on measuring financial constraints: Moving beyond the kz index, *Review of Financial Studies* 23, 1909–1940.

Hanlon, Michelle, and Terry Shevlin, 2002, The tax benefits of employee stock options: The accounting and implications, *Accounting Horizons* 16, 1–16.

Harford, Jarrad, Sandy Klasa, and William Maxwell, 2014, Refinancing risk and cash holdings, *Journal of Finance* 69, 975–1012.

Harford, Jarrad, Sattar Mansi, and William Maxwell, 2008, Corporate governance and firm cash holdings in the US, *Journal of Financial Economics* 87, 535–555.

Harford, Jarrad, Cong Wang, and Kuo Zhang, 2016, Foreign cash: Taxes, internal capital markets, and agency problems, University of Washington Working Paper.

Hart, Oliver, and John Moore, 1994, A theory of debt based on the inalienability of human capital, *The Quarterly Journal of Economics* 109, 841–79.

Holmström, Bengt, and Jean Tirole, 1998, Private and public supply of liquidity, *Journal of political Economy* 106, 1–40.

Jensen, Michael C., 1986, Agency cost of free cash flow, corporate finance, and takeovers, *Corporate Finance, and Takeovers. American Economic Review* 76.

Kaplan, Steven N., and Luigi Zingales, 1997, Do investment-cash flow sensitivities provide useful measures of financing constraints?, *Quarterly Journal of Economics* 112, 169–215.

Katz, Lawrence F., and Kevin M. Murphy, 1992, Changes in relative wages, 1963-1987: Supply and demand factors, *The Quarterly Journal of Economics* 107, pp. 35–78.

Kim, E. Han, David C. Mauer, and Ann E. Sherman, 1998, The determinants of corporate liquidity: theory and evidence, *Journal of Financial and Quantitative Analysis* 33, 335–359.

Kim, E. Han, Ernst Maug, and Christoph Schneider, 2016, Labor representation in governance as an insurance mechanism, University of Michigan Working Paper.

Lamont, Owen, Christopher Polk, and Jesús Saaá-Requejo, 2001, Financial constraints and stock returns, *Review of Financial Studies* 14, 529–554.

Lee, Dong Wook, Hyun-Han Shin, and René Stulz, 2016, Why does capital no longer flow more to the industries with the best growth opportunities?, Ohio State University Working Paper.

Lev, Baruch, and Suresh Radhakrishnan, 2005, The valuation of organization capital, in Carol Corrado, John Haltiwanger, and Dan Sichel, eds., *Measuring Capital in the New Economy*, 73–110 (University of Chicago Press).

Li, Wendy C.Y., 2012, Depreciation of business R&D capital, Bureau of Economic Analysis/National Science Foundation R&D Satellite Account Paper.

Lustig, Hanno, Chad Syverson, and Stijn van Nieuwerburgh, 2011, Technological change and the growing inequality in managerial compensation, *Journal of Financial Economics* 99, 601–627.

Miller, Merton H., and Daniel Orr, 1966, A model of the demand for money by firms, *Quarterly Journal of Economics* 80, 413–435.

Mulligan, Casey B., 1997, Scale economies, the value of time, and the demand for money: Longitudinal evidence from firms, *Journal of Political Economy* 105, 1061–1079.

Opler, Tim, Lee Pinkowitz, René Stulz, and Rohan Williamson, 1999, The determinants and implications of corporate cash holdings, *Journal of Financial Economics* 52, 3–46.

Oyer, Paul, and Scott Schaefer, 2005, Why do some firms give stock options to all employees?: An empirical examination of alternative theories, *Journal of Financial Economics* 76, 99–133.

Peters, Ryan H., and Lucian A. Taylor, 2016, Intangible capital and the investment-$q$ relation, Forthcoming, *Journal of Financial Economics*.

Philippon, Thomas, and Germán Gutiérrez, 2016, Investment-less growth: An empirical investigation New York University Working Paper.

Pinkowitz, Lee, René Stulz, and Rohan Williamson, 2006, Do firms in countries with poor protection of investor rights hold more cash?, *Journal of Finance* 61, 2725–2751.

Pinkowitz, Lee, René Stulz, and Rohan Williamson, 2016, Do U.S. firms hold more cash than foreign firms do?, *Review of Financial Studies* 29, 309–348.

Sun, Qi, and Mindy X. Zhang, 2017, Financing intangible capital, Shanghai University of Finance and Economics Working Paper.

Thakor, Richard T., and Andrew W. Lo, 2015, Competition and R&D financing decisions: Theory and evidence from the biopharmaceutical industry, NBER Working Paper.

Whited, Toni, and Guojun Wu, 2006, Financial constraints risk, *Review of Financial Studies* 19, 531–559.

# Appendix A Proofs and Extensions of the Model

## A.1 Proof of Proposition 1

This appendix proves the result of Proposition 1, that optimal period-1 cash holdings increase in the firm's technological reliance on intangibles, i.e. that $\frac{dC_1^*}{d\eta} \geq 0$. To prove the proposition, we first derive the following intermediate result:

**Lemma 2.** *Consider two pairs $(\omega', C_1')$ and $(\omega'', C_1'')$ that are the firm's optimal choice given two different parameter values $\eta' \neq \eta''$. If $\omega'' > \omega'$ then it must also be that $C_1'' \geq C_1'$.*

*Proof.* Suppose the contrary. We will show that this is inconsistent with the firm's optimization. To see this, use (4) to write the firm's first order condition (5) as

$$[\mathbb{E}R + (1-\chi)C_1]\frac{S'(C_1)}{S(C_1)} = \frac{(1-\omega)(1-\chi)-1}{\omega}$$

Since $(\omega', C_1')$ and $(\omega'', C_1'')$ are both optimal choices, the first order condition must be satisfied for each pair.

Clearly, the RHS increases in $\omega$. Similarly, the LHS can be written as

$$-(1-\chi)\frac{\int(R+(1-\chi)C_1)dF(R)\int(R+(1-\chi)C_1)^{-\gamma}dF(R)}{\int(R+(1-\chi)C_1)^{1-\gamma}dF(R)},$$

which increases in $C_1$ for $\gamma \geq 0$. However, this implies that if $\omega'' > \omega'$ and $C_1'' < C_1'$, (5) cannot be satisfied for both $(\omega', C_1')$ and $(\omega'', C_1'')$, thus contradicting that both can be optimal choices by the firm. □

Next, observe that a higher $\eta$ increases the bargaining power of the employee. If $\eta'' > \eta'$, the incentive compatibility constraint (IC) requires that $\omega'' > \omega'$, or $C_1'' > C_1'$, or both. The only way an increase in $\eta$ can possibly decrease cash holdings is therefore if $\omega'' > \omega'$ and $C_1'' < C_1'$. However, this is ruled out by the result in lemma 2, completing the proof of Proposition 1. □

## A.2 Deferred cash compensation

This appendix shows that when the employee is compensated with a deferred cash payment instead of unvested equity, the firm still optimally retains cash to reduce retention costs. Suppose that at $t = 0$, the firm grants the employee a cash payment $w$ that vests after returns are realized at $t = 2$. The crucial insight is that if the firm does not retain enough cash, it may default on the promised compensation.[21] In particular, the firm's effective payment to the employee is

$$\min\{RI + (1-\chi)C_1, w\}.$$

The cash grant is therefore riskless if and only if $C_1 \geq \frac{w}{(1-\chi)}$. Essentially, deferred cash compensation has a debt-like payout structure, and cash holdings shrink the default region.

Now, denote by

$$\hat{R}(C_1) = \frac{w - (1-\chi)C_1}{I}$$

the threshold such that for realizations of $R < \hat{R}(C_1)$ the firm defaults on the employee's compensation. The incentive compatibility constraint to prevent the employee from leaving can be re-expressed as

$$\int_{\hat{R}(C_1)}^{\bar{R}} U(w) + \int_0^{\hat{R}(C_1)} U([RI + (1-\chi)C_1])dF(R) \geq \int U((1-\alpha)\eta RI)dF(R). \tag{IC$'$}$$

The first term on the left-hand side is the employee's utility from the deferred cash payment, and the second term is the expected utility upon default. As in the model with unvested equity, this must exceed the expected utility from starting an own firm.

The firm's problem is now to choose a level of period-1 cash holdings $C_1$ and deferred cash payment $w$ to maximize

[21] Recall that the support of $\tilde{R}$ is $[0, \bar{R}]$.

$$
\begin{aligned}
\max_{C_1, w} \quad & V(w, C_1) = \Pr[R \geq \hat{R}(C_1)][\mathbb{E}\tilde{R} + (1-\chi)C_1 - w] - (\alpha H + K + \lambda C_p + C_1), \\
s.t. \quad & (IC), \\
& C_1, w \geq 0.
\end{aligned}
$$

We return to denote $C_1$ by $C_R$, as the choice relates to retention. Clearly, the firm's objective function is decreasing in $w$, so that it chooses the minimum level consistent with (IC$'$), implicitly defining $w(C_R)$. Condition (IC$'$) shows that the employee's utility from staying inside the firm (the left-hand-side of the condition) is increasing in both $w$ and $C_R$. This implies that $w'(C_R) \leq 0$, i.e., holding cash reduces the size of the deferred cash grant necessary to retain the employee.

There are now two cases to consider. First, the firm may choose to fully insure the worker by setting $w = \underline{w}$ and $C_R = \frac{\underline{w}}{(1-\chi)}$, where

$$
\underline{w} = \eta(1-\alpha)\left[\int (R)^{1-\gamma} dF(R)\right]^{\frac{1}{1-\gamma}}.
$$

Note that the firm will never hold more cash than $\frac{\underline{w}}{(1-\chi)}$, since the employee is already fully insured and additional cash holdings have a moral hazard cost $\chi$. Second, the firm may choose an interior solution $C_R^* \in \left[0, \frac{\underline{w}}{(1-\chi)}\right)$ and $w^* > \underline{w}$ that maximizes $V(w, C_R)$.

Importantly, under deferred cash compensation the same motive to hold cash prevails. Since the firm is risk-neutral, it may choose to hold some cash to insure the risk-averse employee against defaulting on the promised payment, decreasing the overall cost of employee retention.

# Appendix B Variable Definitions

This appendix contains detailed definitions of all variables used in the analysis. Unless otherwise noted, the source of each data item is Compustat.

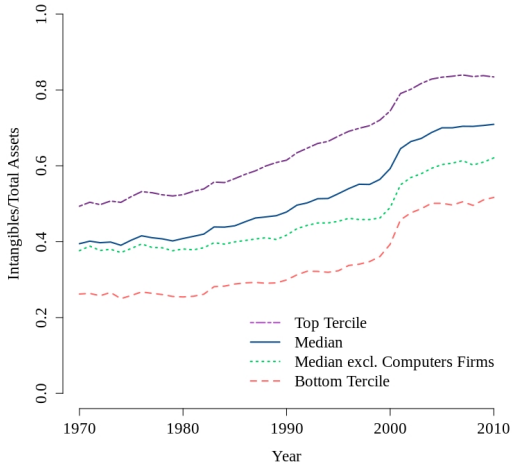
| Variable | Definition |
|---|---|
| *Intangibles Ratio* | The value of the firm's stock of intangible assets, divided by total assets. The stock of intangible assets is measured as in Peters and Taylor (2016), by summing up the capitalized value of spending on R&D, investment into organizational capital, and acquisition of externally produced intangible assets. Two differences between our procedure and that of Peters and Taylor (2016) is that we measure investment into organizational capital as 20% of SG&A instead of 30%, and we exclude Goodwill from the acquisition of externally produced intangible assets. Throughout this appendix, total assets is defined as the sum of intangible assets and PP&E (data item PPENT). |
| *Post Transition* | An indicator that is equal to 0 for observations that precede a technological transition, and 1 for observations that follow it. Technological transitions are identified separately for each of the 48 Fama-French industries as a structural break in the time series of *Intangible/Total Investment*, using the method developed by Andrews (1993). |
| *Tangible Investment* | The annual change in PP&E (data item PPENT) net of depreciation (DPACT), divided by *Operating Cashflows*. This variable is set to missing for firms with negative *Operating Cashflows*. This variable is winsorized at the 1-99 level. |
| *Intangible Investment* | The sum of R&D spending (data item XRD), 0.2×SG&A expenditures (SGA), and acquisition of externally produced intangibles, divided by *Operating Cashflows*. Acquisition of externally produced intangibles is measured as the annual change in Other Intangibles (INTANO) plus Amortization of Intangibles (AM). Starting in 2006, we deduct from SG&A the fair-value expense of stock option grants to employees (data item OPTFVGR), as this is not a cash outlay. This variable is set to missing for firms with negative *Operating Cashflows*. This variable is winsorized at the 1-99 level. |
| *Intangible/Total Investment* | *Intangible Investment* divided by *Total Investment*. This variable is winsorized at the 1-99 level. |
| *Avg. Total Investment* | The average of the sum of *Tangible Investment* and *Intangible Investment* from the three previous years. This variable is winsorized at the 1-99 level. |
| *Free Cashflows* | *Operating Cashflows* minus *Total Investment*, divided by *Operating Cashflows*. This variable is winsorized at the 1-99 level. |
| *Net Leverage* | The sum of total debt (data items DLTT plus DLC) minus cash and marketable securities (data item CHE), divided by total assets. This variable is winsorized at the 1-99 level. |
| *Equity Grants* | The sum of the value of annual stock grants (data item STKCO) and the Black-Scholes value of stock option compensation, divided by market capitalization (PRCC_F × CSHO). Prior to 2004, the Black-Scholes value of stock options is inferred using the procedure of (Bergman and Jenter, 2007). Afterward, it is data item OPTFVGR. Prior to 2001, the value of stock grants is set to 0 as Compustat did not collect STKCO in these years, and only 7.5% of firms granted stock in the early 2000s. This variable is measured only for ExecuComp firms, and is winsorized at the 1-99 level. |
| *Retained Cash* | *Free Cashflows* minus total payouts, divided by *Free Cashflows*. This variable is winsorized at the 1-99 level. |
| *Cash Holdings* | The sum of cash and marketable securities (data item CHE), divided by total assets. This variable is winsorized at the 1-99 level. |
| *Repurchases/Payouts* | Stock repurchases divided by the sum of stock repurchases and common dividends (data item DVC). Repurchases are the year-on-year change in the number of shares in the corporate treasury (TSTKC). For firms with zero or missing values of treasury shares in the past two years, repurchases equals open-market purchases of common stock (PRSTKC) minus sales of common stock (SSTK).This variable is winsorized at the 1-99 level. |
| *Tobin's Q* | Total debt (the sum of data items DLTT and DLC) plus the market value of equity (PRCC_F×CSHO) minus current assets (ACT), all divided by total assets. This variable is winsorized at the 1-99 level. |
| *Log Total Assets* | The natural logarithm of total assets. This variable is winsorized at the 1-99 level. |
| *Operating Cashflows* | Operating earnings (data item OIDBP) plus intangible investment minus tax payments (TXT) and interest payments (XINT), all divided by total assets. This variable is winsorized at the 1-99 level. |
| *Cashflow Volatility* | The standard deviation of *Operating Cashflows* over the previous 10 years. It is set to missing for firms with fewer than 3 years of data. This variable is winsorized at the 1-99 level. |
| *Book Leverage* | Total debt (data items DLTT plus DLC) divided by total assets. This variable is winsorized at the 1-99 level. |
| *Stock Volatility* | The standard deviation of the firm's stock returns from the 48 months prior to the start of the year. Monthly stock returns are CRSP data item RET. This variable is winsorized at the 5-95 level. |

| Variable | Definition |
|---|---|
| *High Volatility* | An indicator that is equal to 1 for firm-fiscal years with above-median *Stock Volatility*, and 0 for firm-years with below-median volatility. |
| *High Equity Grants* | An indicator that is equal to 1 for firm-fiscal years with above-median values of *Equity Grants*, and 0 for firm-years with below-median values. |
| *High Constraints* | An indicator that is equal to 1 for firm-fiscal years with Hadlock-Pierce, Whited-Wu, or Kaplan-Zingales index values in the top tercile; 1 for firms without a credit rating (data item SPLTICRM and SPSTICRM); 1 for firms that do not pay any dividends (DVC) during the year; and 0 otherwise. The Kaplan-Zingales index is measured according to Lamont et al. (2001). |
| *Alt. Tangible Investment* | The sum of capital expenditures (data item CAPX) and cash spent on acquisitions (AQC), divided by *Operating Cashflows*. |
| *Alt. Free Cashflows* | *Operating Cashflows* minus *Alt. Tangible Investment* and *Intangible Investment*, divided by *Operating Cashflows*. |
| *Pledged Equity* | The number of shares underlying all stock options held by employees, divided by this number plus the number of publicly traded shares (data item CSHO). The number of shares underlying stock options is the total number of shares underlying conversion of all options, preferred stock, and convertible debt (CSHRT) minus shares underlying conversion of preferred stock (CSHRP) minus shares underlying conversion of convertible debt (CSHRC). The latter two items are set to 0 if missing. Data used to construct this variable is only available for fiscal years 1970 through 1995. This variable is winsorized at the 1-99 level. |

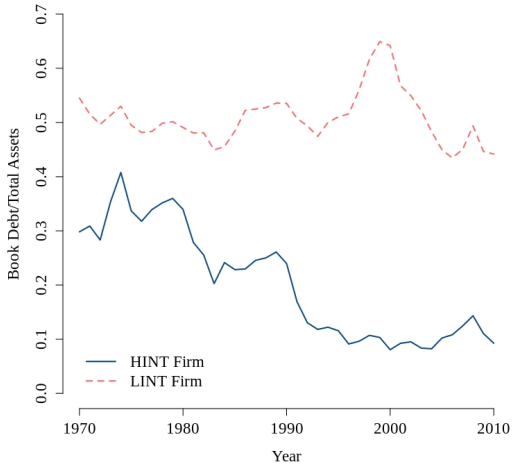
Figure 1: Evolution of Intangibles Usage and Corporate Financing

HINT firms have an *Intangibles Ratio* in the highest tercile of the sample distribution, and LINT firms have an *Intangibles Ratio* in the lowest tercile. *Intangibles Ratio* is the firm's stock of intangible assets divided by the sum of intangible assets and net PP&E. Computers firms are those in the Fama-French 48 industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). Panels B and C plot values for the median HINT and LINT firm.

Panel A. Intangibles Usage




Panel B. Leverage




Panel C. Cash Holdings

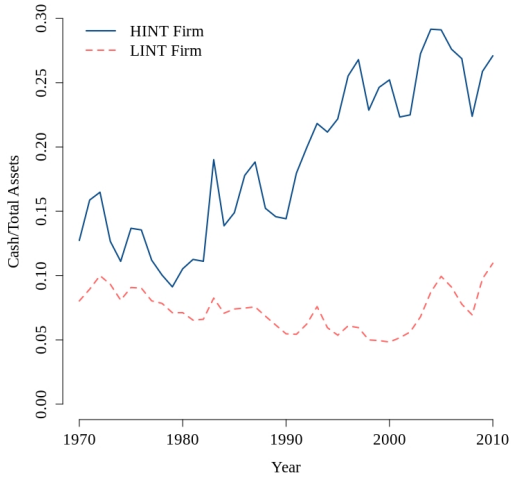


Figure 4: Corporate Investment around Technological Transitions

For each Fama-French 48 industry, we measure technological transitions as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). Plots show values of *Tangible Investment* and *Intangible Investment* for the median firm, after adjusting for differences in *Log Total Assets* using a regression analysis.

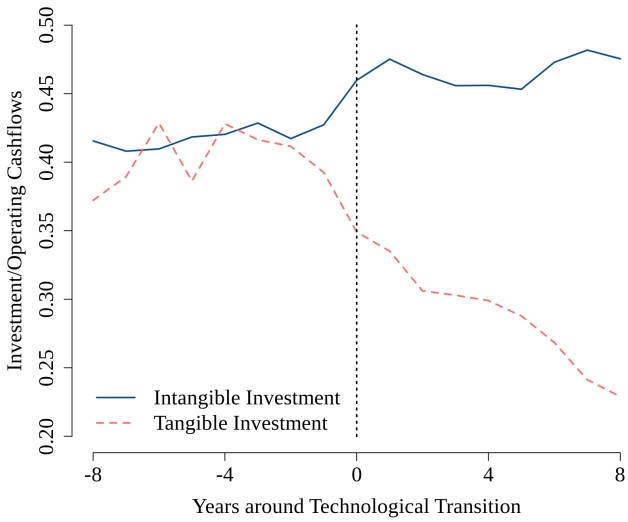
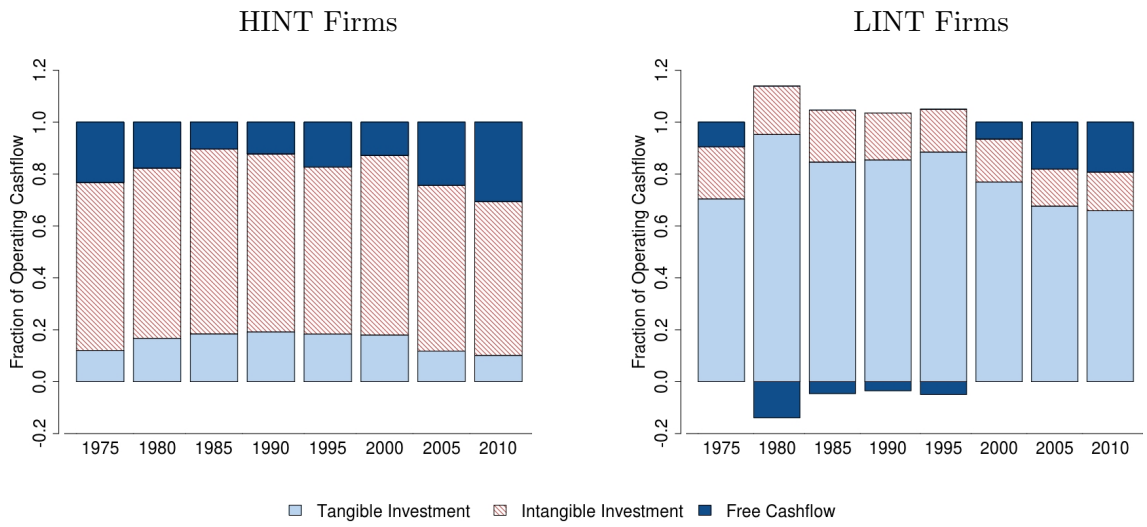


Figure 5: Intangibles Usage, Investment Outlays, and Free Cashflows

Panel A shows the fraction of operating cashflows spent on tangible and intangible investment, as well as free cashflows that remain after investment. Values are plotted for the median HINT and LINT firm. HINT firms have an *Intangibles Ratio* in the highest tercile of the sample distribution, and LINT firms have an *Intangibles Ratio* in the lowest tercile. *Intangibles Ratio* is the firm's stock of intangible assets divided by the sum of intangible assets and net PP&E. In Panel B, we measure technological transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993).

Panel A. Composition of Outlays




Panel B. Time-Series Evolution of Free Cashflows

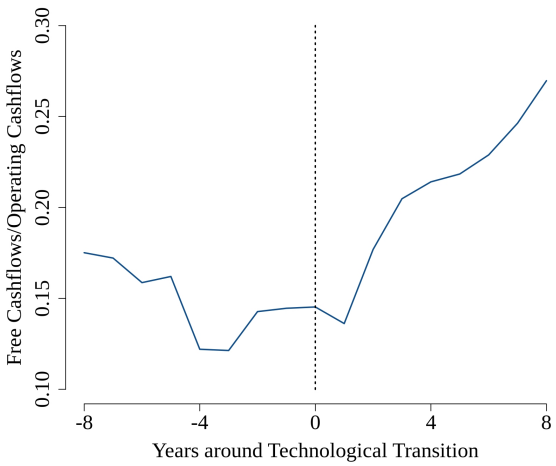
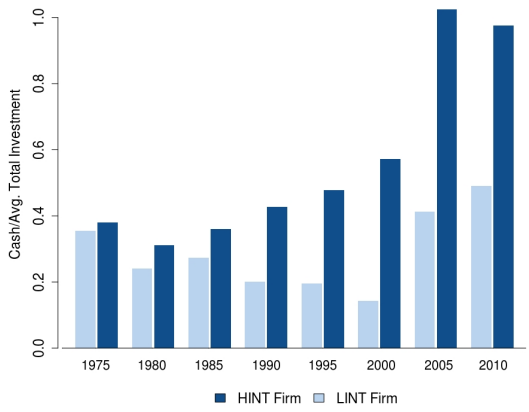


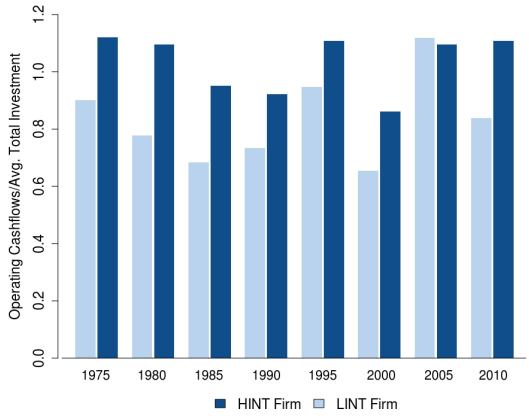
Figure 6: Intangibles Usage and Need for Precautionary Savings

Panel A plots the ratio of *Cash Holdings* from the start of the year to *Avg. Total Investment*, the average of annual tangible and intangible investment from the three previous years. Panel B plots the ratio of *Operating Cashflows* from the current year to *Avg. Total Investment*. Both panels show plots for the median HINT and LINT firm. Panel C plots, for all HINT and LINT firms, the fraction of sample years that the sum of *Cash Holdings* and *Operating Cashflows* exceeds *Avg. Total Investment*. Firms that are in the sample for fewer than five years are excluded. HINT firms have an *Intangibles Ratio* in the highest tercile of the sample distribution, and LINT firms have an *Intangibles Ratio* in the lowest tercile. *Intangibles Ratio* is the firm's stock of intangible assets divided by the sum of intangible assets and net PP&E.

Panel A. Coverage from Cash Holdings




Panel B. Coverage from Cashflows




Panel C. Frequency of Sufficient Coverage

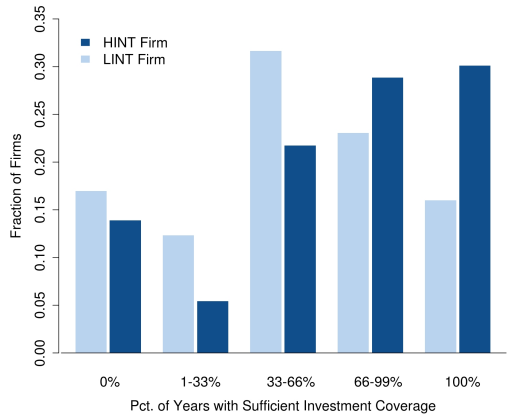


Table 1: Growth of Intangibles Usage across Industries

The table presents the median value of *Intangibles Ratio* at the start and end of our sample for a selection of industries. *Intangibles Ratio* is the firm's stock of intangible assets divided by the sum of intangible assets and net PP&E. Industries are based on the Fama-French 48-industry classification.

| Industries Experiencing Large Change | *Intangibles Ratio* in 1970 | *Intangibles Ratio* in 2010 | Change from 1970 to 2010 |
|---|---|---|---|
| Healthcare | 0.097 | 0.637 | 0.540 |
| Business Services | 0.381 | 0.882 | 0.501 |
| Communication | 0.112 | 0.556 | 0.444 |
| Candy & Soda | 0.359 | 0.731 | 0.372 |
| Personal Services | 0.186 | 0.539 | 0.353 |
| Computers | 0.545 | 0.897 | 0.352 |
| Pharmaceutical Products | 0.625 | 0.962 | 0.337 |
| Medical Equipment | 0.542 | 0.859 | 0.317 |
| Apparel | 0.492 | 0.808 | 0.316 |
| Recreation | 0.586 | 0.886 | 0.300 |
| **Industries Experiencing Small Change** | ***Intangibles Ratio* in 1970** | ***Intangibles Ratio* in 2010** | **Change from 1970 to 2010** |
| Steel Works | 0.182 | 0.257 | 0.076 |
| Shipping Containers | 0.214 | 0.261 | 0.047 |
| Entertainment | 0.200 | 0.239 | 0.039 |
| Transportation | 0.071 | 0.087 | 0.016 |
| Shipbuilding & Railroad Equipment | 0.220 | 0.203 | -0.017 |
| Non-Metallic & Industrial Metal Mining | 0.095 | 0.067 | -0.029 |
| Petroleum & Natural Gas | 0.085 | 0.045 | -0.040 |
| Agriculture | 0.320 | 0.271 | -0.050 |
| Coal | 0.113 | 0.035 | -0.078 |
| Precious Metals | 0.334 | 0.037 | -0.297 |

Table 2: Summary Statistics

Summary statistics are measured across all sample years of 1970 to 2010. HINT firms have an *Intangibles Ratio* in the highest tercile of the sample distribution, and LINT firms have an *Intangibles Ratio* in the lowest tercile. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Tangible Investment* is the annual change in PP&E net of depreciation, divided by *Operating Cashflows*. *Intangible Investment* is the sum of R&D spending, 0.2×SG&A expenditures, and acquisition of externally produced intangibles, divided by *Operating Cashflows*. *Intangible/Total Investment* is *Intangible Investment* divided by this number and *Tangible Investment*. *Avg. Total Investment* is the average of the sum of *Tangible Investment* and *Intangible Investment* from the three previous years. *Free Cashflows* is *Operating Cashflows* minus the sum of *Tangible Investment* and *Intangible Investment*, all divided by *Operating Cashflows*. *Net Leverage* is total debt minus cash and marketable securities, divided by total assets. *Equity Grants* is the grant-date fair value of annual stock and stock option compensation, divided by market capitalization. It is measured only for ExecuComp firms. *Retained Cash* is *Free Cashflows* minus total payouts, divided by *Free Cashflows*. *Cash Holdings* is the sum of cash and marketable securities, divided by total assets. *Repurchases/Payouts* is stock repurchases divided by the sum of stock repurchases and common dividends. It excludes repurchases in which shares are immediately used to fulfill employee option exercises. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. *Stock Volatility* is the standard deviation of the firm's stock returns from the previous 48 months. Standard errors are clustered by firm and year. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | HINT Firm | | | | LINT Firm | | | | Diff. |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | St. Dev. | No. Obs. | Mean | Median | St. Dev. | No. Obs. | in Means |
| *Intangibles Ratio* | 0.815 | 0.814 | 0.103 | 54,931 | 0.131 | 0.115 | 0.103 | 51,679 | 0.684*** |
| *Tangible Investment* | 0.238 | 0.151 | 0.790 | 41,077 | 1.249 | 0.783 | 1.741 | 43,727 | -1.012*** |
| *Intangible Investment* | 1.04 | 0.654 | 1.319 | 41,086 | 0.29 | 0.178 | 0.638 | 43,752 | 0.750*** |
| *Intangible/Total Investment* | 0.801 | 0.825 | 0.313 | 53,500 | 0.196 | 0.142 | 0.309 | 49,985 | 0.605*** |
| *Avg. Total Investment* | 1.120 | 0.834 | 1.098 | 29,554 | 1.417 | 1.053 | 1.325 | 31,735 | -0.297*** |
| *Free Cashflows* | -0.331 | 0.179 | 2.134 | 41,077 | -0.606 | 0.008 | 2.339 | 43,727 | 0.275*** |
| *Net Leverage* | -0.036 | -0.035 | 0.959 | 54,717 | 0.462 | 0.411 | 0.815 | 51,518 | -0.498*** |
| *Equity Grants* | 0.029 | 0.018 | 0.036 | 15,272 | 0.013 | 0.006 | 0.024 | 8,010 | 0.017*** |
| *Retained Cash* | -0.446 | 0.097 | 2.224 | 41,026 | -0.785 | -0.155 | 2.419 | 43,623 | 0.339*** |
| *Cash Holdings* | 0.45 | 0.211 | 0.653 | 54,925 | 0.234 | 0.072 | 0.525 | 51,660 | 0.216*** |
| *Repurchases/Payouts* | 0.497 | 0.487 | 0.463 | 19,489 | 0.245 | 0.000 | 0.392 | 29,173 | 0.252*** |
| *Tobin's Q* | 2.07 | 0.842 | 3.763 | 48,206 | 1.791 | 1.027 | 2.851 | 39,567 | 0.279** |
| *Log Total Assets* | 3.856 | 3.651 | 1.778 | 51,196 | 4.670 | 4.522 | 2.081 | 47,725 | -0.814*** |
| *Operating Cashflows* | 0.324 | 0.299 | 0.394 | 43,655 | 0.230 | 0.194 | 0.290 | 42,917 | 0.094*** |
| *Cashflow Volatility* | 0.244 | 0.145 | 0.309 | 38,216 | 0.132 | 0.070 | 0.230 | 36,160 | 0.112*** |
| *Book Leverage* | 0.432 | 0.174 | 0.723 | 51,006 | 0.677 | 0.499 | 0.727 | 47,583 | -0.246*** |
| *Stock Volatility* | 0.172 | 0.163 | 0.067 | 42,614 | 0.135 | 0.122 | 0.055 | 36,999 | 0.037*** |

Table 3: Intangibles Usage and Investment Outlays

Columns (1) through (6) report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. Columns (7) through (10) report estimates from regressions using five-year (two-sided) windows around technological transitions. We measure transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). *Tangible Investment* is the annual change in PP&E net of depreciation, divided by *Operating Cashflows*. *Free Cashflows* are *Operating Cashflows* minus tangible and intangible investment, divided by *Operating Cashflows*. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Post Transition* is equal to 0 for observations that precede a technological transition, and 1 for observations that follow it. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Pooled Regressions | | | | | | Staggered technological transitions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dependent Variable | *Tangible Investment* | | | *Free Cashflows* | | | *Tangible Investment* | | *Free Cashflows* | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *Intangibles Ratio* | -1.588*** | -1.443*** | -1.505*** | 0.517*** | 0.338*** | 0.457*** | | | | |
| | (-55.85) | (-50.14) | (-46.94) | (11.10) | (7.59) | (9.27) | | | | |
| *Post Transition* | | | | | | | -0.205*** | -0.169*** | 0.102** | 0.091** |
| | | | | | | | (-7.12) | (-6.17) | (2.47) | (2.32) |
| *Tobin's Q* | 0.008*** | 0.021*** | 0.022*** | 0.016*** | -0.040*** | -0.039*** | 0.011 | 0.030*** | 0.020* | -0.018 |
| | (3.98) | (7.57) | (6.28) | (4.92) | (-9.05) | (-7.41) | (1.52) | (3.13) | (1.95) | (-1.33) |
| *Log Total Assets* | -0.073*** | -0.055*** | -0.060*** | 0.135*** | 0.107*** | 0.113*** | -0.011 | -0.009 | 0.086*** | 0.070*** |
| | (-23.68) | (-17.46) | (-16.43) | (25.87) | (22.04) | (20.53) | (-1.28) | (-1.04) | (6.73) | (5.55) |
| *Operating Cashflows* | | -0.403*** | -0.443*** | | 1.471*** | 1.500*** | | -0.497*** | | 1.228*** |
| | | (-16.95) | (-15.41) | | (31.44) | (27.98) | | (-6.32) | | (10.28) |
| *Cashflow Volatility* | | 0.201*** | 0.221*** | | -0.427*** | -0.405*** | | 0.045 | | -0.563*** |
| | | (7.08) | (6.44) | | (-8.59) | (-7.13) | | (0.45) | | (-3.38) |
| *Book Leverage* | | -0.009 | 0.002 | | -0.055*** | -0.084*** | | 0.059** | | -0.058 |
| | | (-0.76) | (0.12) | | (-3.10) | (-4.37) | | (2.05) | | (-1.40) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No | No |
| Computer Firms Omitted | No | No | Yes | No | No | Yes | No | No | No | No |
| Observations | 112,478 | 89,777 | 75,075 | 112,478 | 89,777 | 75,075 | 11,568 | 9,923 | 11,568 | 9,923 |
| Adjusted $R^2$ | 0.165 | 0.161 | 0.161 | 0.047 | 0.070 | 0.074 | 0.076 | 0.078 | 0.033 | 0.056 |

Table 4: Intangibles Usage and Corporate Financing

Columns (1) through (6) report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. Columns (7) through (10) report estimates from regressions using five-year (two-sided) windows around technological transitions. We measure transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). *Net Leverage* is total debt minus cash and marketable securities, divided by total assets. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Post Transition* is equal to 0 for observations that precede a technological transition, and 1 for observations that follow it. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Pooled Regressions | | | | | | Staggered technological transitions | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dependent Variable | *Net Leverage* | | | *Equity Grants* | | | *Net Leverage* | | *Equity Grants* | |
| Sample | All Firms | | | ExecuComp Firms | | | All Firms | | ExecuComp Firms | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| *Intangibles Ratio* | -0.618*** | -0.547*** | -0.473*** | 0.015*** | 0.013*** | 0.008*** | | | | |
| | (-20.13) | (-15.89) | (-12.47) | (10.42) | (9.97) | (6.18) | | | | |
| *Post Transition* | | | | | | | -0.030 | -0.046** | 0.002** | 0.002** |
| | | | | | | | (-1.57) | (-2.34) | (2.08) | (2.48) |
| *Tobin's Q* | -0.037*** | -0.024*** | -0.015** | -0.001*** | -0.001*** | -0.001*** | -0.026** | 0.011 | -0.000** | -0.001*** |
| | (-13.20) | (-5.14) | (-2.47) | (-7.62) | (-7.72) | (-7.50) | (-2.32) | (0.70) | (-2.41) | (-4.02) |
| *Log Total Assets* | 0.022*** | 0.026*** | 0.029*** | -0.003*** | -0.003*** | -0.003*** | 0.036*** | 0.028** | -0.002*** | -0.001* |
| | (6.02) | (6.60) | (7.04) | (-17.02) | (-15.00) | (-13.27) | (3.43) | (2.53) | (-3.67) | (-1.91) |
| *Operating Cashflows* | | -0.260*** | -0.242*** | | -0.007*** | -0.006*** | | -0.363*** | | -0.006** |
| | | (-8.87) | (-6.86) | | (-6.53) | (-5.25) | | (-4.27) | | (-2.28) |
| *Cashflow Volatility* | | 0.227*** | 0.250*** | | 0.009*** | 0.008*** | | 0.082 | | 0.019*** |
| | | (5.31) | (4.91) | | (6.53) | (5.60) | | (0.61) | | (3.29) |
| *Book Leverage* | | | | | 0.001** | 0.003*** | | | | 0.003*** |
| | | | | | (2.18) | (5.22) | | | | (3.12) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No | No |
| Computer Firms Omitted | No | No | Yes | No | No | Yes | No | No | No | No |
| Observations | 132,344 | 99,987 | 83,440 | 22,416 | 19,033 | 15,349 | 12,966 | 10,794 | 2,284 | 2,093 |
| Adjusted $R^2$ | 0.153 | 0.136 | 0.108 | 0.171 | 0.176 | 0.132 | 0.053 | 0.054 | 0.048 | 0.092 |

Table 5: Resource Retention and Cash Holdings

Columns (1) through (3) report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. Columns (4) and (5) report estimates from regressions using five-year (two-sided) windows around technological transitions. We measure transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). *Retained Cash* is *Free Cashflows* minus total payouts, divided by *Free Cashflows*. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Post Transition* is equal to 0 for observations that precede a technological transition, and 1 for observations that follow it. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Pooled Regressions | | | Staggered technological transitions | |
|---|---|---|---|---|---|
| Dependent Variable | *Retained Cash* | | | *Retained Cash* | |
| | (1) | (2) | (3) | (4) | (5) |
| *Intangibles Ratio* | 0.282*** | 0.412*** | 0.404*** | | |
| | (7.49) | (9.25) | (8.43) | | |
| *Post Transition* | | | | 0.160*** | 0.174*** |
| | | | | (4.11) | (3.95) |
| *Tobin's Q* | -0.003 | -0.013*** | -0.019*** | -0.001 | -0.019 |
| | (-1.40) | (-3.55) | (-4.21) | (-0.18) | (-1.46) |
| *Log Total Assets* | -0.115*** | -0.105*** | -0.112*** | -0.119*** | -0.101*** |
| | (-24.48) | (-19.97) | (-19.68) | (-10.03) | (-7.45) |
| *Operating Cashflows* | | -0.043 | -0.071** | | -0.016 |
| | | (-1.52) | (-2.10) | | (-0.21) |
| *Cashflow Volatility* | | 0.030 | 0.009 | | 0.138 |
| | | (0.67) | (0.17) | | (1.41) |
| *Book Leverage* | | 0.278*** | 0.288*** | | 0.184*** |
| | | (17.22) | (16.22) | | (4.79) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | No | No |
| Computer Firms Omitted | No | No | Yes | No | No |
| Observations | 72,183 | 59,748 | 49,985 | 7,709 | 6,774 |
| Adjusted $R^2$ | 0.043 | 0.050 | 0.050 | 0.029 | 0.032 |

Table 6: Employee Insurance for Cash Holdings

All columns report estimates from pooled OLS regressions using U.S. non-financial and utilities firms in ExecuComp, for which equity grant data is available. *Cash Holdings* is the sum of cash and marketable securities, divided by total assets. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *High Volatility* equals 1 for firm-fiscal years with above-median *Stock Volatility*, and 0 for firm-years with below-median volatility. *Stock Volatility* is the standard deviation of the firm's stock returns from the 48 months prior to the start of the year. *High Equity Grants* equals 1 for firm-fiscal years with above-median values of *Equity Grants*, and 0 for firm-fiscal years with below-median values. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Cash Holdings* | | | | |
|---|---|---|---|---|---|
| Sample | ExecuComp Firms | | | | |
| | (1) | (2) | (3) | (4) | (5) |
| *Intangibles Ratio* | 0.110** | 0.092* | 0.064 | -0.004 | 0.210*** |
| | (2.08) | (1.80) | (1.16) | (-0.07) | (2.84) |
| *Intangibles Ratio × High Volatility* | 0.171*** | | 0.152*** | 0.127*** | 0.084** |
| | (4.50) | | (3.71) | (2.94) | (2.40) |
| *Intangibles Ratio × High Equity Grants* | | 0.147*** | 0.097*** | 0.084** | 0.047** |
| | | (4.38) | (2.95) | (2.50) | (2.04) |
| *High Volatility* | -0.030 | | -0.024 | -0.025 | -0.028 |
| | (-1.33) | | (-0.97) | (-0.91) | (-1.49) |
| *High Equity Grants* | | -0.053*** | -0.042** | -0.038* | -0.035*** |
| | | (-2.68) | (-2.11) | (-1.94) | (-2.91) |
| *Tobin's Q* | 0.048*** | 0.049*** | 0.049*** | 0.046*** | 0.030*** |
| | (16.25) | (16.65) | (15.55) | (12.58) | (10.38) |
| *Log Total Assets* | -0.056*** | -0.064*** | -0.056*** | -0.047*** | -0.101*** |
| | (-10.03) | (-11.89) | (-9.26) | (-7.64) | (-8.45) |
| *Operating Cashflows* | | | | 0.039 | |
| | | | | (1.52) | |
| *Cashflow Volatility* | | | | 0.204*** | |
| | | | | (2.97) | |
| *Book Leverage* | | | | -0.058** | |
| | | | | (-2.55) | |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | No |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Firm Fixed Effects | No | No | No | No | Yes |
| Observations | 23,605 | 20,687 | 19,913 | 17,878 | 19,913 |
| Adjusted $R^2$ | 0.337 | 0.342 | 0.337 | 0.333 | 0.108 |

Table 7: Intangibles and Cash Holdings: Accounting for Financial Constraints

All columns report estimates from pooled OLS regressions using U.S. non-financial and utilities firms in ExecuComp, for which equity grant data is available. Regressions in Panel A control for various measures of financial constraints, listed above each column. Regressions in Panel B are estimated on a subsample of firms that have a partially or fully undrawn line of credit (column (6)); or that paid out cash to shareholders during the year (column (7)). *Cash Holdings* is the sum of cash and marketable securities, divided by total assets. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *High Volatility* equals 1 for firm-fiscal years with above-median *Stock Volatility*, and 0 for firm-years with below-median volatility. *Stock Volatility* is the standard deviation of the firm's stock returns from the 48 months prior to the start of the year. *High Equity Grants* equals 1 for firm-years with above-median values of *Equity Grants*, and 0 for firm-years with below-median values. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *High Constraints* equals: 1 in columns (1) through (3) for firm-years with Hadlock-Pierce, Whited-Wu, or Kaplan Index values in the top tercile of the sample distribution; 1 in columns (4) and (5) for firm-years without a credit rating or in which no dividends were paid; and 0 in all other firm-years. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Panel A. Financial Constraint Controls | | | | | Panel B. Subsample Analysis | |
|---|---|---|---|---|---|---|---|
| Dependent Variable | *Cash Holdings* | | | | | *Cash Holdings* | |
| | | | | | | ExecuComp Firms with: | |
| Sample | ExecuComp Firms | | | | | Undrawn Credit Line | Positive Payouts |
| Measure of Constraints | HP Index | WW Index | KZ Index | Credit Rating | Dividend Payouts | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| *Intangibles Ratio* | 0.057 | 0.085 | -0.043 | 0.012 | 0.065 | 0.038 | 0.070 |
| | (0.97) | (1.50) | (-0.74) | (0.22) | (1.19) | (0.92) | (1.20) |
| *Intangibles Ratio × High Volatility* | 0.086** | 0.170*** | 0.142*** | 0.124*** | 0.132*** | 0.191*** | 0.158*** |
| | (2.06) | (4.14) | (3.50) | (2.88) | (2.96) | (3.65) | (3.01) |
| *Intangibles Ratio × High Equity Grants* | 0.057* | 0.088*** | 0.063* | 0.064* | 0.070** | 0.105** | 0.119*** |
| | (1.65) | (2.63) | (1.89) | (1.92) | (2.16) | (2.11) | (2.99) |
| *Intangibles Ratio × High Constraints* | 0.250*** | -0.293*** | 0.093*** | 0.170*** | 0.098** | | |
| | (5.24) | (-16.83) | (4.55) | (4.06) | (2.27) | | |
| *High Volatility* | 0.031 | 0.023 | 0.038 | 0.027 | 0.025 | -0.028 | -0.025 |
| | (1.30) | (0.96) | (1.62) | (1.08) | (0.99) | (-0.93) | (-0.81) |
| *High Equity Grants* | -0.009 | -0.013 | 0.005 | -0.013 | -0.016 | -0.053* | -0.053** |
| | (-0.45) | (-0.65) | (0.26) | (-0.65) | (-0.89) | (-1.92) | (-2.42) |
| *High Constraints* | -0.040 | 0.049*** | -0.160*** | -0.003 | -0.015 | | |
| | (-1.41) | (4.08) | (-13.04) | (-0.12) | (-0.64) | | |
| *Tobin's Q* | 0.051*** | 0.050*** | 0.049*** | 0.052*** | 0.053*** | 0.042*** | 0.050*** |
| | (16.62) | (16.09) | (15.56) | (17.10) | (17.20) | (10.97) | (10.68) |
| *Log Total Assets* | | | | | | -0.043*** | -0.063*** |
| | | | | | | (-6.83) | (-8.13) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 19,912 | 18,414 | 18,414 | 19,913 | 19,913 | 7,165 | 13,138 |
| Adjusted $R^2$ | 0.324 | 0.335 | 0.337 | 0.323 | 0.316 | 0.319 | 0.345 |

Table 8: Intangibles Usage and Payout Policy

Columns (1) through (3) report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. Columns (4) and (5) report estimates from regressions using five-year (two-sided) windows around technological transitions. All regressions include only firm-fiscal years with positive payouts. We measure transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). *Repurchases/Payouts* is stock repurchases divided by the sum of stock repurchases and common dividends. It excludes repurchases in which shares are immediately used to fulfill employee option exercises. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Post Transition* is equal to 0 for observations that precede a technological transition, and 1 for observations that follow it. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | Pooled Regressions *Repurchases/Payouts* | | | Staggered technological transitions *Repurchases/Payouts* | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| *Intangibles Ratio* | 0.238*** | 0.253*** | 0.222*** | | |
| | (13.02) | (12.92) | (10.86) | | |
| *Post Transition* | | | | 0.127*** | 0.114*** |
| | | | | (10.38) | (8.66) |
| *Tobin's Q* | -0.004*** | 0.001 | 0.001 | -0.008** | -0.008* |
| | (-2.65) | (0.53) | (0.33) | (-2.41) | (-1.81) |
| *Log Total Assets* | -0.040*** | -0.035*** | -0.037*** | -0.053*** | -0.045*** |
| | (-19.39) | (-16.07) | (-16.55) | (-10.62) | (-8.32) |
| *Operating Cashflows* | | -0.153*** | -0.150*** | | -0.128*** |
| | | (-11.47) | (-10.09) | | (-3.29) |
| *Cashflow Volatility* | | 0.203*** | 0.185*** | | 0.337*** |
| | | (9.14) | (7.72) | | (5.17) |
| *Book Leverage* | | 0.060*** | 0.068*** | | 0.039** |
| | | (7.72) | (8.27) | | (2.12) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | No | No |
| Computer Firms Omitted | No | No | Yes | No | No |
| Observations | 68,134 | 57,437 | 50,885 | 7,258 | 6,419 |
| Adjusted $R^2$ | 0.250 | 0.255 | 0.227 | 0.144 | 0.158 |

Internet Appendix for

# The (Self-)Funding of Intangibles

This appendix reports supplemental empirical tests. These test re-estimate the main tables after incorporating specification changes that include: adjusting the measurement of *Intangibles Ratio* by varying the weight on SG&A spending or including Goodwill (I.A. Table 1); using firm fixed effects (I.A. Table 2); excluding firms that recently completed an IPO (I.A. Table 3); using an alternative measure of tangible investment and free cashflows (I.A. Table 4); scaling investment and cashflows by total assets (I.A. Table 5); using an alternative measure of equity pledged to employees (I.A. Table 6); changing how high-volatility and high-equity-grant firms are classified (I.A. Table 7).

## I.A. Table 1: Re-estimation using Alternative Intangibles Measures

This table reports results from regressions of corporate policy variables on different variations of *Intangibles Ratio*. Each cell reports the coefficient estimate or $t$-statistic of the adjusted *Intangibles Ratio* measure, obtained from a regression that uses the dependent variable listed in the column header. The Peters-Taylor Intangibles Ratio equals intangible capital measured by Peters and Taylor (2016) divided by net PP&E. All results are from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. The regressions also include *Tobin's Q*, total debt plus the market value of equity minus current assets, all divided by total assets; *Log Total Assets*, the natural logarithm of total assets; *Operating Cashflows*, operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets; *Cashflow Volatility*, the standard deviation of *Operating Cashflows* over the previous 10 years; *Book Leverage*, total debt divided by total assets; and year fixed effects and industry fixed effects based on the Fama-French 48 industries. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Dependent Variable | | | | | |
|---|---|---|---|---|---|---|
| Variation of *Intangibles Ratio* | *Tangible Investment* | *Free Cashflows* | *Net Leverage* | *Equity Grants* | *Retained Cash* | *Repurchases/ Payouts* |
| 5% Weight on SG&A | -1.154*** | 0.003 | -0.637*** | 0.019*** | 0.415*** | 0.287*** |
| | (-45.00) | (0.08) | (-20.08) | (13.37) | (9.97) | (13.78) |
| 10% Weight on SG&A | -1.311*** | 0.162*** | -0.605*** | 0.016*** | 0.418*** | 0.275*** |
| | (-49.08) | (3.68) | (-18.42) | (11.92) | (9.74) | (13.59) |
| 30% Weight on SG&A | -1.507*** | 0.440*** | -0.505*** | 0.012*** | 0.408*** | 0.239*** |
| | (-48.70) | (9.69) | (-14.17) | (8.72) | (8.88) | (12.41) |
| Goodwill Included | -1.403*** | 0.391*** | -0.154*** | 0.011*** | 0.415*** | 0.243*** |
| | (-46.23) | (8.60) | (-4.10) | (8.19) | (9.14) | (12.46) |
| Peters-Taylor Intangibles Ratio | -1.531*** | 0.534*** | -0.180*** | 0.010*** | 0.409*** | 0.230*** |
| | (-45.77) | (11.10) | (-4.73) | (7.10) | (8.41) | (11.86) |

## I.A. Table 2: Within-Firm Changes to Intangibles and Corporate Policies

All columns report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. *Tangible Investment* is the annual change in PP&E net of depreciation, divided by *Operating Cashflows*. *Free Cashflows* are *Operating Cashflows* minus tangible and intangible investment, divided by *Operating Cashflows*. *Net Leverage* is total debt minus cash and marketable securities, divided by total assets. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *Retained Cash* is free cashflows minus total payouts, divided by free cashflows. *Repurchases/Payouts* is stock repurchases divided by the sum of stock repurchases and common dividends. It excludes repurchases in which shares are immediately used to fulfill employee option exercises. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Tangible Investment* | *Free Cashflows* | *Net Leverage* | *Equity Grants* | *Retained Cash* | *Repurchases/ Payouts* |
|---|---|---|---|---|---|---|
| Sample | All Firms | All Firms | All Firms | ExecuComp Firms | All Firms | Firms with Positive Payouts |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Intangibles Ratio* | -2.781*** | 2.054*** | -0.654*** | 0.011*** | 0.775*** | 0.195*** |
| | (-39.56) | (21.13) | (-12.82) | (3.58) | (9.24) | (6.96) |
| *Tobin's Q* | 0.010*** | -0.008 | -0.011*** | -0.001*** | 0.006 | -0.002 |
| | (3.48) | (-1.57) | (-3.88) | (-10.44) | (1.47) | (-1.28) |
| *Log Total Assets* | -0.273*** | 0.275*** | 0.093*** | -0.006*** | -0.068*** | -0.019*** |
| | (-20.27) | (14.36) | (8.39) | (-10.85) | (-4.18) | (-3.15) |
| *Operating Cashflows* | -0.158*** | 0.714*** | -0.130*** | -0.003** | -0.029 | -0.059*** |
| | (-6.23) | (15.34) | (-6.57) | (-2.56) | (-0.88) | (-5.44) |
| *Cashflow Volatility* | 0.244*** | -0.285*** | -0.007 | 0.003 | 0.067 | 0.046* |
| | (3.75) | (-3.18) | (-0.10) | (1.34) | (0.83) | (1.67) |
| *Book Leverage* | -0.066*** | -0.033 | | 0.001 | 0.291*** | 0.009 |
| | (-4.02) | (-1.34) | | (1.10) | (12.93) | (1.21) |
| Industry Fixed Effects | No | No | No | No | No | No |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 89,777 | 89,777 | 99,987 | 19,033 | 59,748 | 57,437 |
| Adjusted $R^2$ | 0.074 | 0.025 | 0.059 | 0.065 | 0.017 | 0.083 |

## I.A. Table 3: Re-estimation of Results Excluding Firms with Recent IPO

All columns report estimates from pooled OLS regressions, using our sample of U.S. non-financial and utilities firms from 1970 to 2010. The sample in this table excludes firms that completed an IPO within the past five years. *Tangible Investment* is the annual change in PP&E net of depreciation, divided by *Operating Cashflows*. *Free Cashflows* are *Operating Cashflows* minus tangible and intangible investment, divided by *Operating Cashflows*. *Net Leverage* is total debt minus cash and marketable securities, divided by total assets. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *Retained Cash* is free cashflows minus total payouts, divided by free cashflows. *Repurchases/Payouts* is stock repurchases divided by the sum of stock repurchases and common dividends. It excludes repurchases in which shares are immediately used to fulfill employee option exercises. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Tangible Investment* | *Free Cashflows* | *Net Leverage* | *Equity Grants* | *Retained Cash* | *Repurchases/ Payouts* |
|---|---|---|---|---|---|---|
| Sample | Firms with Recent IPO Omitted | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Intangibles Ratio* | -1.438*** | 0.307*** | -0.534*** | 0.014*** | 0.584*** | 0.280*** |
| | (-47.30) | (6.69) | (-15.22) | (10.43) | (13.07) | (13.92) |
| *Tobin's Q* | 0.021*** | -0.040*** | -0.024*** | -0.001*** | -0.011*** | 0.003 |
| | (7.14) | (-8.72) | (-5.03) | (-7.59) | (-3.14) | (1.37) |
| *Log Total Assets* | -0.053*** | 0.105*** | 0.027*** | -0.003*** | -0.112*** | -0.036*** |
| | (-16.77) | (21.79) | (6.74) | (-14.95) | (-21.31) | (-16.39) |
| *Operating Cashflows* | -0.411*** | 1.461*** | -0.256*** | -0.007*** | 0.151*** | -0.133*** |
| | (-16.86) | (30.08) | (-8.40) | (-6.35) | (4.94) | (-9.85) |
| *Cashflow Volatility* | 0.206*** | -0.441*** | 0.227*** | 0.009*** | 0.020 | 0.216*** |
| | (7.19) | (-8.80) | (5.22) | (6.38) | (0.44) | (9.55) |
| *Book Leverage* | -0.087** | -0.161*** | | 0.008*** | 1.471*** | 0.241*** |
| | (-2.14) | (-2.59) | | (3.75) | (27.38) | (9.02) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 86,261 | 86,261 | 95,911 | 18,643 | 57,738 | 55,923 |
| Adjusted $R^2$ | 0.161 | 0.070 | 0.134 | 0.176 | 0.061 | 0.257 |

## I.A. Table 4: Re-estimation of Table 3 using Alternative Investment Measure

All columns report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. *Alt. Tangible Investment* is the sum of capital expenditures and cash spent on acquisitions, divided by *Operating Cashflows*. *Alt. Free Cashflows* are *Operating Cashflows* minus *Alt. Tangible Investment* and intangible investment, divided by *Operating Cashflows*. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Alt. Tangible Investment* | | | *Alt. Free Cashflows* | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Intangibles Ratio* | -1.572*** | -1.333*** | -1.369*** | 0.454*** | 0.170*** | 0.259*** |
| | (-48.18) | (-41.86) | (-38.73) | (8.64) | (3.45) | (4.73) |
| *Tobin's Q* | 0.008*** | 0.028*** | 0.030*** | 0.014*** | -0.052*** | -0.052*** |
| | (3.41) | (8.53) | (7.25) | (3.70) | (-9.93) | (-8.24) |
| *Log Total Assets* | -0.062*** | -0.039*** | -0.044*** | 0.129*** | 0.096*** | 0.102*** |
| | (-16.78) | (-10.69) | (-10.38) | (21.31) | (17.25) | (16.08) |
| *Operating Cashflows* | | -0.659*** | -0.732*** | | 1.805*** | 1.877*** |
| | | (-23.43) | (-21.63) | | (33.60) | (30.23) |
| *Cashflow Volatility* | | 0.241*** | 0.253*** | | -0.465*** | -0.436*** |
| | | (7.32) | (6.42) | | (-8.34) | (-6.80) |
| *Book Leverage* | | 0.124*** | 0.131*** | | -0.207*** | -0.233*** |
| | | (8.41) | (8.06) | | (-8.94) | (-9.26) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Computer Firms Omitted | No | No | Yes | No | No | Yes |
| Observations | 111,614 | 89,086 | 74,477 | 111,614 | 89,086 | 74,477 |
| Adjusted $R^2$ | 0.157 | 0.164 | 0.165 | 0.043 | 0.074 | 0.079 |

## I.A. Table 5: Re-estimation of Table 3 Scaling by Total Assets

All columns report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. *Tangible Investment/Assets* is the annual change in PP&E net of depreciation, divided by total assets measured as the sum of intangible assets and net PP&E. *Free Cashflows/Assets* are *Operating Cashflows* minus tangible and intangible investment, divided by total assets. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Tangible Investment/Assets* | | | *Free Cashflows/Assets* | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| *Intangibles Ratio* | -0.388*** | -0.340*** | -0.334*** | 0.169*** | 0.123*** | 0.140*** |
| | (-70.09) | (-60.23) | (-53.59) | (15.46) | (14.93) | (15.64) |
| *Tobin's Q* | 0.021*** | 0.012*** | 0.013*** | -0.005*** | -0.009*** | -0.008*** |
| | (40.41) | (16.92) | (13.39) | (-3.70) | (-7.00) | (-5.76) |
| *Log Total Assets* | -0.021*** | -0.015*** | -0.016*** | 0.039*** | 0.020*** | 0.021*** |
| | (-35.04) | (-24.90) | (-24.06) | (32.04) | (23.80) | (23.39) |
| *Operating Cashflows* | | 0.121*** | 0.131*** | | 0.409*** | 0.411*** |
| | | (26.05) | (23.34) | | (45.46) | (41.39) |
| *Cashflow Volatility* | | 0.047*** | 0.045*** | | -0.131*** | -0.125*** |
| | | (8.19) | (6.65) | | (-12.89) | (-10.92) |
| *Book Leverage* | | -0.005** | -0.004* | | -0.024*** | -0.027*** |
| | | (-2.33) | (-1.80) | | (-6.25) | (-6.59) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Computer Firms Omitted | No | No | Yes | No | No | Yes |
| Observations | 132,476 | 100,067 | 83,492 | 126,092 | 98,940 | 82,757 |
| Adjusted $R^2$ | 0.266 | 0.241 | 0.228 | 0.099 | 0.220 | 0.219 |

## I.A. Table 6: Re-estimation of Table 4 using Alternative Pledged Equity Measure

Columns (1) through (3) report estimates from pooled OLS regressions using our entire sample of U.S. non-financial and utilities firms, from 1970 to 2010. Columns (4) and (5) report estimates from regressions using five-year (two-sided) windows around technological transitions. We measure transitions for each Fama-French 48 industry as a structural break in the time series of *Intangible/Total Investment*, following Andrews (1993). *Pledged Equity* is the number of shares underlying all stock options held by employees, divided by this number plus the number of publicly traded shares. Data used to construct this measure is only available until 1996. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. *Operating Cashflows* is operating earnings prior to depreciation and investment minus taxes and interest payments, all divided by total assets. *Cashflow Volatility* is the standard deviation of *Operating Cashflows* over the previous 10 years. *Book Leverage* is total debt divided by total assets. Industry fixed effects are based on Fama-French 48 industries. Computers firms are those in the industries "Computers", "Electronic Equipment", "Measuring and Control Equipment", or "Business Services" (SIC codes 7370-7379 only). In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| | Pooled Regressions | | | Staggered technological transitions | |
|---|---|---|---|---|---|
| Dependent Variable | *Pledged Equity* | | | *Pledged Equity* | |
| | (1) | (2) | (3) | (4) | (5) |
| *Intangibles Ratio* | 0.035*** | 0.044*** | 0.037*** | | |
| | (8.25) | (8.79) | (7.06) | | |
| *Post Transition* | | | | 0.021*** | 0.020*** |
| | | | | (7.55) | (5.75) |
| *Tobin's Q* | -0.001*** | -0.002*** | -0.003*** | -0.001 | -0.000 |
| | (-5.72) | (-5.60) | (-5.85) | (-1.57) | (-0.35) |
| *Log Total Assets* | -0.005*** | -0.002*** | -0.003*** | -0.004*** | -0.003** |
| | (-9.83) | (-3.72) | (-4.57) | (-3.25) | (-2.02) |
| *Operating Cashflows* | | -0.022*** | -0.027*** | | -0.031*** |
| | | (-5.80) | (-6.66) | | (-2.93) |
| *Cashflow Volatility* | | 0.024*** | 0.019** | | 0.026* |
| | | (3.65) | (2.44) | | (1.84) |
| *Book Leverage* | | 0.027*** | 0.029*** | | 0.006 |
| | | (12.34) | (12.49) | | (1.50) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | No | No |
| Computer Firms Omitted | No | No | Yes | No | No |
| Observations | 68,077 | 51,597 | 44,424 | 7,008 | 5,755 |
| Adjusted $R^2$ | 0.084 | 0.105 | 0.090 | 0.057 | 0.069 |

## I.A. Table 7: Re-estimation of Table 6 using Alternative Specifications

All columns report estimates from pooled OLS regressions using U.S. non-financial and utilities firms in ExecuComp, for which equity grant data is available. *Cash Holdings* is the sum of cash and marketable securities, divided by total assets. *Intangibles Ratio* is the firm's stock of intangible assets divided by total assets, measured as the sum of intangible assets and net PP&E. *High Volatility* equals: 1 in column (1) for firm-fiscal years with *Stock Volatility* values above the sample median; 1 in columns (2) and (3) for values in the highest tercile of the sample distribution; and 1 in columns (4) and (5) for values in the highest quartile. It equals 0 in column (1) for firm-fiscal years with below-median *Stock Volatility*; 0 in columns (2) and (3) for values in the lowest tercile; and 0 in columns (4) and (5) for values in the lowest quartile. In column (1), *Stock Volatility* is the standard deviation of the firm's stock returns over the 365 days prior to the start of the year. In all other columns, it is the standard deviation over the 48 months prior to the start of the year. *High Equity Grants* equals: 1 in column (1) for firm-fiscal years with *Equity Grants* values above the sample median; 1 in columns (2) and (3) for values in the highest tercile of the sample distribution; and 1 in columns (4) and (5) for values in the highest quartile. It equals 0 in column (1) for firm-fiscal years with below-median *Equity Grants*; 0 in columns (2) and (3) for values in the lowest tercile; and 0 in columns (4) and (5) for values in the lowest quartile. *Equity Grants* is the total dollar value of annual stock and option grants to all employees, divided by market capitalization. It is measured only for ExecuComp firms, from 1992 to 2010. *Tobin's Q* is total debt plus the market value of equity minus current assets, all divided by total assets. *Log Total Assets* is the natural logarithm of total assets. Industry fixed effects are based on Fama-French 48 industries. In parentheses we report $t$-statistics based on standard errors that are clustered at the firm level. ***, **, * indicate significance levels of 1%, 5%, and 10%, respectively.

| Dependent Variable | *Cash Holdings* | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample | ExecuComp Firms | | | | | | |
| Specification Change | Volatility over 365 days | Volatility/Equity Grants Partitioned by Tercile | | Volatility/Equity Grants Partitioned by Quartile | | Continuous Measures of Volatility/Equity Grants | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| *Intangibles Ratio* | 0.148*** | 0.097 | 0.127** | 0.077 | 0.141** | -0.032 | 0.150*** |
| | (2.98) | (1.57) | (2.34) | (1.11) | (2.34) | (-0.45) | (2.89) |
| *Intangibles Ratio × High Volatility* | 0.098*** | 0.177*** | | 0.179*** | | | |
| | (2.90) | (3.28) | | (2.79) | | | |
| *Intangibles Ratio × High Equity Grants* | | | 0.161*** | | 0.182*** | | |
| | | | (3.65) | | (3.28) | | |
| *Intangibles Ratio × Stock Volatility* | | | | | | 1.506*** | |
| | | | | | | (4.62) | |
| *Intangibles Ratio × Equity Grants* | | | | | | | 0.602 |
| | | | | | | | (0.75) |
| *High Volatility* | 0.006 | -0.015 | | -0.027 | | | |
| | (0.33) | (-0.45) | | (-0.68) | | | |
| *High Equity Grants* | | | -0.063** | | -0.081** | | |
| | | | (-2.39) | | (-2.31) | | |
| *Stock Volatility* | | | | | | -0.330 | |
| | | | | | | (-1.51) | |
| *Equity Grants* | | | | | | | 0.233 |
| | | | | | | | (0.39) |
| *Tobin's Q* | 0.050*** | 0.050*** | 0.049*** | 0.048*** | 0.049*** | 0.048*** | 0.049*** |
| | (18.41) | (14.49) | (16.12) | (11.70) | (15.12) | (16.24) | (16.50) |
| *Log Total Assets* | -0.061*** | -0.062*** | -0.070*** | -0.069*** | -0.073*** | -0.056*** | -0.064*** |
| | (-11.55) | (-8.34) | (-10.93) | (-7.29) | (-9.98) | (-9.07) | (-12.19) |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 24,903 | 15,897 | 13,600 | 11,875 | 9,793 | 23,605 | 20687 |
| Adjusted $R^2$ | 0.350 | 0.350 | 0.344 | 0.343 | 0.343 | 0.337 | 0.340 |