Financing Intangible Capital *

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Abstract

Firms finance intangible investment through employee compensation contracts. In a dynamic model in which intangible capital is embodied in a firm's employees, we analyze the firm's optimal decisions of intangible capital investment, employee compensation contracts, and financial leverage. Employee financing is achieved by delaying wage payments in the form of future claims. We document that intangible capital investment is highly correlated with employee financing, but not with debt issuance or regular equity refinancing. In the quantitative analysis, we show that this new channel of employee financing explains the cross-industry differences in leverage and financing patterns.

Key Words: Intangible Investment, Limited Commitment, Employee Financing, Debt Capacity

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1 Introduction

Understanding how firms finance their investment opportunities is one of the most important questions in corporate finance. However, the fundamental shift in production function from physical-intensive to intangible-intensive[1] over recent decades poses a challenge: How precisely are these new types of firms being financed? Intangible capital is difficult to finance in the free marketplace given its low redeployability, non-exclusiveness, and low liquidity (e.g., Arrow (1962); Hall and Lerner (2009)).[2] In this paper, we propose a new channel of financing intangibles, i.e., financing through compensation contracts. We also document this channel in the data.

We develop a dynamic model that involves intangible capital accumulation and costly external financing. The key insight of the model is that, when a firm invests in intangible capital to boost labor productivity, a fraction of that capital is inseparably attached to the employees. Employees have limited commitment, and they can walk away with a fraction of intangible capital when they perceive better outside options. To retain employees, the firm offers wage contracts that promise higher future compensations. Because of the increasing deferred wage obligations, the future cash flows pledgeable to external creditors are reduced, which crowds out debt financing.

This does not, however, imply that the total financing capacity for intangible capital shrinks. Anticipating higher future compensations, employees are willing to accept lower wages today. Lowering wages then frees up internal cash flows that can be used in place of traditional debt to finance intangible investment. The wage contract thus prescribes an optimal timing of firms' wage obligations to facilitate investment. Michelacci and Quadrini (2009) and Guiso et al. (2013), among a few others, illustrate this back-loaded wage scheme

[1]These intangible–intensive firms, also called "new economy" firms (e.g., pharmaceuticals, software, semiconductor, information, and high-technology manufacturing), are characterized by a high degree of R&D and innovation, activities which are conducted by a highly skilled workforce.

[2]Intangible capital is not an efficient collateral asset. For example, innovation activities are hard to exclude from other users. Innovation activities require the management of a highly skilled workforce, which is also costly to retain.

as an internal financing channel. Consistent with their mechanism, in cases where firms are financially constrained, the optimal wage contract allows implicit borrowing by lowering current wages in exchange for higher future wages. However, in our employee financing channel, firms optimally choose to finance investment through wage contracts even if they are not financially constrained. Moreover, our prediction specifically links employee financing to intangible investment, but not to tangible investment.

Our dynamic model highlights two important features. First, intangible capital can be used as a collateral to "borrow" from employees. According to Falato et al. (2013)) and Rampini and Viswanathan (2013), a low collateral rate for intangible capital leads to insufficient lending through collateralized debt contracts. In our model, similar to the external investors' threat of liquidating the firm's assets if the firm defaults on debt, the employee's option of walking away from the current wage contract provides a credible liquidation threat to the firm's intangible capital. Although financing through collateral debt is constrained, intangible capital can be an efficient collateral when "borrowing" from employees.

Second, the portability of intangible capital with limited commitment relates the dynamics of retention motives to the dynamics of investment. When intangible capital is accumulated, the incentive provision (i.e., employee financing) dominates, and debt contracts are crowded out by the increasing promised claims to employees. This is what we call the intangible capital *overhang* effect on a firm's financial decisions through long-term wage contracts. Distinct from the literature of dynamic contracting with limited commitment (Albuquerque and Hopenhayn (2004), Rampini and Viswanathan (2010)), this overhang effect reduces the firm's debt financing capacity and potentially urges the firm to save additional unused debt capacity to prevent future downturns.

We document this novel channel of financing intangible investment in a sample of publicly traded firms in the United States. We use the granted but not yet exercised employee stock-based compensation (SBC) as the measure of employee financing to proxy for the amount of the deferred employee compensation.[3] We find that intangible investment is highly correlated with employee financing, and employee financing displays a stronger correlation with intangible investment than with physical investment. This suggests that financing through employees is specific to intangible investment. In the sample, we find no evidence that firms which invest more in intangible capital issue more shares, even though the low collateral value of intangible capital makes equity financing a natural alternative. Consistent with our model mechanism, we document a strong intangible capital overhang effect: Firms with more employee financing are engaged in less debt financing.

We then take a structural approach to quantify the importance of the employee financing channel. The reason is that the amount of financing substituted by deferred employee claims is not directly observable in the data, and it requires explicit assumptions of employees and shareholders' preferences. The model is estimated using two split samples: the high-tech industries and traditional industries, which are characterized by highly distinct capital intangibility and financing patterns. We show that our model has the explanatory power for the cross-industry differences both in financial leverage and financing patterns we had documented.

We conduct two counterfactual analyses. First, we provide a comparison of our model with the dynamic investment models featuring physical capital investment and financial frictions (e.g., Gomes (2001); Hennessy and Whited (2005); Jermann and Quadrini (2012)). We find that when the employee financing channel is shut down, the correlation between intangible investment and debt issuance is positive, which is inconsistent with the empirical findings. Therefore, the employee financing channel in our paper can not be simply achieved by re-interpreting the physical capital as intangible capital in the typical dynamic investment models.

In the second counterfactual analysis, we evaluate the financial effects of borrowing through wage contracts. We shift the portability level of intangible capital in the traditional

[3] Fama and French (2005) and Babenko et al. (2011) consider the cash proceeds from the exercise of employee stock options as a source of financing.

industries to that in the high-tech industries, and examine the change in firms' financial decisions. On the side of financing capacity (per unit of capital), the increase in the portability of intangible capital raises the employee financing through promised future claims by 18.6%, while it reduces the firm's debt capacity through the overhang effect by 4%. But, overall, the borrowing capacity increases by 14.6%. On the side of financial flexibility, the increase in intangible portability tightens the employees' participation constraint and reduces the savings of unused debt.

Our paper contributes to the literature on understanding the determinants of firms' capital structure, starting with Miller (1977), Myers (1984), Titman and Wessels (1988). Berk et al. (2010) were among the first to explore a dynamic trade-off theory when introducing the bankruptcy cost of firm-specific human capital. Our paper emphasizes that employee contracts displace debt contracts as a new source of financing. We focus on the financing needs for investment in intangible capital but not in physical capital (Gomes (2001); Hennessy and Whited (2005)). To the best of our knowledge, we are the first to provide a theoretical underpinning for financing intangible capital through non-financial contracts.

Our theory is aligned with the literature on dynamic contracting with limited commitment. Closely related to Michelacci and Quadrini (2009), we highlight the interaction between long-term wage contracts and investment with the endogenous collateral rate of intangible capital. The portability of intangible capital relates investment to retention motives, which is consistent with the findings of Oyer and Schaefer (2005) and Oyer and Schaefer (2006). Theoretical papers introduce the friction of limited commitment (starting with Harris and Holstrom (1982)) to understand a variety of subjects, such as labor economics (Thomas and Worrall (1988)), financial constraints and firm dynamics (Albuquerque and Hopenhayn (2004); Ai et al. (2013)), investment (Schmid (2008); Cooley et al. (2013)), risk management (Rampini and Viswanathan (2010); Bolton et al. (2015)), managerial compensation (Lustig et al. (2011)), tax versus leverage (Li et al. (2014)), and cash flow risk (Zhang (2014)). However, our paper is the first to quantify the effects of limited commitment in the labor sector on a firm's financial decisions.

Several empirical studies have explored the increasing importance of equity issued directly to employees (Fama and French (2005); Babenko et al. (2011); McKeon (2013); Chang et al. (2014)). Babenko et al. (2011) empirically examine how firms use the proceeds from the exercise of stock options, and they found consistent evidence of a correlation between R&D investment and option exercise cash flows, while our paper focuses on the employee financing channel achieved by deferring wage payments to the future. Our structural analysis allow us to quantify the cash value of deferred compensations by specifying employee preference. Graham et al. (2004), Babenko and Tserlukevich (2009), and several others emphasize the tax advantage of employee stock options. Our empirical and theoretical analysis reveals a link between employee retention, intangible investment, and optimal debt policy. To the our best knowledge, this has not been studied in the literature.

Our findings are also related to the empirical studies on financing from employees. Garmaise (2008) studies the informational advantage of labor over physical capital for the financing of constrained firms. Guiso et al. (2013) show that back-loaded wages help firms implicitly raise funds from workers. Our mechanism of employee financing also arises from back-loaded wage payments, but our prediction is very specific to financing intangible investment and is not conditional on the access to external markets. For the same reason, our finding is distinct from prior research that documents that financial health is an important factor in financing labor (Benmelech et al. (2011)). Brown et al. (2009) document that during the 1990s R&D boom, firms finance R&D from various sources including cash flow and equity issuance, while we show that equity issuance is negatively correlated with R&D after controlling for employee financing. Our findings are also related to the understanding of the ownership of intangible capital (Eisfeldt and Papanikolaou (2014)).

The rest of the paper proceeds as follows. Section 2 presents our new facts on employee financing and intangible investment. Section 3 describes the model. Section 4 analyzes the model result. Section 5 presents our estimation results and counterfactual analysis. The

Appendices contain details about data construction and proofs of propositions.

2 Empirical Facts

In this section, we examine financing patterns for intangible investment in a quarterly sample of publicly traded firms. In Subsection 2.1, we discuss the data and how we measure employee financing using the new accounting variable. In Subsection 2.2, we establish the positive relationship between employee financing and intangible investment, both in cross-sections and in time series.

2.1 Data

We use quarterly firm–level data from the CRSP/Compustat Merged Database from 2006q1 to 2015q1. We exclude utilities and financial firms with SIC codes in the intervals 4900–4999 and 6000–6999, and we also exclude firms with SIC codes greater than 9000.

2.1.1 Measure of Employee Financing

Firms typically offer stocks or options as part of compensation packages to their key employees. After the revised SFAS No.123R in 2014, all companies, both public and private, are required to recognize the cost of stock-based compensation using a fair value based method. In the Compustat sample, the expenses of stocks/options issued to employees are recorded as *Stock-based Compensation Expense* (STKCOQ). Given the focus of our analysis, we use this granted but *not yet* exercised stock-based compensation as our main measure of the flow of the deferred employee claims. Since SFAS No.123R became effective on January 1, 2006[4],

[4] In December 2004, the Financial Accounting Standards Board (FASB) issued Revised Statement of Financial Accounting Standards No.123, Share-Based Payment (SFAS No.123R), which was an amendment to FAS 123, Accounting for Stock-Based Compensation, and a replacement of Accounting Principles Board Opinion No. 25, Accounting for Stock Issued to Employees, and its related implementation guidance. SFAS No.123R requires public entities to measure the cost of employee services received in exchange for an award of equity instruments based on the grant-date fair value of the award and to recognize that cost over the requisite service period.

our analysis focuses on the quarterly panel sample starting in 2006q1 to avoid any concerns regarding the sample selection.[5] Over the period of 2006q1 to 2015q1, more than 90% of the publicly traded firms recognize expenses in stock-based compensation.

It is worth noticing that the use of not yet exercised share-based compensation relaxes the financing constraint of a firm in a way that is different from what has been documented by literature. Fama and French (2005), Babenko et al. (2011), and McKeon (2013) among many others show that the proceeds generated from exercising vested stock options are substantial amount of cash flows, which can be a good source of internal financing.[6] However, we emphasize in this paper that firms use employee share-based compensation as a way to defer or substitute the current wage and salary obligations. By paying employees less today, firms can free up internal cash flows and relax their budget constraints, even though there are no actual cash inflows at the time SBC was granted. We refer to this second channel as employee financing and use SBC to proxy it.

2.1.2 Measure of Intangible Investment

The investment of intangible capital is the primary driver of knowledge creation in high-wage economies like the US. Ideally, the measure of intangible capital should account for the cost of knowledge production, including "expenditures for human capital, in the form of education and training, public and private scientific research, and business expenditures for product research and development, market development" (van Ark et al. (2014)). Measuring intangible capital in a sample of publicly traded firms is challenging because firms do not report itemized expenses along with the general operating expenses. For our purposes, we measure firm-level intangible investment using R&D expenses. R&D expenses are widely available

[5] Recognizing the expense is a voluntary accounting choice that has been available to firms since the issuance of SFAS No.123 in 1995. However, SFAS No.123 permits firms either to recognize the expense or to disclose in financial statement footnotes what net income would have been had the expense been recognized. Therefore, not many reported the employee stock-based compensation before the 2006 revision of SFAS No.123.

[6] Noted by Fama and French (2005), Babenko et al. (2011), and McKeon (2013), the cash proceeds from employee stock option exercises is larger than the regular seasoned equity offerings.

accounting data which record the costs of human capital investment in the R&D department, as well as the related costs of innovation activities. R&D expenses constitute a major part of investment in a knowledge-based investment; however, a measurement of intangible investment should include firms' investment in organizational capital through on-the-job training, distribution of system, and other labor-related expenses for improving teamwork. So, following literature (Lev and Radhakrishnan (2005); Eisfeldt and Papanikolaou (2014); Falato et al. (2013); Zhang (2014); Peters and Taylor (2015)) we use 30% of *Selling, General and Administrative* expenses (XSGA) plus R&D expenses as an alternative measure of intangible investment. Given that XSGA also contains information other than intangible related investment,[7] we rely on R&D expenses as a main measure of intangible investment in our quantitative analysis. The appendix A.1 contains the details of the construction of our data.

The summary statistics of our sample are reported in Table 1. When computing firm-level moments, all variables are normalized by total assets (ATQ). The average leverage ratio in our sample (2006q1-2015q1) is around 0.14, which is lower than the average leverage ratio of the sample that begins in 1980. We group firms into five industries based on our modified Fama-French 5 industry classification.[8] In the subsample that consists of only high-tech companies, the financial leverage ratio is 0.10, while the traditional industries (manufacturing and consumer products) group has a higher leverage ratio of 0.178. In the full sample, the SBC-to-assets ratio is on average at 0.005. The high-tech industries group has a SBC-to-assets ratio of 0.007, which is almost double the ratio of the traditional industries group. In terms of the relative magnitude of employee financing, the SBC-to-assets ratio is on average twice the size of standard external financing activities, including both the debt issuance and the equity issuance (excluding employee equity financing). During our sample period, the investment of intangible capital is twice as high as that of physical capital, which is consistent with the increasing importance of intangible capital as a production factor emphasized in the

[7]XSGA also includes advertising expenses, bad debt expenses, provisions for doubtful accounts, and marketing expenses, all of which are less relevant to our definition of intangible capital. Our results are robust if we use only XSGA as the measure of intangible investment.

[8]See the Appendix A.2 for an industry classification definition.

literature (Corrado et al. (2004); Falato et al. (2013); van Ark et al. (2014)).

2.2 The Evidence

In this subsection, we describe the evidence of financing intangible investment through the employee financing channel.

2.2.1 Cross-Firm Characteristics

First, we look at major firm characteristics across firms with different amounts of SBC. For each quarter, we group firms into five quintiles based on their SBC-to-assets ratios. Figure 1 shows some basic characteristics of firms across the five quintiles. In Panels (a) and (b), we show that firms with higher SBC-to-assets ratios are significantly lower in average leverage ratio and higher in average market-to-book ratio. This implies an interesting question whether employee financing substitutes out other financing activities. Panel 1(c) highlights a new empirical fact: Debt financing activity is not predominant in the high-SBC groups. The average debt issuance declines as the SBC-to-assets ratio increases. The average debt issuance even becomes negative in the high-SBC groups.

In Panel 1(d), the R&D-to-assets ratio is monotonic in SBC ranking groups, but we do not observe different CAXP-to-assets ratio across groups. Physical investment policy does not seem to be affected through the employee financing channel. In Panel 1(e), we observe that cash flows and sales do not change much based on the group of SBC. Finally, we examine the industry composition within each SBC group. Panel 1(f) shows that more than 60% of firms in high-SBC groups are in high-tech industries. If the health product industry is taken into account, about 90% of the firms in high-SBC groups fall into intangible-intensive industries.

2.2.2 Intangible Investment and Stock-Based Compensation

Figure 2 presents the time series of intangible investment and financing. For each quarter, we calculate the firm-level average of investment and financing, and then plot the average across quarters. In Panel (a), we show that, on average, R&D investment comoves with SBC with a correlation coefficient of 0.65. However, the correlation between R&D investment and regular financing activity of the firm, including both equity issuance (0.30) and debt issuance (-0.03), is much lower (see Panels (b) and (c)). In Figure 3, we utilize each firm's industry group as a coarse method for distinguishing intangible capital intensity in the production function and focus on the comparison between High-tech industries and Traditional industries. As shown in Figure 3, for the more intangible capital-intensive high-tech industries, the correlation between R&D investment and SBC is 0.51 (Panel (a)), while this correlation falls to 0.30 for traditional industries (Panel (b)). From Panel (c) to Panel (f) in Figure 3, both debt issuance and regular equity issuance exhibit low correlation with R&D investment.[9]

We confirm the positive correlation between SBC and R&D investment using panel regressions after controlling for other possible sources of funds. Panel A of Table 2 reports the regression results. In column 1, we show that consistent with the literature, debt financing is a reliable external source of financing physical capital investment. In column 2, we find that after controlling cash flows and Q, SBC is still positively correlated with R&D investment. However, the coefficients of debt issuance and regular equity issuance are either negative or insignificant. Although we cannot test the causality, those results indicate that debt and equity financing may not be a source of financing intangibles, while SBC might be.

We also examine the firm-level regression results separately for traditional industries and high-tech industries (see Panels B and C of Table 2). If firms in the high-tech industries are more intangible-intensive firms, our theory predicts that the sensitive of intangible capital investment to SBC should higher in high-tech industries. Column (5) and (8) confirms that the coefficients of SBC in the R&D regressions are indeed higher in high-tech industries than in traditional industries.

The existing literature emphasize the role of financial constraints on a firm's R&D invest-

[9]The correlation between debt issuance and R&D investment is 0.12 in traditional industries, and 0.14 in high-tech industries. The correlation between equity issuance and R&D investment is 0.21 in traditional industries, and -0.14 in high-tech industries. All the correlation coefficients are computed using seasonal adjusted time series.

men.[10] Brown et al. (2009) suggested a "financing hierarchy" for R&D investment: "The least-cost form of finance is internal cash flow. When cash flow is exhausted and debt is not an option, firms must turn to new share issues." However, there has been little exploration of other internal sources for R&D financing. Our empirical evidence shows that the channel of financing R&D through substituting cash compensation with SBC can be significant.

To sum up, our empirical findings are (i) Firms with high SBC-to-assets ratios tend to use less debt financing. (ii) Intangible investment is strongly and positively correlated with SBC, but not (or weakly negatively) correlated with debt issuance and regular equity issuance. And, (iii) the above two relations are more robust in high-tech industries. In the rest of the paper, we propose a theory to reconcile these new facts we documented on financing intangible investment.

3 A Model of Financing Intangible Investment

In this section, we introduce a model of financing intangible investment. The model embeds a dynamic contracting problem within a neoclassical investment model in which financing investment is achieved endogenously through both financial and wage contracts.

3.1 The Environment

We consider the optimization of an infinitely-lived firm, owned by a risk-neutral capital owner with time preference $\beta < 1$. The firm produces its final output by investing in intangible capital and hiring employees from the labor market. To finance investment, the firm is allowed to contract with both creditors and employees. The firm has access to capital markets by issuing equity and debt, and determines the compensation of employees. By maximizing the capital owner's present value of life-time cash flows, the optimal wage contract, investment, and financing decisions are determined.

[10] Hall (2002) provides an intensive survey.

Technology Production requires the inputs of intangible capital and labor. The firm hires employees from the labor market, who are embedded with some initial level of intangible capital h_0. The initial level of intangible capital can be interpreted as general human capital. Along with production, the firm invests to accumulate intangible capital h_t. To simplify the model, we normalize the size of the labor force to 1 and focus on the accumulation of intangible capital.[11] The capital accumulation enhances the firm-level human capital and increases the labor productivity.[12]

We assume that h_t is not exclusive either to the employee or to the firm. Employees can leave the firm with a fraction η of intangible capital. This assumption of partial intangible capital portability is first adopted in Lustig et al. (2011).[13] The variable $\eta < 1$ (i.e., the portability of h_t) governs the generality of the intangible capital embedded with the employee. As η increases, the intangible capital is less specific to the firm. The portability directly affects the employees' outside option, which is key for determining the optimal compensation. We discuss the compensation contract in detail in the next section.

Production technology is constant return to scale, $y_t = z_t h_t$, subject to a technology shock z_t with a bounded support $\mathcal{Z} = [\underline{z}, \overline{z}]$. The shock z_t follows a first-order autoregressive process $\log(z_t) = \rho_z \log(z_{t-1}) + \sigma_z \epsilon_t$, where ϵ_t is *i.i.d.* innovation with standard normal distribution $N(0, 1)$, $\rho_z < 1$, and σ_z denotes the volatility.

In each period, the firm makes investment decision e_t and the intangible capital evolves according to:

$$h_{t+1} = (1 - \delta)h_t + \phi\left(\frac{e_t}{h_t}\right)h_t, \tag{1}$$

where δ is the depreciation rate, and the function $\phi(\cdot)$ specifies the capital adjustment cost,

[11] One way to interpret the accumulation of h can be that firms increase h by hiring highly skilled employees.

[12] Firm-level human capital is accumulated while the employee participates in production. Firms invest in employees in a variety of ways (e.g., on-the-job training, teamwork, and learning-by-doing in the process of research and development). Usually, this kind of investment is part of selling, general, and administrative expenses as well as research and development expenses.

[13] Zhang (2014) also assumes the partial portability of the firm-level human capital to understand the within-firm risk sharing.

which is concave in e_t. The concavity of $\phi(\cdot)$ captures the idea that quick adjustment of capital is more costly than slow adjustment.

Labor Market Each employee is matched with one firm for production. The employee is risk-averse with preference $u(\cdot)$, where $u'(\cdot) > 0, u''(\cdot) < 0$, and has no access to the saving technology. The wage contract is the only technology for consumption smoothing. Assume that the employee has a limited commitment to the wage contract (i.e., they can always leave the firm whenever an outside option is better than the contract provided by the match). In this case, in order to retain the employee, the firm pre-commits to a long-term wage contract with the employee. The optimal contract specifies the complete contingent compensation plan $\{c_t(z^t, h^t)\}_t^\infty$ that maximizes the lifetime utility of the employee $\mathbf{m}_t(z, h) = \mathbb{E}_t \{\sum_{s=t}^{\infty} \beta^t u(c_s(z^s, h^s))\}$, where $z^t = \{z_0, z_1, ...z_t\}$ is the entire history of productivity shock, and $h^t = \{h_0, h_1, ...h_t\}$ is the entire history of intangible capital level. The firm commits to complete wage payments at the time the match is formed.

To keep track of the employee's claims and ensure the problem is recursive, the employee's promised utility $\mathbf{m}_t(z_t, h_t)$ is treated as a new state variable. The complete recursive contract is captured by two components: $\{c_t,\ \mathbf{m}_{t+1}(z_{t+1}, h_{t+1})\}$.[14] To characterize the firm's commitment, c_t and $\mathbf{m}_{t+1}(z_{t+1}, h_{t+1})$ must satisfy the following promise-keeping constraint:

$$m_t(z_t, h_t) = u(c_t) + \beta_w \mathbb{E}_t[\mathbf{m}_{t+1}(z_{t+1}, h_{t+1})], \tag{2}$$

where β_w is the discount factor of employees.

The firm commits to deliver the promised utility $\mathbf{m}_t(z_t, h_t)$ today by delivering current consumption c_t and committing to the state contingent promised utility $\mathbf{m}_{t+1}(z_{t+1}, h_{t+1}), \forall z_{t+1}$, $\forall h_{t+1}$ in the next period. The promised utility $\mathbf{m}_{t+1}(z_{t+1}, h_{t+1})$ can be interpreted as the *deferred* employee claim (in utility terms) that is attributed to the employees.

The compensation structure $\{c_t, \mathbf{m}_{t+1}(z_{t+1}, h_{t+1})\}$ provides leeway for the firm to deter-

[14] In the on-line appendix, we show the equivalence of the recursive contract and the original contract.

mine the timing of wage payments. In fact, the firm can "restructure" the compensation package by reducing c_t and increasing the deferred compensation $\mathbf{m}_{t+1}$ to spare internal cash flows for investment, which we treat as a new financing channel. The timing of wage payments, optimally determined, is then important for the availability of funds.

Because of the limited commitment, promises $\mathbf{m}_{t+1}$ are constrained by the employee's outside option. Denote the outside option of the employee with intangible capital h_{t+1} at period $t+1$ as $\omega(z_{t+1}, h_{t+1})$. Since our focus is the firm's decision making, we consider the employee's outside option exogenously. Specifically, we assume that if the employee leaves the firm, she will take away η fraction of the intangible capital, which will remain constant in the future. Also, in each period, the employee has access to a spot labor market with an exogenous wage rate of z_{t+1}.[15]

Thus, the employee's outside option at period $t+1$ can be written as $\omega(z_{t+1}, h_{t+1}) = \mathbb{E}_{t+1}\left\{\sum_{s=0}^{\infty}\beta_w u\big(\eta z_{t+1+s}h_{t+1}\big)\right\}$. The outside option is defined as the lifetime utility achieved by the consumption from re-entering a spot labor market each period, with a constant capital level and an exogenous wage rate. With the linear technology and log utility, we can rewrite this in a recursive formula, $\omega(z_{t+1}, h_{t+1}) = \frac{1}{1-\beta_w}\log(\eta h_{t+1}) + \frac{\log(z_{t+1})}{1-\beta_w\rho_z}$.

Since the employee has limited commitment to the wage contract, the following constraint guarantees her participation:

$$\mathbf{m}_{t+1}(z_{t+1}, h_{t+1}) \geq \omega(z_{t+1}, h_{t+1}, \eta),\ \forall z_{t+1}, h_{t+1}. \tag{3}$$

As long as the utility achieved by the contingent compensation plan is greater than the outside option, the employee is better off staying in the current match. Note that the participation constraints (3) must be satisfied for any realization of productivity and for any level of accumulated intangible capital.

[15] We can allow intangible capital to depreciate after the employee leaves the firm, or assume a different wage rate. But this does not change the results since the employee's outside option is exogenous. The only variable that matters for the employee's outside option is the portability η.

Capital Market The firm obtains external financing either by issuing new shares on the secondary equity market or by borrowing through debt contracts. The firm issues one-period debt b_{t+1} at period t, with an interest rate $\tilde{R}_t = \frac{1}{\beta}$. Denoting the corporate tax rate by τ_c, the "effective" interest rate is $R_t = 1 + (1 - \tau_c)(\tilde{R}_t - 1)$.[16] Interest payments to debt holders are tax deductible, so debt contracts have an advantage over equity according to the standard trade-off theory. The tax shield of the debt contract gives $R_t < \frac{1}{\beta}$. Suppose that lenders cannot force the firm to repay the debt unless the debt contract is secured, then we consider the enforcement constraint on the firm as follows:

$$\frac{b_{t+1}}{R_t} \leq \xi \beta \mathbb{E}_t[V_{t+1}], \tag{4}$$

where $E_t[V_{t+1}]$ is the discounted *cum dividend* value of the firm's dividend flows $\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s d_{t+1+s}$, and ξ is the debt enforcement rate governed by the credit market. We assume that h_t cannot be collateralized directly, but the firm can use its future cash flows as the pledgeable assets to the creditors. We use the specific form of constraint (4) for two reasons. First, intangibles are not effective collateral assets because of the low redeployability, the information asymmetry, and the low liquidation value. Second, in practice, the output of intangible capital, such as patents, can be used as collateral in debt contracts (e.g., Loumioti (2012)). The revenue from royalties for intellectual property generally does not realize in the present period, but rather in the future. Thus, in most cases, firms can only use future cash flows as pledgeable assets.

The firm determines the *net* equity payout d_t each period. A negative d_t indicates equity issuance. Following Jermann and Quadrini (2012), we model the rigidity of adjusting equity by introducing a quadratic cost $\kappa \cdot (d_t - \bar{d})^2$, where $\kappa > 0$ (i.e., the substitutions between equity and other sources of financing are costly),[17] and $\bar{d}$ is set as the steady-state equity

[16] The typical approach in modeling the fiscal benefits of debt is to tax the net corporate income after the interest payments (e.g., Hennessy and Whited (2007)). An alternate approach is to calculate the effective interest rate after considering the tax shield (e.g., Jermann and Quadrini (2012)).

[17] In the model, the firm does not face any adjustment costs of issuing debt, when the debt enforcement constraint is not binding, the firm can freely issue debt to pay out dividends. Thus, to prevent firms from issuing debt to pay out dividends, we assume it is costly to pay out both positive and negative devidends.

payout. The actual cash outflow is then written as $\varphi(d_t) = d_t + \kappa \cdot (d_t - \bar{d})^2$. As the residual claimer, the equity holder of the firm is subject to the following budget constraint:

$$\varphi(d_t) = z_t h_t - c_t - e_t + \frac{b_{t+1}}{R} - b_t. \tag{5}$$

Financing Investment How does the firm finance investment? In our model, standard financing tools, debt issuance $\frac{b_{t+1}}{R} - b_t$ and public equity offering $-d_t$, generate cash flows for intangible investment e_t. In addition, deferring wage compensations to the future serves as another financing channel, which we refer to as the employee financing channel. Different from Babenko et al. (2011) where investment is financed from the exercised employee stock options, here the investment budget constraint (5) can be relaxed by lowering the wage c_t. Instead of paying the employee a lump-sum of the value of her intangible capital, the firm can offer a back-loaded wage contract, which prescribes a lower wage c_t today but higher compensation package $\mathbf{m}_{t+1}$ in the future. In Section 4, we discuss the wage dynamics in detail, and highlight its link to the optimal financing choices of the firm.

3.2 Optimization

The optimal wage and debt contract determines the rents sharing from the match between capital and labor. The firm maximizes the present value of the lifetime dividend flows subject to the capital market and to labor market frictions. We now write down the firm's optimization problem $\mathcal{P}$ in a recursive form in which the state variables are $\{h, \mathbf{m}, z\} \in \mathcal{H} \times \mathcal{M} \times \mathcal{Z}$:

$$V(h, \mathbf{m}, b; z) = \max_{e,c,\mathbf{m}',b'} \left\{ d + \beta \mathbb{E}\big[V'(h', \mathbf{m}', b'; z'|z)\big] \right\}.$$

The problem $\mathcal{P}$ chooses the optimal investment e_t, wage contracts $\{c_t, \mathbf{m}_{t+1}\}$, and debt level b_{t+1}, subject to the law of motion of intangibles (1), the promise-keeping constraint (2), the participation constraint (3), the enforcement constraint (4), and the budget constraint

(5).

The optimization $\mathcal{P}$ takes into consideration the interactions between debt contracts and labor contracts. The firm optimally allocates the liability depending on both the tightness of the participation constraints (3) and the tightness of the enforcement constraint (4). Note that constraints (3) and (4) are not always binding, so we define the slack in constraint (3) $\beta_w m'(z',h') - \beta_w w(z',h')$ as a *labor-induced operating buffer* and the slack in constraint (4) $\beta\xi\mathbb{E}(V') - \frac{b'}{R}$ as a *financial buffer.*

As the firm accumulates h, it must also increase the promised utility to retain the employee, according to the participation constraint (3). Investment leads to the increase of deferred employee claims, which in turn creates a hold-up problem. Furthermore, when the firm defers the labor liability to the future, the cum dividend firm value declines, which in turn tightens the enforcement constraint for debt capacity. Hence, the choice of compensation structure not only bypasses the financial constraints, but also has a direct impact on the liability structure of the firm through the debt enforcement constraint (4).

4 Financial Implications of Employee Financing

In this section, we first discuss our theoretical definition of employee financing in the model, and then elaborate the implications of employee financing on firms' financial structure.

4.1 Intangible Investment and Employee Financing

The optimal employee contract serves as a financing channel by specifying the growth of contingent wage payments each period. More specifically, the wage contract spares some internal cash flows for intangible investment by deferring employee claims.

Recall the promise-keeping constraint (2): $m_t(z_t,h_t) = u(c_t) + \beta_w\mathbb{E}_t[\mathbf{m}_{t+1}(z_{t+1},h_{t+1})]$, where $m_t(z_t,h_t)$ represents the delayed compensations to the employees, measured in units of utilities. In order to measure the delayed compensations in cash terms, we first express the employee's promised utility m_t into its equivalent wealth. We denote the present monetary value of the lifetime consumption stream from the wage contract as:

$$\tau_t(z_t, h_t) = c_t + \beta_\omega \mathbb{E}_t[\mathcal{T}_{t+1}(z_{t+1}, h_{t+1})],$$

where $\tau_t(z_t, h_t)$ is the corresponding delayed employee claims in units of cash.

Given τ_t is the stock of total delayed compensations to the employees, we define the change of τ_t as employee financing $\Delta\tau_t = \mathbb{E}_t[\mathcal{T}_{t+1}] - \tau_t$. We show that the evolvement of the employee's wealth τ_t can be implemented by commonly observed financial instruments in compensation contracts. For example, uncontingent debt-like cash payment,[18] employee equities, and stock options. We show the detailed proof in Appendix B.1.

Under the assumptions of the employee's limited commitment and risk aversion, the exact employee financing mechanism works as follows: First, when the firm delays wage payments to the future to retain the employee, it can use more internal funds to finance investment in the current period. The investment has a direct impact on the employee's outside option. To retain the employee, the employee's claim on the future production surplus needs to increase with investment so the employee's deferred claim is positively correlated with investment in intangible capital h. We refer to this channel as the *retention* channel of employee financing.

Second, the risk sharing between employees and shareholders also facilitates financing. Risk-averse employees value consumption smoothing, so they are willing to accept lower wages in a long-term contract than that they would obtain in a spot labor market. If the risk aversion of employees is relatively higher than that of shareholders,[19] employees essentially pay an insurance premium, which also implicitly relaxes the budget constraint. Going forward, we refer to this second channel as the *risk-sharing* channel of employee financing.

[18] The cash payment to employees is the debt-like component, which we can map to pension or other fixed payments promised to employees.

[19] In our model, the rigidity of adjusting equity also imposes a degree of risk-aversion on shareholders. The assumption of rigid equity comes from the facts that dividend payouts are sticky and equity issuances are costly.

We examine both channels although the focus is the retention channel. The reason is that the retention channel is necessary to generate the positive correlation between intangible investment and employee financing, since the change of deferred employee claims is directly linked to intangible investment. However, borrowing from employees through the risk-sharing channel is not specific to finance intangible capital investment, but rather to finance all types of firms operations, including physical capital investment, intangible capital investment, and other operating expenses (Guiso et al. (2013)).

4.2 Retention and Risk Sharing

We start with the benchmark case where the perfect risk sharing between employees and shareholders is achieved. Then, we show the dynamics of employee financing tilted by the retention motive once labor market frictions are introduced. Intertemporally, the general risk-sharing rule between employees and shareholders, captured by the marginal rate of substitution (MRS) between dividend and consumption, is conditional on the tightness of the labor participation constraint and the tightness of the the debt enforcement constraint. The following proposition describes the dynamic interaction between the risk-sharing, retention, and the enforcement constraint of debt.

Proposition 1 *Given the firm's optimization problem $\mathcal{P}$, if neither the employees' participation constraint* (3) *nor the debt enforcement constraint* (4) *is binding, MRS between dividends and wages remains unchanged; if the employees' participation constraint* (3) *is not binding but the debt enforcement constraint* (4) *is binding, MRS between dividends and wages decrease over time; if the participation constraint is sufficiently tight, MRS increases.*

Please find the proof in Appendix B. The intuition of the proposition works as follows. The intertemporal risk-sharing rule not only indicates the rent splitting between employees and shareholders, but also implies the optimal timing of wage payments in the long-term contract. MRS between dividend and wage is also the marginal benefit of the deferred employee claims. Increase in MRS means higher marginal benefit of employee financing through retention channel.

When neither the participation constraint nor the debt enforcement constraint is binding, the perfect risk sharing is achieved, i.e., MRS between dividend and wage should be equalized intertemporally. In the case where employees are more risk averse, perfect risk sharing indicates a constant compensation plan to employees and fulfills the risk-sharing channel of financing.

When either the participation constraint or the debt enforcement constraint is binding, the perfect risk sharing can be violated. There are two general scenarios. First, the binding labor market participation constraint is the key to introduce the retention financing channel. A positive productivity shock leads to increases in intangible investment and also increases of the employee's outside option. Assume that $\gamma(z', h')$ is the Lagrangian multiplier of participation constraint (3). When $\gamma(z', h') > 0$, the marginal benefit of employee financing increases. In order to retain the employee with higher outside options, firms raise the deferred compensation by paying lower wages today. Second, firms are subject to the binding enforcement constraint (4). Note that μ is the Lagrangian multiplier of enforcement constraint (4). When low debt capacity leads to financial tightness ($\mu > 0$), firms tend to relax the enforcement constraint by reducing deferred employee compensation while keeping the participation constraint hold. Shareholders raise the debt capacity by using less of employee financing.

4.3 Intangible Capital Overhang Effect

One of the key features of our model is that the participation constraint of labor market (3) and the enforcement constraint (4) do not affect the financing and investment decisions of a firm independently. They interact through the net worth of shareholders $V(h, m, b; z)$, which can lead to a negative correlation between investment and debt financing.

The interaction between the participation constraint (3) and the enforcement constraint

(4) leads to the endogenous determinant of debt capacity, defined as the *intangible capital overhang effect*: When the firm increases investment in h today, the deferred employee claim must increase in order for the firm to retain the employee. As a result, we expect a lower net worth of the shareholder, which leads to lower expected borrowing capacity from debt holders. This intangible capital overhang effect from our model is the key driving force behind the negative correlation between investment and debt capacity. Also, this overhang effect differs from the standard investment model with collateral constraints in which the debt capacity increases with investment opportunity. In our model, the intangible overhang channel crowds out debt capacity through the retention channel since investment opportunity co-moves with the employee's outside option.

The alternative interpretation of the overhang effect is that intangible capital can be used as "collateral" to borrow from employees. Intangibles are considered to have low collateral rates when pledged to debt holders, but they can be collateral assets when contracting with employees, depending on the portability of the intangible capital η. Similar to the external investors' threat of liquidating the firm's assets if the firm defaults on debt, the employee's option of walking away from the current wage contract provides a credible liquidation threat to the firm's intangible capital. As the portability of intangible capital increases, so does the "collateral" rate of the wage contract.[20]

The overhang effect can go the other direction: Firms can increase the financial debt capacity by using less deferred employee claims without violating the participation constraint. Quantitatively, the optimal allocation of financing capacity, financial debt versus deferred employee claims, is summarized by the following proposition.

Proposition 2 *The firm dynamically trades off between financial debt and employee claims until their intertemporal marginal rates of substitution are equal.*

[20]Note that treating intangible capital as implicit collateral for employee financing also leads to an endogenous adjustment cost for investment. The adjustment cost is on the intangible capital embodied in employees, but not on the labor firing and hiring decisions, as in Michaels et al. (2015). Employees play the role of intangible "capital" owners. Given the properties of optimal policies, our endogenous adjustment cost of intangible investment is non-convex and lumpy.

See the proof in Appendix B. Our recursive wage contract with limited commitment and financial frictions shares common properties of wage contract dynamics in the standard literature (e.g., Harris and Holstrom (1982), Thomas and Worrall (1988), Kocherlakota (1996)), but our results deviate from the literature in the following perspectives: The optimal wage contract serves to provide insurance to employees against income fluctuation, but the contract also specifies the optimal rent-splitting rule between the shareholders and the employees. The incentive provisions are the driving force of optimal financing allocation. On the other hand, because of financial frictions, shareholders may become more "risk averse" than employees when the cost of financial tightness is high enough. As a result, in our model, when the firm's financial tightness cost dominates the marginal benefit of employees' consumption smoothing, the MRS may decrease over time even if the employee's participant constraint is binding.

5 Structural Estimation

In this section, we estimate our model and quantitatively analyze the financial effects of the employee financing channel. Although reduced form results are established in Section 2, a structural estimation is necessary to quantify the amount of financing substituted by deferred employee claims (SBC) under the explicit assumptions of employees and shareholders' preference, and also provide meaningful counterfactual exercises.

5.1 The Model Solution

To solve the model numerically, we assume that the employee is endowed with log utility $u(c) = \log(c)$ and the production function is linear $y = zh$. Both the log utility and the linear technology allow us to normalize the wage contract by the level of intangible capital and thus reduce the number of computational dimensions. Although we make these two assumptions, all the model properties discussed in Section 4 remain the same.

The functional form of the capital adjustment cost is specified as $\phi(e) = \frac{a_1}{1-\zeta}e^{1-\zeta} + a_2$, where the variable δ is the depreciation rate of intangible capital, and the value $1/\zeta$ is the elasticity of the investment-to-capital ratio with respect to the marginal q. The parameters $a_1 = \delta^{\zeta}$ and $a_2 = \frac{-\zeta}{1-\zeta}\delta$ are set so that, in the steady state capital adjustment cost is 0 and the marginal $q = \frac{1}{\phi'(i)} = 1$. This adjustment cost function has been used in the investment and production-based asset pricing literature (Jermann (1998)).

5.2 Parameters and Moments

The estimation procedure is based on the simulated method of moments (SMM), as in Lee and Ingram (1991) and Nikolov and Whited (2014). The general idea of SMM is to choose model parameters such that the distance between the data and the model is minimized. See Appendix D for a detailed description of estimation procedures.

Most of the model parameters are estimated with the exception of the shareholders' discount factor β, the effective interest rate R after considering corporate tax τ_c, the employees' discount factor β_w, and the depreciation rate δ. We calibrate the shareholders' discount factor β to match the firm-level discount factor from the survey evidences. Graham and Harvey (2012) and Jagannathan et al. (2014) find that the firm's discount rate is approximately 12%, which implies a quarterly discount factor of 0.97. The corporate tax rate is approximately 30%. Given the discount factor and the corporate tax rate, the effective interest rate of debt can be calculated as $R = 1 + (1/\beta - 1) \cdot (1 - \tau_c) \approx 1.02$. The employee's discount factor is set lower than that of shareholders, $\beta_w = 0.96$. Thus, without labor market or financial market frictions, our model exhibits the *static pecking order* of financing: Firms prefer debt finance over equity finance, and prefer regular equity finance over employee equity finance. Following Eisfeldt and Papanikolaou (2013), the quarterly depreciation rate δ is set to 0.08.

After calibrating the parameters described above, six parameters remain to be estimated: (1) the persistence of the productivity shock ρ_z, (2) the volatility of the productivity shock σ_z, (3) the capital adjustment cost parameter ϕ, (4) the financing cost parameter κ, (5) the debt enforcement parameter ξ, and (6) the portability of intangible capital η.

In the structural estimation, we obtain the empirical moments using the same data source and variable definitions described in Section 2. Table 3 provides the model definition of variables used in the structural estimation. Because we calculate empirical moments that require repeated observations for each individual firm (e.g., standard deviations and auto-correlations), we drop firms with fewer than eight quarters of data. To map the model to the data, we scale the investment, debt issuance, and employee financing all by value of the assets $(v + b')$, since our empirical variables are scaled by total assets given the measurement errors in constructing the level of intangible capital h directly in the data.[21]

In order to successfully identify the model, we choose nine moments that are sensitive to the variation of the parameters, to jointly identify the model parameters. These nine moments are: the average financial leverage; the standard deviation of leverage; the auto-correlation of leverage; the standard deviation and the auto-correlation of R&D investment, debt issuance, and stock-based compensation (SBC); the correlation coefficient between R&D investment and debt issuance; and the correlation coefficient between R&D investment and SBC.

In the benchmark structural estimation, we do not include the three first order moments of R&D investment, debt issuance, and SBC. Instead, we focus on the correlations between these variables. SBC as the employee compensation does not exactly measure the current wage flows saved by shareholders for financing. For example, under fair value rule, the value of SBC could be different subject to different usage of financial instruments. Also, we omit the physical capital investment in the model, hence there are potential mismatches between the level of debt issuance in the model and that in the data. Another important reason is that the correlations can help us to identify the model parameters accurately. Despite potential measurement errors, we also report the estimation with first moments included in the Online

[21] Another caveat is that we abstract physical capital k from the model for simplicity. Even if we construct h in the data to scale investment and cash flows, we will still be subject to some biases of measurement. For example, in the data debt issuance is used to finance physical investment. If scaling debt issuance by h, the level of debt issuance is not a reasonable target for our model to match since our model only has intangible capital.

Appendix to check the model's robustness.

5.3 Identification

In this subsection, we provide intuitions on how each of the six parameters is identified.[22] The portability of intangible capital parameter η is our parameter of interest, since η captures the effectiveness of the employee financing channel and the scale of the intangible overhang effect. The correlation between R&D investment and employee financing is increasing in η (see Figure 6), which helps identify η by quantifying the employee financing channel directly. Also, the level of financial leverage acts to pin down η in the estimation through the intangible overhang effect.

The debt enforcement parameter ξ is almost uniquely identified by the level of leverage. In Figure 5, a higher enforcement rate implies a higher debt capacity. Thus, on average, firms borrow more. Moreover, the correlation between debt issuance and R&D investment is declining in ξ since investment is less affected by external debt financing if the enforcement constraint is less likely to bind.

The persistence of the productivity shock ρ_z is determined by the autocorrelation of leverage and R&D investment. If the productivity shocks are persistent, the firm makes an investment and adjusts its financial structure smoothly. The standard deviation of the productivity shock σ_z is identified by the standard deviation of leverage and the standard deviation of debt issuance. If the volatility of the shock is higher, the firm would adjust its debt position more frequently, and thus incur more volatile debt issuance and financial leverage.

The autocorrelation of R&D helps us identify the capital adjustment cost parameter ϕ, since this cost directly affects the timing of the firm's investment. Further, the capital adjustment cost has a strong impact on the correlation between investment and financing. If the adjustment cost of intangible capital is higher, it implies that the correlation between

[22] For all figures of sensitivity analysis, please see Online Appendix.

investment and financing is also higher. The financing adjustment cost parameter κ is determined by the auto-correlation of leverage. The firm's leverage becomes more persistent when its financing rigidity is significant. The financing adjustment cost parameter also impacts the correlation between financing and investment.

We conclude this section by noting that the number of moments used in the estimation is larger than the number of parameters. Thus, there is no one-to-one mapping between the estimated parameters and the moments used in the estimation. All the parameters are jointly identified and the sensitivity exercise provides only an intuition for the identification mechanisms.

5.4 Estimation Results

5.4.1 Benchmark Estimation

Table 4 reports the results of our structural estimation. We use the estimation results of the high-tech industries as the benchmark, since the theoretical model is better designed to capture the features of the intangible-intensive industries.

As shown in Panel A of Table 4, the model fits the data reasonably well, especially in matching the mean of leverage, the standard deviation of R&D investment, and the standard deviation and autocorrelation of SBC. Furthermore, the model produces a high positive correlation between R&D investment and SBC, and a negative correlation between R&D investment and debt issuance. When there is a positive productivity shock, the firm increases investment and raises funds through both employee financing and debt financing. However, because of the concave utility function, the employee financing is stickier compared to the debt financing. Thus, when the positive shock decays, the firm keep borrowing through employee financing, while it retires debt at the same time. Thus, our model generates a positive correlation between investment and employee financing, but a negative correlation between investment and debt financing.

Our estimation sets the debt enforcement parameter ξ at 0.129 and the intangible capital portability parameter η at 0.283. The enforcement parameter ξ is lower than other estimates in the literature, because the sample of firms used for the estimation are high-tech firms, which typically do not have substantial collateral assets for debt financing. The intangible capital portability parameter η measures the implicit collateral rate of intangible capital when the firm borrows from employees. The higher the value of η, the more employee equity firms would use. To our knowledge, there is no well known reference in the literature to evaluate our estimated value of η. In order to convey the economic significance of parameter η, we compare it with the results of the structural estimation of traditional industries in the next section.

The estimated value of the standard deviation of the productivity shock σ_z is 0.145 and the persistence of the shock ρ_z is 0.460. The estimated capital adjustment cost parameter ϕ is 0.325, which implies the elasticity of the investment-capital ratio with respect to the marginal q is approximately 3.07, that is, $\frac{\Delta i/i}{\Delta q/q} = \frac{1}{0.325}$. The estimated financing adjustment cost parameter κ is 1.193, implying that the average financing cost is about 0.1% of total assets per quarter.

5.4.2 Optimal Financing Policies

Given the estimation result, we now illustrate the substitution between debt and employee financing quantitatively. Figure 4 demonstrates the non-linear impulse response functions calculated under the set of parameter values from the benchmark estimation (Table 4).

Figure 4 panel (a) shows the impulse response of the debt-to-promise ratio ($\frac{b_{t+1}}{E_t(\tau_{t+1})}$) to a one-standard deviation positive productivity shock. The firm increases investment and accumulates intangible capital given a positive productivity shock. In the meantime, the employee faces a better outside option. The contingent wage contract offers higher deferred compensation in order to satisfy the participation constraint (3). An increase in deferred employee claims shrinks the debt capacity in future periods, so the firm can either save debt buffers by reducing debt financing ($\mu = 0$), or it can reduce the current wage payment c

when the economic state precludes it from saving debt buffers for precautionary purposes ($\mu > 0$). On average, a positive shock leads to co-movement between investment and deferred employee claims, but leads to zero correlation, or a negative correlation, between investment and debt financing. In Figure 4, the debt-to-promise ratio responds negatively to the positive productivity shock.

When a negative productivity shock is realized, the investment motive is low. An employee's outside options are weak, and the participation constraint is not binding ($\gamma(z', h') = 0$). Given that the employee is risk averse, the contingent wage contract offers a constant deferred compensation to provide full insurance to the employee when the firm saves enough buffers ($\mu = 0$). However, during a period of financial tightness ($\mu > 0$), the firm can use some of its operating buffers to relax the budget constraint by reducing the deferred compensation. In Figure 4, Panels (c) and (d) show that the debt-to-promised ratio increases as the shadow price of employee financing declines. To summarize, a negative shock leads to a positive correlation between investment and deferred employee claims but leads to a negative, or zero, correlation between investment and debt financing.

5.4.3 Cross-industry Estimation

We then conduct a structural estimation for the traditional industries. This helps to examine the effects of wage contracts on the financial leverage of firms that are homogeneous *ex ante*, and most importantly, given we test our model using the entire sample period from 2006q1 to 2015q1, we justify our benchmark estimation results by comparing the benchmark estimation results with that for the traditional industries.

Panel A of Table 5 reports the observed and simulated moments for the traditional industries. The average leverage ratio for the traditional industries is 0.186, which is almost double the ratio of 0.105 found in the high-tech industries. In the column of simulated moments, the model conforms well to the average leverage and the standard deviation of financial leverage. As expected, the model generates a lower correlation (0.243) between R&D investment and employee financing for the traditional industries than the correlation (0.395) found in the high-tech industries.

Panel B of Table 5 reports the estimated parameters for the traditional industries. The debt enforcement parameter ξ for the traditional industries is 0.225, higher than that for the high-tech industries, which is 0.129. This is in line with the intuition that the collateral rate of assets is lower in the high-tech industries, but relatively higher in the traditional industries. The capital portability parameter $\eta = 0.223$ is lower for the traditional industries than η found for the high-tech industries ($\eta = 0.283$), which suggests that intangible capital in high-tech industries are less firm specific.[23] The financing adjustment cost parameter κ is 0.749 for the traditional industries, which is lower than the one estimated (1.193) for the high-tech industries. The estimated intangible capital adjustment cost parameter ϕ is 0.414, higher than 0.325 for high-tech industries. That is, in traditional industries, it is more costly to adjust intangible capital.

The estimated standard deviation of the productivity shock is slightly higher in the traditional industries, with a value of 0.153. Similarly, in the traditional industries, the estimated persistence of the productivity shock ρ_z is 0.720, which is higher than the estimate for the high-tech industries. Although the second moments, such as the standard deviation of R&D investment, are low in the traditional industries, the estimated capital adjustment cost parameter ϕ is significantly higher for the traditional industries. As a result, even with a higher standard deviation and a higher persistence of the productivity shock, the simulated model is still able to match the lower volatility observed in the data.

5.5 The Model without Employee Financing

In this subsection, we compare our model to a typical dynamic investment model with financial frictions, but without the employee financing channel. Specifically, to disable the employee financing channel while keeping the model comparable to the literature, we modify

[23]For example, general human capital or skills are considered important characteristics of intangible capital in the high-tech industries.

our benchmark model $\mathcal{P}$ in two aspects. First, we set the promised utility $\mathbf{m}_{t+1}$ as a fixed number (the simulated average in the benchmark model), and thus a constant wage c_t to satisfy the promise-keeping constraint (2). Second, we remove the employee's participation constraint (3). The modified problem $\mathcal{P}'$ maximizes the value of shareholders, subject to the law of motion of capital (1), the promise-keeping constraint (2) with fixed promised utility, the debt enforcement constraint (4), and the budget constraint (5).[24] Thus, if we redefine the firm's cash flows by subtracting the current wage bills, the modified problem is exactly a corporate physical investment model with financial frictions (e.g., Gomes (2001); DeAngelo et al. (2011); Jermann and Quadrini (2012)).[25]

Table 6 reports the simulated results of the modified model. First, the modified model generates a positive correlation (0.438) between R&D investment and debt issuance, but a negative correlation (-0.437) between R&D investment and SBC. However, in the data, those two correlations have opposite signs respectively: -0.014 and 0.307. This suggests that, if we shut down the employee financing channel, the counterfactual result contradicts the evidence. That is, the employee financing channel identified in our paper can not be explained by typical dynamic investment models, simply through re-interpreting tangible capital as intangible capital.

Second, the average leverage is lower (0.073) in the modified model than (0.098) in the benchmark model. This is because, in the modified model the promised utility is fixed. By offering a fixed promised utility, the long-term wage contract provides perfect insurance to the employee. However, this would reduce the equity value of the firm, and thus the firm's debt capacity through the debt enforcement constraint.

[24] The modified model without employee financing channel $\mathcal{P}'$ is:

$$V(h, b; z) \quad = \quad \max_{e,c,b'} \Big\{ d + \beta \mathbb{E}\big[V'(h', b'; \bar{\mathbf{m}}, z'|z)\big] \Big\}.$$

subject to: constraint (1), (4), (5), and modified participation constraint $\bar{m} = u(c) + \hat{\beta}\mathbb{E}[\bar{\mathbf{m}}']$.

[25] The modified model is an investment model with financial frictions and wages as fixed costs. To some extent, we give full insurance to risk-averse workers, so the risk-sharing channel is still present in this counterfactual, which is obtained in the standard risk sharing channel, e.g., Guiso et al. (2013). However, by doing this, we completely eliminate the retention channel from the portability assumption.

Third, the predicted level of employee financing is lower (0.0077) than the benchmark model (0.0083), while the predicted level of debt financing (0.0019) is higher than the benchmark (0.0006). That is, when we shut down the employee financing channel, the debt financing increases.

5.6 Financial Effects of Employee Contracts

In this subsection, we examine two types of financial effects induced by the employee contracts. First, the accumulation of intangible capital reduces the firm's debt capacity through the overhang effect. Second, for precautionary purposes, the firm is motivated to maintain a lower leverage to avoid future financial tightness as intangible capital increases. We identify the overhang effect by demonstrating the changes in the firm's total debt capacity as the level of capital portability changes, and identify the precautionary effect by examining the financial buffers derived from the slackness of the debt enforcement constraint and the operating buffers from the employee's participation constraint. The stronger the precautionary effect, the more unused buffers the firm holds.

To quantify the above two effects, we conduct a counterfactual exercise. First, we report the moments of the model (i.e., capacity and buffers) using the estimated parameters of the traditional industries. Then, we replace the value of the capital portability parameter η with that for the high-tech industries, while keeping the other parameters the same as for the traditional industries.

In Table 7, we report the value of debt capacity, as well as the value of employee financing capacity in the case of low intangible capital portability (traditional industries with $\eta = 0.223$) and in the case of high capital portability (traditional industries with $\eta = 0.283$). As shown in Panel A of Table 7, the intangible capital overhang effect is identified. When the intangible capital portability increases, the debt capacity per capital decreases, from 0.09 to 0.05. At the same time, the firm's financing capacity from employees increases, from 0.66 to 0.85 for high state, and from 0.62 to 0.80 for low state. Furthermore, the increases in employee financing capacity on average overturn the decreases in debt capacity by 0.146. Our estimation indicates that the overall financing capacity of the firm can actually increase if intangible capital becomes more portable. It is the firm's optimal choice to finance intangible capital with wage contracts, because wage contracts can be more efficient than debt contracts when the intangible capital is less firm specific.

In Panel B of Table 7, we consider the precautionary effects. We show that firms hold less financial and operating buffers as the capital portability η increases, i.e., both the participation constraint and the debt constraint become tighter. The intuition is as follows: when the capital portability η increases, the employee faces better outside options, which tightens the participation constraint. The firm now has to offer better compensations to retain the employee, and therefore its debt capacity decreases due to the overhang effect. The caveat to interpret the result is that decreases in debt capacity can reduce the firm's financial buffers, but it does not necessarily rule out the possibility that the firm choose to issue less debt. Our result shows that the decrease in debt capacity is actually more than the reduction in debt issuance, and overall, the financial buffer decreases as the capital portability increases.

6 Conclusion

In this paper we document a new channel of financing intangible capital through employee compensation contracts. We show that intangible capital investment is positively correlated with stock-based compensations, but not with debt issuance or regular equity issuance. We develop a model in which firms issue self-enforcing debt contracts to external investors and also offer long-term wage contracts to employees who have limited commitment. The long-term wage contract serves as a financing instrument for shareholders by deferring employee claims to the future. Our employee financing channel features the retention motive from the long-term compensation contract. As a result, the accumulation of intangible capital in production imposes an intangible capital overhang effect on the firm's financial structure decisions.

We quantify that the intangible overhang effect is a sizable and dominant force in explaining cross-industry differences in financial leverage. We also argue that rising intangible capital shrinks firms' debt capacity but expands the total borrowing capacity if one takes employee financing into account. By identifying the different financing channels, this paper opens a new pathway to understand the link between the fundamental economic forces and the financial decisions of firms.

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Tables

Table 1: **Summary Statistics**

Variable	Obs	Mean	Std. Dev.	P10	P50	P90
Leverage	53826	0.1413	0.1697	0	0.0696	0.4038
Q	53826	2.1815	1.2166	0.9821	1.767	4.4145
MV	53826	3502.569	7571.636	48.3816	541.0713	9845.771
R&D	53826	0.0265	0.03	0	0.0164	0.0732
Debt Issuance	53826	0.0005	0.0181	-0.017	0	0.0166
SBC	53826	0.0055	0.0053	0.0006	0.0034	0.0157
Sales	53826	0.0899	0.0615	0	0.0871	0.182
Equity Issuance	53826	0.0049	0.009	0	0.001	0.0153
CAPX	53826	0.0094	0.0103	0.0007	0.0059	0.0223

Data Source: CRSP/Compustat Merged Database Quarterly from 2006q1 to 2015q1. Variables in the bottom panel are normalized by the book value of total assets. We exclude utilities and financial firms with SIC codes in the intervals 4900-4999 and 6000-6999, as well as firms with SIC codes greater than 9000. We also exclude firms with missing values of assets, debt, R&D expenses, debt issuance, and stock-based compensation (SBC) during the sample period. To limit the impact of outliers (e.g., mergers and acquisitions), we also winsorize all level variables at the 5% and 95% percentiles. All variables are deflated by CPI.

Table 2: **Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1**

	Panel A: Full Sample			Panel B: Traditional			Panel C: High Tech		
	CAPX	RD	SGA	CAPX	RD	SGA	CAPX	RD	SGA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Debt Issuance	0.032***	-0.002	-0.007**	0.036***	-0.002	-0.014***	0.019***	-0.004	-0.002
	(11.31)	(-0.62)	(-2.43)	(8.60)	(-0.60)	(-3.91)	(6.02)	(-0.75)	(-0.58)
Equity Issuance	-0.014***	-0.053***	-0.041***	-0.026*	-0.050***	-0.048***	-0.011**	-0.057***	-0.044***
	(-2.85)	(-4.28)	(-3.52)	(-1.74)	(-2.63)	(-2.74)	(-2.16)	(-3.76)	(-2.97)
SBC	0.078***	1.093***	1.293***	0.034	0.693***	1.065***	0.099***	1.192***	1.352***
	(3.98)	(16.10)	(19.14)	(0.66)	(6.54)	(10.08)	(4.67)	(14.62)	(16.22)
CF	0.014***	0.029***	0.133***	0.017***	0.014**	0.104***	0.011***	0.035***	0.147***
	(6.62)	(5.04)	(23.10)	(3.36)	(2.08)	(14.06)	(5.07)	(4.61)	(18.84)
Q	0.001***	0.002***	0.000	0.002***	0.001*	-0.000	0.001***	0.002***	0.001**
	(10.86)	(6.62)	(1.43)	(7.47)	(1.81)	(-1.14)	(7.27)	(6.47)	(2.08)
Const.	0.006***	0.014***	0.021***	0.008***	0.005***	0.018***	0.005***	0.021***	0.025***
	(17.17)	(16.91)	(26.81)	(10.40)	(5.22)	(16.86)	(11.12)	(17.95)	(23.11)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
N of Obs.	53,826	53,826	48,197	18,028	18,028	17,597	33,972	33,972	28,906
ID	2,862	2,862	2,673	1,102	1,102	1,087	1,637	1,637	1,467
Adj.R^2	0.053	0.096	0.234	0.085	0.066	0.200	0.034	0.106	0.252

The table reports the results of regressing investment on sources of finance. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). All variables are scaled by total book asset (atq). Data source: Compustat-CRSP merged quarterly 2006q1-2015q1. t-statistics in parentheses. $* \ p < 0.10$, $** \ p < 0.05$, $*** \ p < 0.01$.

Table 3: **Variable Definitions in Structural Estimation**

	Model	Data	Compustat
Leverage	$\frac{b'}{v+b'}$	$\frac{\text{Debt}_t}{\text{Total Assets}_t}$	$\frac{\text{dlttq+dlcq}}{\text{atq}}$
R&D	$\frac{e}{v+b'}$	$\frac{\text{R\&D Expenses}_t}{\text{Total Assets}_t}$	$\frac{\text{xrdq}}{\text{atq}}$
Debt Issuance	$\frac{b'-b}{v+b'}$	$\frac{\text{Debt Issuance}_t}{\text{Total Assets}_t}$	$\frac{\text{dltisq-dltrq+dlcchq}}{\text{atq}}$
SBC	$\frac{\mathbb{E}\tau'-\tau}{v+b'}$	$\frac{\text{SBC}_t}{\text{Assets}_t}$	$\frac{\text{stkcoq}}{\text{atq}}$

This table contains definitions of variables and empirical measures. In Compustat/CRSP Merged Quarterly, dlttq denotes Short-Term Debt, dlcq denotes Long-Term Debt, atq denotes Total Assets, xrdq denotes R&D Expenses, dltisq denotes Long-Term Debt Issuance, dltrq denotes Long-Term Debt Reduction, dlcchq denotes Current Debt Changes, and stkcoq denotes Stock-Based Compensation Expense.

Table 4: **Benchmark Estimation**

Panel A: Target Moments	*Data*	*Simulated*	*T-Statistics*
Average leverage	0.105	0.098	(1.11)
Standard deviation of leverage	0.074	0.022	(9.89)
Autocorrelation of leverage	0.912	0.626	(8.21)
Standard deviation of R&D	0.009	0.008	(0.97)
Autocorrelation of R&D	0.488	0.907	(7.36)
Standard deviation of debt issuance	0.014	0.012	(3.68)
Autocorrelation of debt issuance	0.006	-0.153	(6.28)
Standard deviation of SBC	0.002	0.002	(0.27)
Autocorrelation of SBC	0.366	0.337	(0.80)
Correlation between R&D and debt issuance	-0.014	-0.118	(6.18)
Correlation between R&D and SBC	0.307	0.395	(1.11)

Panel B: Estimated Parameters	*Estimators*	*T-Statistics*
Persistence of productivity shock, ρ_z	0.460	(17.3)
Volatility of productivity shock, σ_z	0.145	(18.1)
Debt enforcement, ξ	0.129	(15.4)
Financing adjustment cost, κ	1.193	(9.2)
Capital adjustment cost, ϕ	0.325	(13.3)
Capital portability, η	0.283	(114.0)

The reported 11 moments are estimated using data from Compustat Fundamental Quarterly 2006q1–2015q1, with NAICS codes classified as ICT industries. The estimation is conducted using SMM as described in Appendix D, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments in the data. Panel A contains the observed and simulated moments from the estimation. Panel B reports the parameters estimated using SMM.

Table 5: **Estimation with Traditional Industries**

Panel A: Target Moments	*Data*	*Simulated*	*T-Statistics*
Average leverage	0.186	0.180	(0.52)
Standard deviation of leverage	0.070	0.011	(9.03)
Autocorrelation of leverage	0.934	0.486	(9.25)
Standard deviation of R&D	0.004	0.004	(0.17)
Autocorrelation of R&D	0.441	0.617	(2.86)
Standard deviation of debt issuance	0.017	0.011	(9.25)
Autocorrelation of debt issuance	0.009	-0.008	(0.48)
Standard deviation of SBC	0.001	0.002	(2.54)
Autocorrelation of SBC	0.271	0.030	(4.63)
Correlation between R&D and debt issuance	-0.024	0.107	(4.43)
Correlation between R&D and SBC	0.173	0.243	(1.46)

Panel B: Estimated Parameters	*Estimators*	*T-Statistics*
Persistence of productivity shock, ρ_z	0.720	(160.9)
Volatility of productivity shock, σ_z	0.153	(31.3)
Debt enforcement, ξ	0.225	(15.3)
Financing adjustment cost, κ	0.749	(24.3)
Capital adjustment cost, ϕ	0.414	(33.8)
Capital portability, η	0.223	(63.5)

The reported data moments are estimated using data from Compustat Fundamental Quarterly 2006q1–2015q1, with NAICS codes classified as the manufacturing and consumer goods industry. The estimation is conducted using SMM as described in Appendix D, which chooses structural model parameters by matching the moments from a simulated panel of firms to the corresponding moments in the data. Panel A contains the observed and simulated moments from the estimation. Panel B reports the parameters estimated using SMM.

Table 6: **The Model without Employee Financing**

Panel A: Target Moments	*Data*	*Benchmark*	*Counterfactual*
Average leverage	0.105	0.098	0.073
Standard deviation of leverage	0.074	0.022	0.049
Autocorrelation of leverage	0.912	0.626	0.693
Standard deviation of R&D	0.009	0.008	0.033
Autocorrelation of R&D	0.488	0.907	0.571
Standard deviation of debt issuance	0.014	0.012	0.032
Autocorrelation of debt issuance	0.006	-0.153	-0.036
Standard deviation of SBC	0.002	0.002	0.000
Autocorrelation of SBC	0.366	0.337	0.075
Correlation between R&D and debt issuance	-0.014	-0.118	0.438
Correlation between R&D and SBC	0.307	0.395	-0.437
Panel B: Predicted Moments	*Data*	*Benchmark*	*Counterfactual*
Mean of debt issuance	0.0001	0.0006	0.0019
Mean of SBC	0.0060	0.0083	0.0077

This table reports the results of the counterfactual exercise of disabling the employee financing channel. The modified model $\mathcal{P}'$ maximizes the value of shareholders, subject to the law of motion of capital (1), the promise-keeping constraint (2) with fixed promised utility, the debt enforcement constraint (4), and the budget constraint (5). Panel A reports the target moments used in the structural estimation, and Panel B reports the model predicted moments.

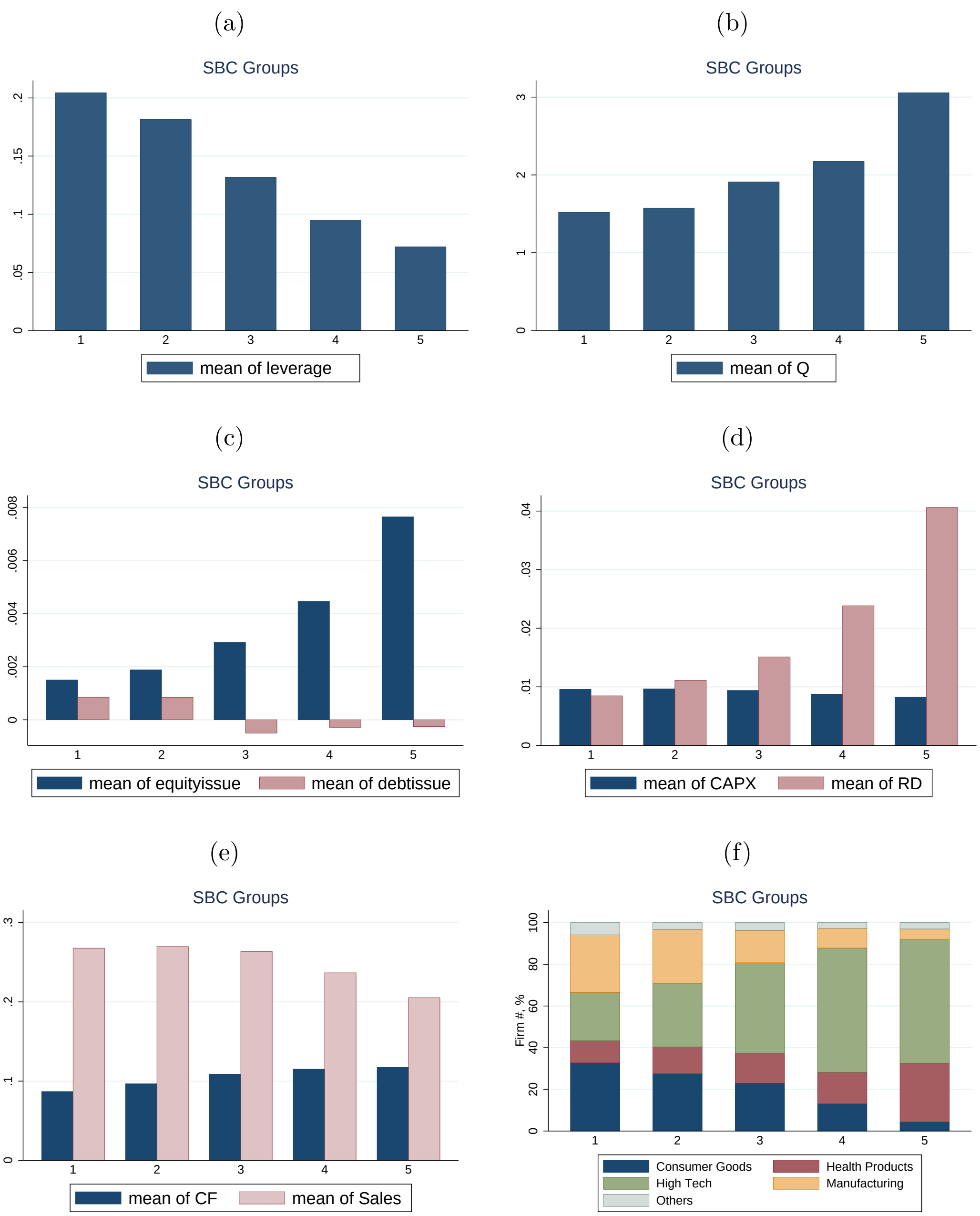
Table 7: **Decomposing the Financial Effects of Wage Contracts**

	(1) Traditional $\eta = 0.223$	(2) Traditional $\eta = 0.283$	(3) **Changes**
PANEL A: CAPACITY			
Debt capacity, $\frac{\xi\beta\mathbb{E}[V']}{h}$	0.09	0.05	-0.04
Employee financing capacity, $\frac{\beta_w \tau'_H}{h}$	0.66	0.85	+0.19
Employee financing capacity, $\frac{\beta_w \tau'_L}{h}$	0.62	0.80	+0.18
PANEL B: BUFFER			
Financial buffer, $\frac{\xi\beta\mathbb{E}[V'] - \frac{b'}{R}}{h}$	0.0026	0.0023	-0.0003
Operating buffer, $\beta_w m'_H - \beta_w \omega'_H$	0.1253	0.1017	-0.0236
Operating buffer, $\beta_w m'_L - \beta_w \omega'_L$	0.1256	0.1180	-0.0076

This table reports the value of financing capacities, as well as buffers (slack of the constraints) in the case of low intangible capital portability (traditional industries with $\eta = 0.223$) and in the case of high capital portability (traditional industries with $\eta = 0.283$) while keeping the other parameters the same as for the traditional industries. Column (1) uses the parameters estimated from the traditional industries. In Column (2), the value of portability η is replaced by the value found for the high-tech industries group. With the exception of the labor-induced operating buffer, which is expressed in units of utility, all other variables are expressed in units of cash flow.

Figures

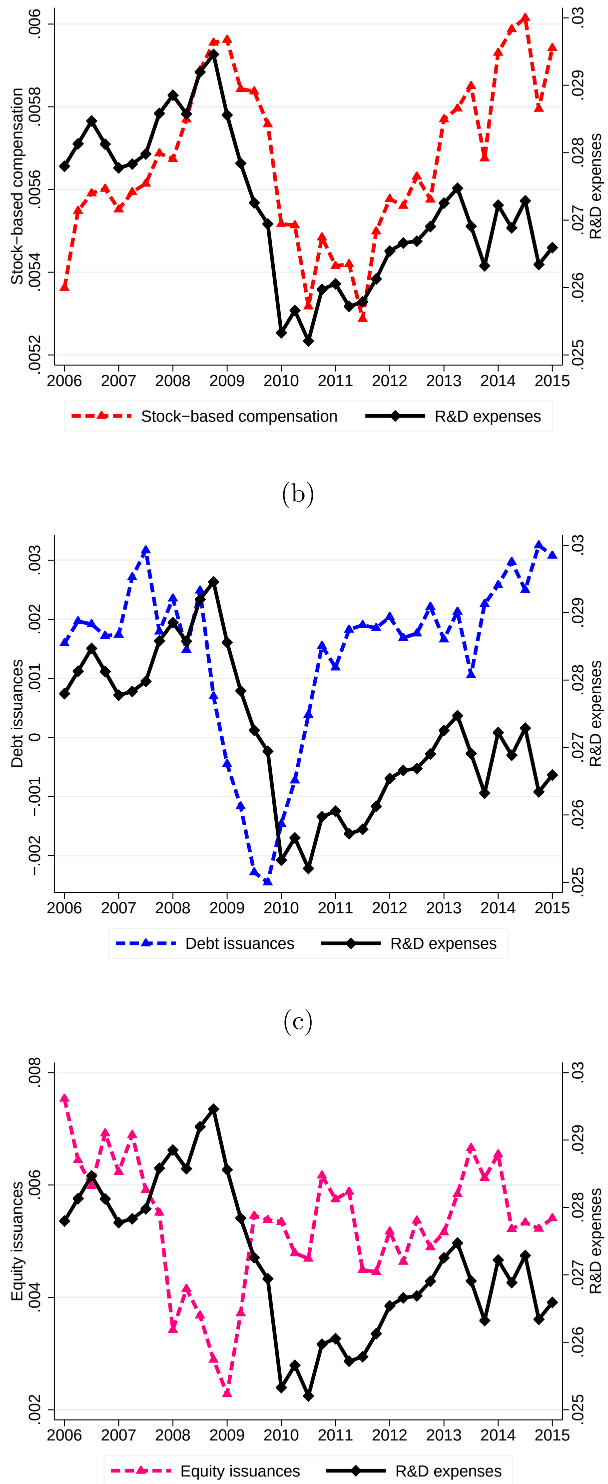
Figure 1: **Firm Characteristics of SBC Groups**



Panel (a) to (e) show the average leverage, Tobin's Q, equity issuance ($\frac{\text{SSTKQ}}{\text{ATQ}}$), debt issuance ($\frac{\text{DLTISQ-DLTRQ+DLCCHQ}}{\text{ATQ}}$), investments, sales, and cash flows within each SBC-to-assets quintile. Panel (f) shows the percentage of firms in different industries within each SBC-to-assets quintile. All variables are first scaled by quarterly book assets, then they are averaged across firms at each quarter. The data are shown at quarterly frequency, from Compustat Fundamental Quarter 2006q1–2015q1. A detailed description of the variables is in the Appendix A.1.

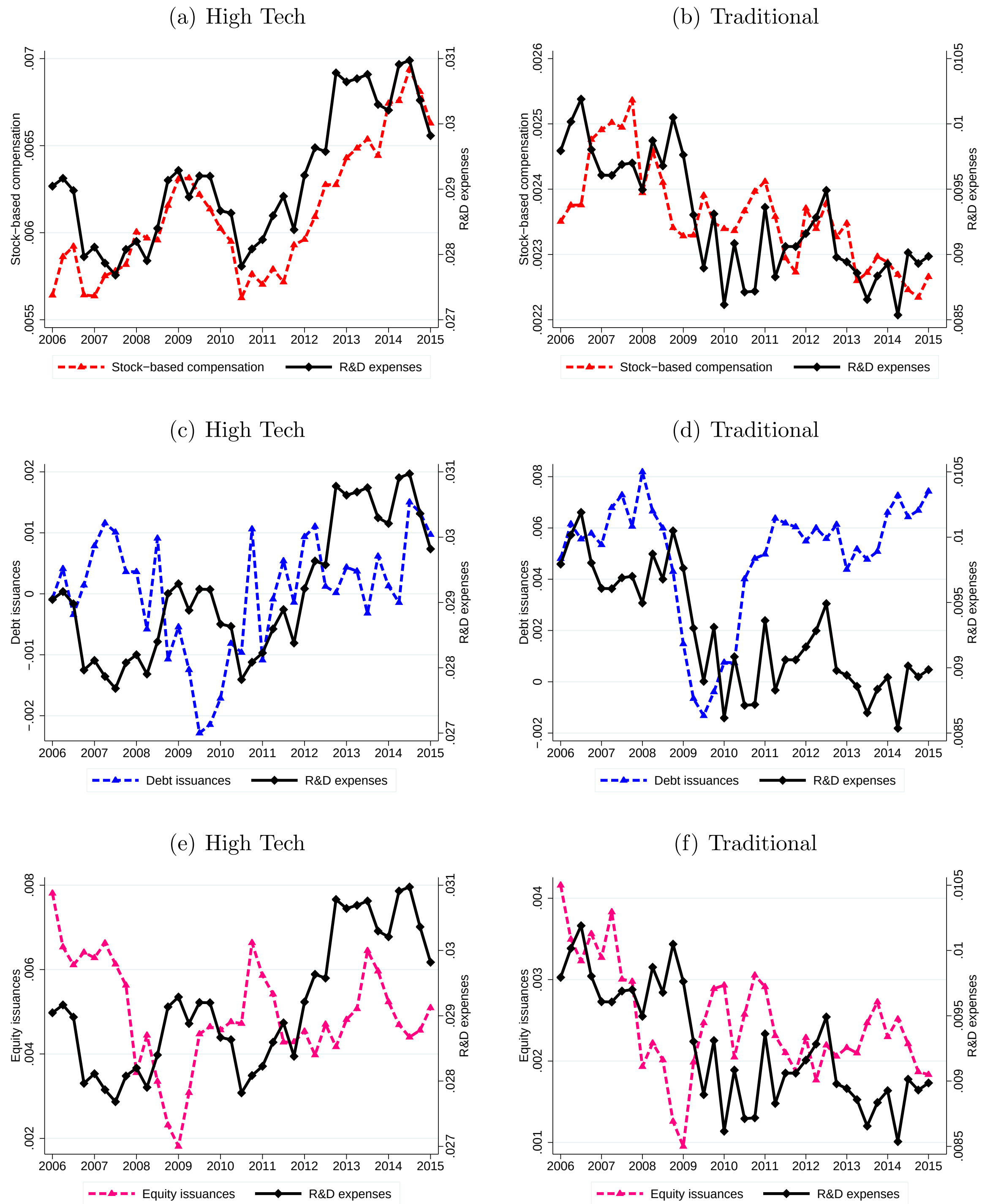
Figure 2: **Firm-Level Time Series**

(a)



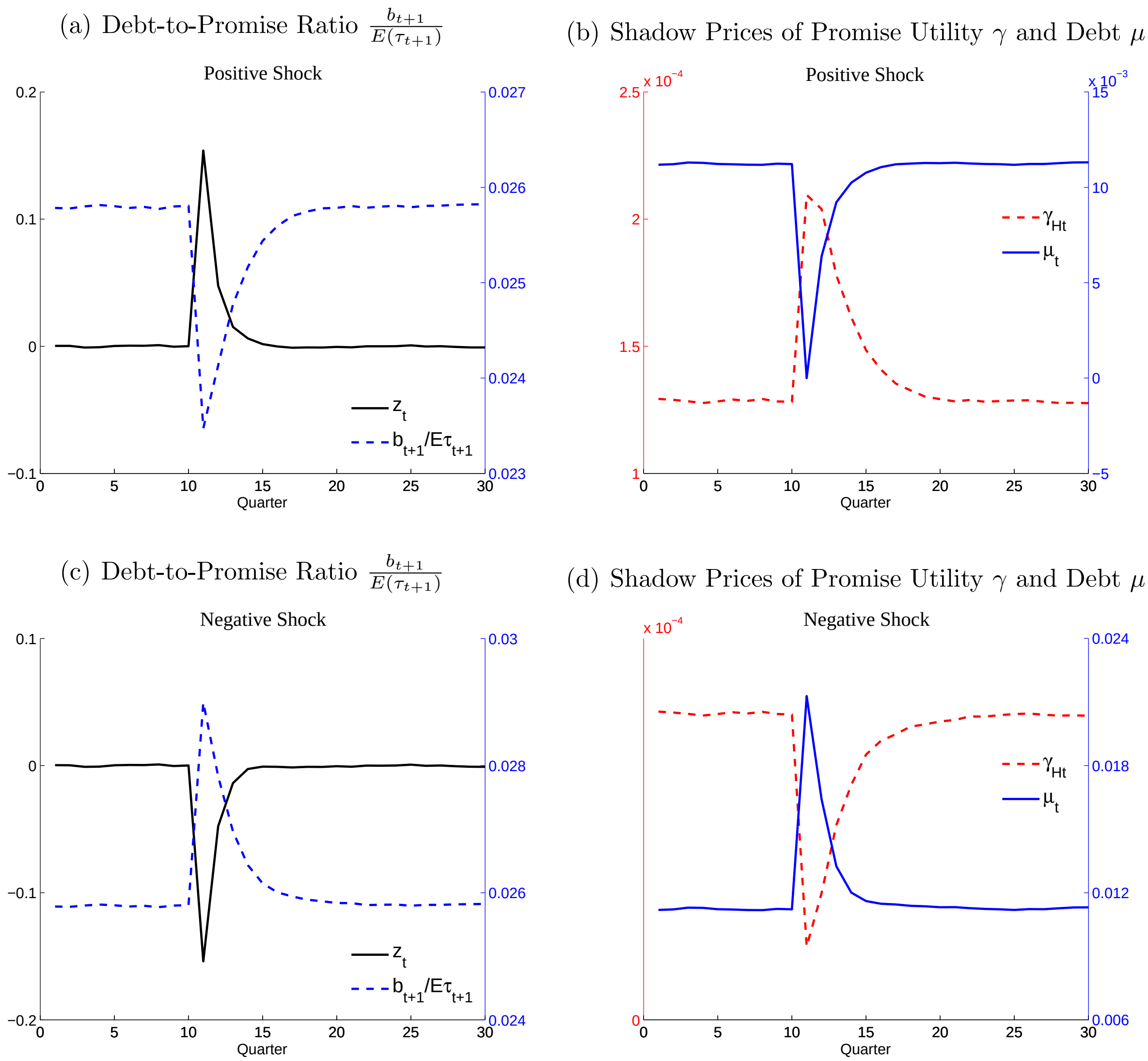
This figure shows the time series of average firm-level stock-based compensation (SBC), debt issuance, equity issuance, and intangible investment (R&D expenses). All the time series are seasonal adjusted. All variables are scaled by total book assets, and they are quarterly observations from Compustat Fundamental 2006q1-2015q1.

Figure 3: **Firm-Level Time Series (Cross-Industries)**



This figure shows the time series of average firm-level stock-based compensation (SBC), debt issuance, equity issuance, and intangible capital investment (R&D expenses), separately for the high-tech and traditional industries. All the time series are seasonal adjusted. All variables are quarterly observations from Compustat Fundamental 2006q1–2015q1.

Figure 4: **Impulse Responses**



(a) Debt-to-Promise Ratio $\frac{b_{t+1}}{E(\tau_{t+1})}$

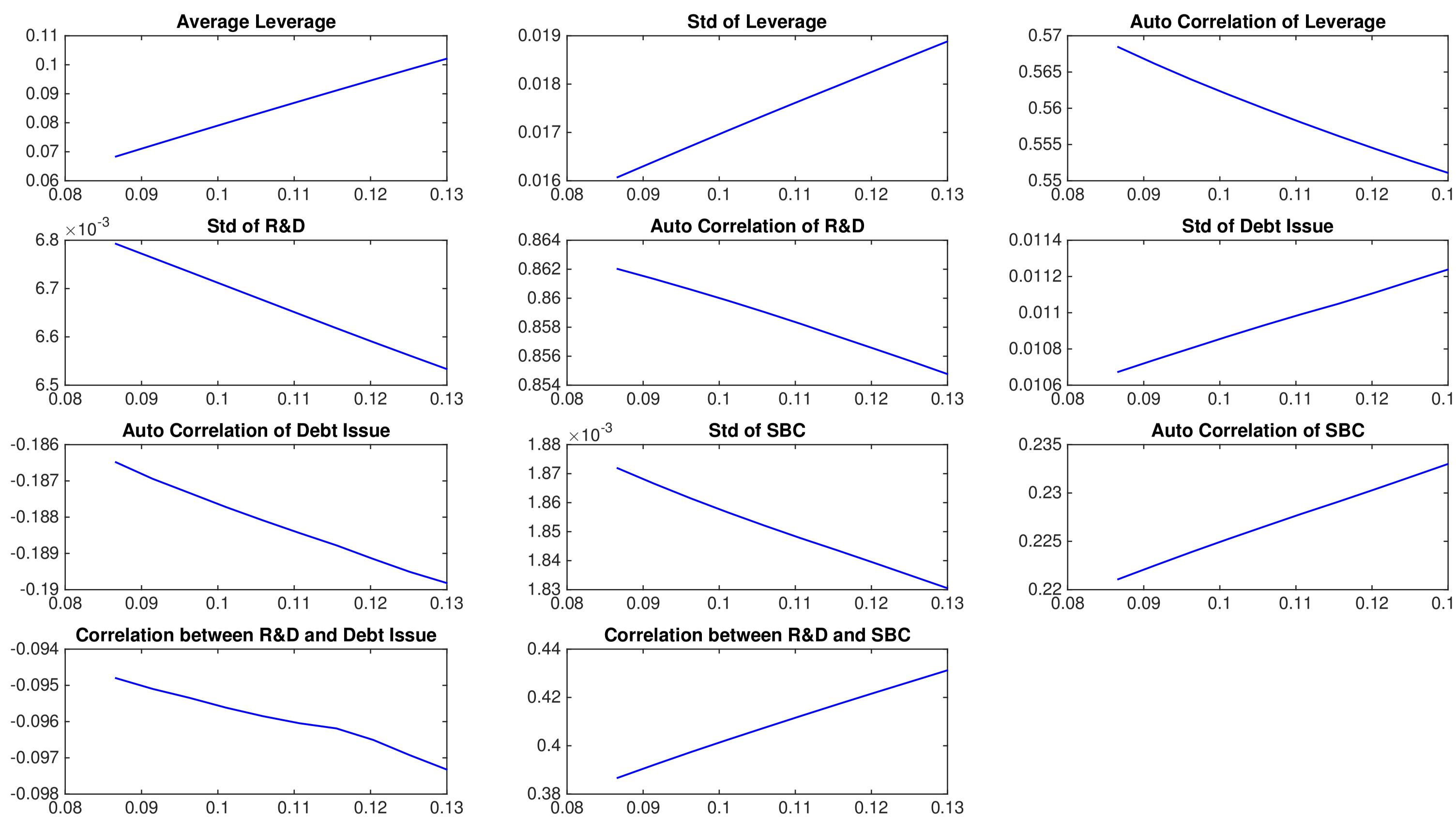
(b) Shadow Prices of Promise Utility γ and Debt μ

(c) Debt-to-Promise Ratio $\frac{b_{t+1}}{E(\tau_{t+1})}$

(d) Shadow Prices of Promise Utility γ and Debt μ

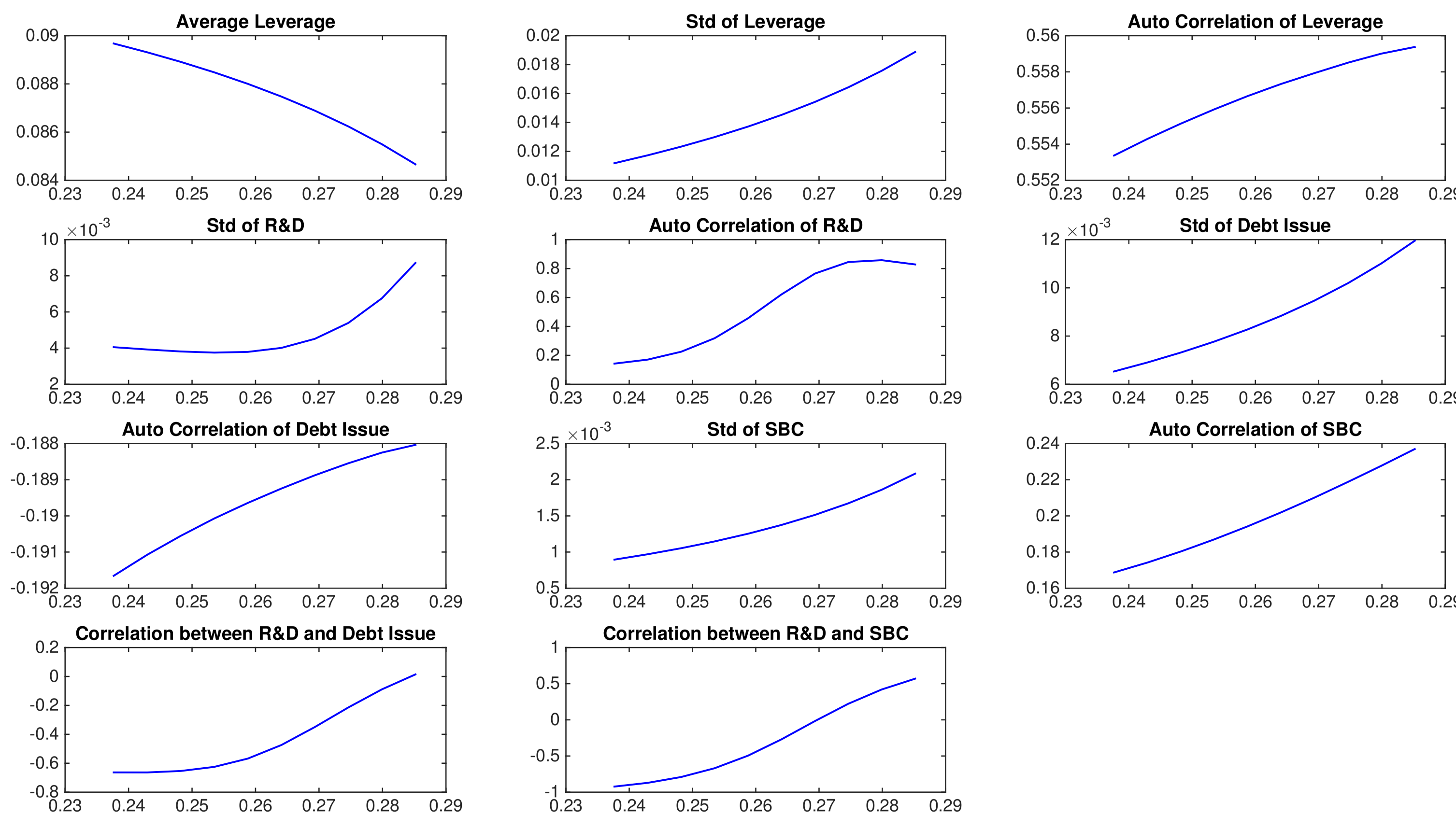
This figure shows the non-linear impulse response functions calculated under the set of parameter values from the benchmark estimation (Table 4). The x-axis represents the quarter, while the y-axis are the moments. Since the model is non-linear, we depict the actual transition path instead of showing the percent deviations around the steady state. To derive the transition paths, we simulate 50,000 firms with each firm having 30 periods. For the first 10 periods, we simulate the firm using the estimated parameters. At period 11, we add an additional one-shot positive or negative productivity shock. From period 11 onward, we simulate each firm's transition paths and calculate the average of transition paths across the 50,000 simulated firms. Panels (a) and (b) report the impulse responses of a positive shock, while Panels (c) and (d) report the impulse responses of a negative shock.

Figure 5: **The Debt Enforcement Parameter ξ.**



This figure shows the sensitivity of each moment to the change of the debt enforcement parameter ξ. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 6: **The Portability of Intangible Capital η.**



This figure shows the sensitivity of each moment to the change of the portability of intangible capital η. The x-axis is the parameter, and the y-axis represents the simulated moments.

A Data

A.1 Data Construction

All the quarterly variables are from the CRSP/Compustat Merged Database–Fundamentals Quarterly from 2006q1 to 2015q1. Income statement and cash flow statement items ending in "y" in the database are reported on a year-to-date basis. We thus generate quarterly data by subtracting lagged variables. All quarterly fundamental variables in Compustat are scaled by quarterly total assets (ATQ). We exclude utilities and financial firms with SIC codes in the intervals 4900-4999 and 6000-6999, as well as firms with SIC codes greater than 9000. We also exclude firms with missing values of assets, debt, R&D expenses, debt issuance, and stock-based compensation (SBC) during the sample period. We also drop firms with negative values of assets, sales, capital expenditure, and SBC. To limit the impact of outliers (e.g., mergers and acquisitions), we also winsorize all level variables at the 5% and 95% percentiles. All variables are deflated by CPI. When calculating empirical moments that require repeated observations for each individual firm (such as standard deviations and auto-correlations), we drop firms with fewer than eight quarters of data.

A.2 Industry Classification

We classify firms into five industries: consumer goods, manufacturing, health products, high tech, and others. The classification of consumer goods, manufacturing, and health products industries are taken from Fama-French 5-industry classification. The high-tech industries category is defined following the definition of the information, computer, and technology industry classification from the BEA Industry Economic Accounts, which consists of computer and electronic products, publishing industries (including software), information and data processing services, as well as computer systems design and related services. We classified all the remaining firms (including the finance industry) into other industries. We combine the consumer goods and manufacturing categories to form the traditional industries group. To categorize the new economy industries, or highly intangible-intensive industries, we use our definition of high-tech (ICT) industries.

B Proofs

B.1 Implementation of Wage Contracts

Using a similar proof of Himmelberg and Quadrini (2002), we show that the evolvement of the employee's net worth τ_{t+1} can be implemented by two financial instruments, *uncontingent cash* and *employee equity*, if the productivity shock z_t has only two realizations (i.e., high versus low states).[26] Let a_t denote cash (fixed income securities) and s_t denote shares of the firm that were awarded to the employees. Notice that the implementation decisions $\{a_t, s_t\}$ are made at period t. For simplicity, we compress the period-t state variables.

We show that τ_{t+1} can be replicated in the following equations:

$$\tau_{t+1}(z_{H,t+1}) = a_t + s_t P_{t+1}(z_{H,t+1}), \tag{6}$$

$$\tau_{t+1}(z_{L,t+1}) = a_t + s_t P_{t+1}(z_{L,t+1}), \tag{7}$$

where $P_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s (d_{t+1+s} + c_{t+1+s})$ is the total equity value of the firm. The cash payment to employees a_t is the debt-like component, which we consider as pension or other fixed payments promised to employees. The second component s_t represents the shares owned by employees at time t. The data limitation does not allow us to tease out the pension contribution from the total compensation. Also, the financing channel we want to identify is effective through the equity-like *contingent* component. Thus, we use employee stock-based compensation to measure equity-like component in the empirical counterpart.

[26] In the discrete case in which z_t has three states, Himmelberg and Quadrini (2002) show the general results of implementing the recursive contract with cash, equities, and options. In continuous-time models with limited commitment, Bolton et al. (2015) show that the optimal contract can be implemented using a line of credit and a state-contingent claim.

B.2 Propositions

Write down the Lagrangian associated with the optimization problem $\mathcal{P}$. Denote q as the multiplier on the law of motion on the capital accumulation equation (1), θ as the multiplier on the promise-keeping constraint (2), $\pi(z'|z)\gamma(z',h')$ as multipliers on the (two) participation constraints (3), μ as the multiplier on the debt enforcement constraint (4), and λ as the multiplier on the budget constraint (5).

Solve to obtain the problem's first-order conditions:

$$b' \;:\; \mu = \beta R(1+\mu\xi)E[V_b'|z] + \lambda \tag{8}$$

$$m'(z') \;:\; \gamma(z') = -(1+\mu\xi)V'_{m'(z')} - \theta \tag{9}$$

$$h' \;:\; q = \beta(1+\mu\xi)E[V_h'|z] + \lambda z - \beta\sum_{z'}\pi(z'|z)\gamma(z')\omega_{h'}(z',h') \tag{10}$$

$$d \;:\; \lambda = \frac{1}{\varphi'(d)} \tag{11}$$

$$e \;:\; q = \frac{\lambda}{\phi'(\frac{e}{h})} \tag{12}$$

$$c \;:\; \theta = \frac{\lambda}{u'(c)} \tag{13}$$

and the Envelope conditions:

$$b \;:\; V_b = -\lambda \tag{14}$$

$$m \;:\; V_m = -\theta \tag{15}$$

$$h \;:\; V_h = \lambda z + q[(1-\delta) + \phi(\frac{e}{h}) - \phi'(\frac{e}{h})\frac{e}{h}] \tag{16}$$

Equations (8)-(16) completely capture the system.

B.2.1 Proof of Proposition 1

Notice that the first-order condition of consumption gives the static rule for allocation between dividends and wages:

$$\frac{\lambda}{u'(c)} = \theta, \tag{17}$$

where θ is the shadow price of the expected deferred employee claim. The marginal rate of substitution between dividend and consumption as the ratio of the marginal value of dividend and the employee's marginal utility MRS $= \frac{\lambda}{u'(c)}$ equals the shadow price of the expected deferred employee claim. Each period, the decision of wage payment and payout policy is pinned down by equalizing the marginal value of deferring employee compensation and the relative value of paying out to shareholders today. Intertemporally, this risk-sharing rule is specified as the following Euler equation:

$$\frac{\lambda_t}{u'(c_t)} + \gamma_t(z_t) = (1 + \mu_t \xi)\frac{\lambda_{t+1}}{u'(c_{t+1})}. \tag{18}$$

Conditional on $\gamma_t(\cdot)$ and μ_t, only the lagged MRS contains relevant information in forecasting next period's MRS (Rogerson (1985)). Together with (17), we obtain:

$$\gamma(z') = -\theta + (1 + \mu\xi)\theta' \tag{19}$$

- When $\gamma(z') = 0$, $\theta' = \frac{\theta}{1+\mu\xi}$. Thus, θ' decreases since $\mu \geq 0$.

- When $\gamma(z') > 0$, $\theta' = \frac{\gamma+\theta}{1+\mu\xi}$. Thus, θ' increases whenever $\gamma(z') > \mu\xi\theta$.

Combine equations (9), (13) and (15) to obtain

$$(1 + \mu\xi)\frac{\lambda'(z')}{u'(c'(z'))} = \gamma(z') + \frac{\lambda}{u'(c)} \tag{20}$$

The marginal rate of substitution can be predicted by the last period marginal rate of substitution conditional on μ and $\gamma(z')$:

1. If $\mu > 0, \gamma(z') = 0$, $(1 + \mu\xi)\frac{\lambda'(z')}{u'(c'(z'))} = \frac{\lambda}{u'(c)}$, hence $\frac{\lambda'(z')}{u'(c'(z'))} < \frac{\lambda}{u'(c)}$.

2. If $\mu = 0, \gamma(z') = 0$, $\frac{\lambda'(z')}{u'(c'(z'))} = \frac{\lambda}{u'(c)}$.

3. If $\mu > 0, \gamma(z') > 0$, $(1 + \mu\xi)\frac{\lambda'(z')}{u'(c'(z'))} = \frac{\lambda}{u'(c)} + \gamma(z') > \frac{\lambda}{u'(c)}$.

4. If $\mu = 0, \gamma(z') > 0$, $\frac{\lambda'(z')}{u'(c'(z'))} = \frac{\lambda}{u'(c)} + \gamma(z') > \frac{\lambda}{u'(c)}$.

B.2.2 Proof of Proposition 2

Recall the systems of optimality conditions (8)-(16). Rearrange terms to obtain Euler equations for m and b:

$$m \quad : \quad \gamma(z') - V_m = -(1+\mu\xi)V'_m \tag{21}$$

$$b \quad : \quad \mu + V_b = \beta R(1+\mu\xi)E[V'_b|z] \tag{22}$$

Combining two equations (21) and (22) and substituting out $1+\mu\xi$, we obtain

$$\frac{1}{\beta}\frac{V'_m}{V_m - \gamma(z')} = R\frac{E[V'_b|z]}{V_b+\mu} \tag{23}$$

The ratio $\frac{1}{\beta}\frac{V'_m}{V_m-\gamma(z')}$ is defined as the rate of return on borrowing from the workers, and the ratio $R\frac{E[V'_b|z]}{V_b+\mu}$ is defined as the rate of return on borrowing from the creditors. Since $V'_m < 0$ and $V'_b < 0$, the firm can equalize the marginal rate of return on m' and b' by raising one while reducing the other:

$$\frac{1}{\beta}\frac{V'_m}{V_m} \leq \frac{1}{\beta}\frac{V'_m}{V_m - \gamma(z')} = R\frac{E[V'_b|z]}{V_b+\mu} \leq R\frac{E[V'_b|z]}{V_b}$$

1. $\gamma(z') > 0$: The firm either increases m' or decreases the debt level b'.

2. $\mu > 0$: The firm either decreases the debt level b' or reduces m'.

C Numerical Procedure

We first normalized our optimization given the linearity of the model setup. We define the normalized contract problem as $\tilde{\mathcal{P}}$, by using the transfer $\tilde{m} = m - \frac{1}{1-\beta}\log(\eta h)$, $\tilde{\omega}(z) = \omega(h,z) - \frac{1}{1-\beta}\log(\eta h) = \frac{\log(z)}{1-\beta\rho_z}$, $g' = h'/h$, and $\tilde{x} = x/h$ for other variables.

Normalized Wage Contract The normalized problem $\tilde{\mathcal{P}}$ can be written as:

$$\tilde{V}(\tilde{m}, \tilde{b}; z) = \max_{\tilde{e}, \tilde{c}, \tilde{m}', \tilde{b}'} \left\{ \tilde{d} + \beta g' \mathbb{E}_z \left[\tilde{V}'(\tilde{m}', \tilde{b}'; z') \right] \right\}$$

subject to:

$$\varphi(\tilde{d}) = z - \tilde{c} - \tilde{e} + g' \frac{\tilde{b}'}{R} - \tilde{b} \tag{24}$$

$$g' = (1 - \delta) + \phi(\tilde{e}) \tag{25}$$

$$\xi \beta \mathbb{E}_z[\tilde{V}'] \geq \frac{\tilde{b}'}{R} \tag{26}$$

$$\tilde{m} = \log(\tilde{c}) + \beta \mathbb{E}_z[\tilde{m}'(z')] + \frac{\beta}{1 - \beta} \log(g') - \log(\eta) \tag{27}$$

$$\beta \tilde{m}'(z') \geq \beta \frac{\log(z')}{1 - \beta \rho_z} \tag{28}$$

We solve the (normalized) contract numerically using the projection method. After describing the first-order conditions and the envelope conditions, the firm's problem can be summarized by a system of nonlinear equations associated with two expectation terms. Thus, by solving the system of nonlinear equations, we obtain the solution of the firm's problem.

The numerical procedure requires three steps. First, we parameterize the two expectation terms. Second, given the parameterized expectations, we solve the system of nonlinear equations on each grid. We discretize the productivity shock on 2 grid points and each state variable on 10 grid points. We linearly interpolate between grids when calculating the expectations. Given the specification of shocks with two states, one non-state-contingent enforcement constraint and one state-contingent participation constraint, we need to examine a total of 2^3 cases of occasionally binding constraints. Third, we iterate on the approximated expectations until convergence.

D Simulated method of moments

We follow Lee and Ingram (1991) and Nikolov and Whited (2014) in estimating the model. One issue to implement the simulated method of moments is that the empirical data consists of a panel of heterogenous firms while the artificial data are generated by simulating one firm over a number of periods. To keep consistency between the empirical and simulated data, we demean each variable in the data before calculating the empirical moments. When calculating the autocorrelations, we use the first-difference estimator as suggested by Han and Phillips (2010). We calculate the weighting matrix using the influence function approach as in Nikolov and Whited (2014). Also, as in Nikolov and Whited (2014), we calculate the standard errors using the clustered moment covariance matrix.

The estimation procedure consists of the following steps.

1. For each firm i in the data, we calculate the mean of each variable, and then demean the variable. That is, $\tilde{x}_{it} = x_{it} - \bar{x}_{it}$, where $\bar{x}_{it}$ is the within-firm average of x_{it}. The subscripts i and t identify, respectively, firm and year. There is one except that we do not demean the data before computing the empirical moment, that is, when we take the mean itself as one of our target moments. Also, for the autocorrelations, we use the first-difference estimator as in Han and Phillips (2010).

2. We pool the time series of all firms together to form a new time series $\{\tilde{x}_k\}$, where $k = 1, 2, ..., K$, and $K = I * T$ is the total number of firm-year observations.

3. We calculate the empirical moments using the new series $\tilde{x}_k$, denoted by an M x 1 vector $f(x_k)$, where M is the number of target moments.

4. We then use the model to generate a time series of S periods, denoted by $\{y_s\}$. We set $S = 10K$ as suggested by Lee and Ingram (1991). At this point, we also calculate the model moments, denoted by vector $f(y_s, \theta)$, where θ is an N x 1 vector of estimated parameters.

5. The estimator $\widehat{\theta}$ is the solution to

$$\min_{\theta}\Big[g(x) - g(y, \theta)\Big]' W \Big[g(x) - g(y, \theta)\Big].$$

where $g(x) = \frac{1}{K}\sum_{k=1}^{K} f(x_k)$ and $g(y, \theta) = \frac{1}{S}\sum_{s=1}^{S} f(y_s, \theta)$ are the sample mean of the data and the model, respectively, and W is a weighting matrix given by $W = [\Sigma(1 + K/S)]^{-1}$, where Σ is the $M \times M$ variance-covariance matrix calculated by covarying the influence function as in Nikolov and Whited (2014).

6. Under mild regularity conditions, the limiting distribution of $\hat{\theta}$ is given by

$$\sqrt{K}(\hat{\theta} - \theta) \to N(0, V)$$

where $V = (D\widehat{W}D')^{-1}$ and D' is the $M \times N$ gradient matrix defined as $D' = \frac{\partial g(y,\theta)}{\partial \theta'} \approx \frac{g(y,\theta+\Delta\theta)-g(y,\theta-\Delta\theta)}{2\Delta\theta}$. Here, $\widehat{W}$ is the weighting matrix by taking the inverse of the clustered moment covariance matrix $\widehat{\Sigma}$.[27] The t-statistics of the ith estimator is given by

$$t_i = \frac{\hat{\theta}_i}{\sqrt{\frac{V_{ii}}{K}}},$$

and the t-statistics of the jth moment difference is given by

$$t_j = \frac{g_j(x) - g_j(y, \theta)}{\sqrt{\frac{\widehat{\Sigma}_{jj}}{K}(1 + K/S)}}.$$

[27] See Nikolov and Whited (2014) for more details about the calculation of the clustered moment covariance matrix.