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 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 can explain 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 has remained the most important question in corporate finance. However, the fundamental shift in production function from physical-intensive to intangible-intensive[1] over recent decades raises a challenge in the literature: How precisely are those new type of firms being financed? Intangible capital is difficult to finance in the free market place 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, and this effectively 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 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 labor force, which is also costly to retain.

as an internal financing channel. Consistent with their mechanism, in cases where firms are financially constrained, the optimal 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 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 existing studies (Rampini and Viswanathan (2013), Falato et al. (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 *overhang* effect on firms' 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), Berk et al. (2010)), this overhang effect reduces the firm's debt borrowing capacity and 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 U.S. publicly traded firms. Using employee stock-based compensation as the measure of employee financing, 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 equities, 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 overhang effect: Firms with more employee financing are engaged in less debt financing.

We then conduct structural estimations to quantify the impacts of the employee financing channel on firms' financial decisions. The estimations are done in two split samples: the high-tech industries, and traditional industries. These two industries are characterized by highly distinct intangibility and financing patterns. We show the model's ability to explain the new facts we had documented, and we also identify the cross-industry differences in the intangible capital portability.

In two counterfactual analyses, we illustrate the importance of the employee financing channel in terms of understanding the empirical evidence. First, we provide a comparison of our model with the dynamic investment models with financial frictions (e.g., Gomes (2001), Hennessy and Whited (2005), Jermann and Quadrini (2012)). In the counterfactual exercise in which we shut down the employee financing channel, we find a positive correlation between intangible investment and debt issuance, which contradicts 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 industries to that in the high-tech industries, and examine the change in firms' financial decisions. On the side of financing capacity, the increase in the portability of intangible capital raises the employee financing by 17% through promised future claims, while it reduces the firm's debt capacity by 4% through the overhang effect. On the side of risk management, the

increase in the intangible portability tightens the employees' participation constraint, but induces firms to keep more distance from the debt limit.

Related Literature 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), and Hennessy and Whited (2005)). To the best of our knowledge, we are the first to provide a theoretical underpinning of financing intangible capital through non-financial contracts. Our theoretical implications are not conditional on financial constraints.

Our theory is aligned with the literature on dynamic contracting with limited commitment. Closely related to Michelacci and Quadrini (2009), our paper highlights 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)), macroeconomic dynamics (Cooley et al. (2004)), 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.

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 the 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 volatile 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)).

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 Babenko et al. (2011) use the exercise of stock options as an exogenous cash flow event to test investment-cash flow sensitivity, our paper focuses on the endogenous relationship between intangible investment and stock-based compensation at the time when equities/options are granted to employees. 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 our best knowledge, this has not been studied in the previous literature.

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

2.1 Data

We use quarterly firm–level data from the CRSP/Compustat Merged Database from 2006q1 to 2014q1. We exclude utilities and financial firms with SIC codes in the intervals 4900–4949 and 6000–6999, and we also exclude firms with SIC codes greater than 9000. Given the focus of our analysis, we distinguish between equity issuance involved with employee stock-based compensation (SBC) and standard secondary equity offerings (SEOs). Firms typically offer stocks or options as part of compensation packages to their key employees. Since 2006, public firms are required to expense stocks/options issued to employees, and these are recorded as *Stock-based Compensation Expense* (STKCOQ) in Compustat. We use this as our main measure of the flow of employee claims.[3]

The investment of intangible capital is the primary driver of knowledge creation in high-wage economies such as the US. Ideally, the measure of intangible capital should include 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 the sample of publicly traded firms has remained challenging because firms do not report itemized expenses along with the general operating expenses. For our purpose, we measure firm-level intangible investment using R&D expenses. R&D expenses are widely available accounting data which record the cost of human capital investment in the R&D department, as well as the related costs of innovation activities involved in the research and development process. R&D expenses constitute a major part of *Selling, General and Administrative* expenses (XSGA) which are used by Lev and Radhakrishnan (2005), Eisfeldt and Papanikolaou (2014), Falato et al. (2013), and Peters and Taylor (2015) as the measure of

[3]Although not reported in the paper, to check the robustness, we also use employee-initiated equity issuance to measure employee financing. For the definition of employee-initiated equity issuance, see McKeon (2013).

investment of organizational capital.[4] Appendix B.1 contains the details of the construction of our data.

The summary statistics of our sample are reported in Table 6. When computing firm–level moments, all variables are normalized by total assets (ATQ). The average leverage ratio in our sample is around 0.14, which is lower than the average ratio of the sample that begins in 1980. 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 literature (Corrado et al. (2004), Falato et al. (2013), van Ark et al. (2014)).

2.2 Cross-Firm Characteristics

Cross-sectionally, firms that use different amounts of stock-based compensation exhibit distinguishing characteristics. 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 five quintiles. In Panel (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. Figure 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 Figure 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. Finally, we examine the industry composition within each SBC group. We group firms into five industries based on our modified Fama-French 5 industry classification.[5] Figure 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

[4]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 XSGA as the measure of intangible investment.

[5]See Appendix B.3 for industry classification definition.

Figure 1: **Firm characteristics of SBC groups.**

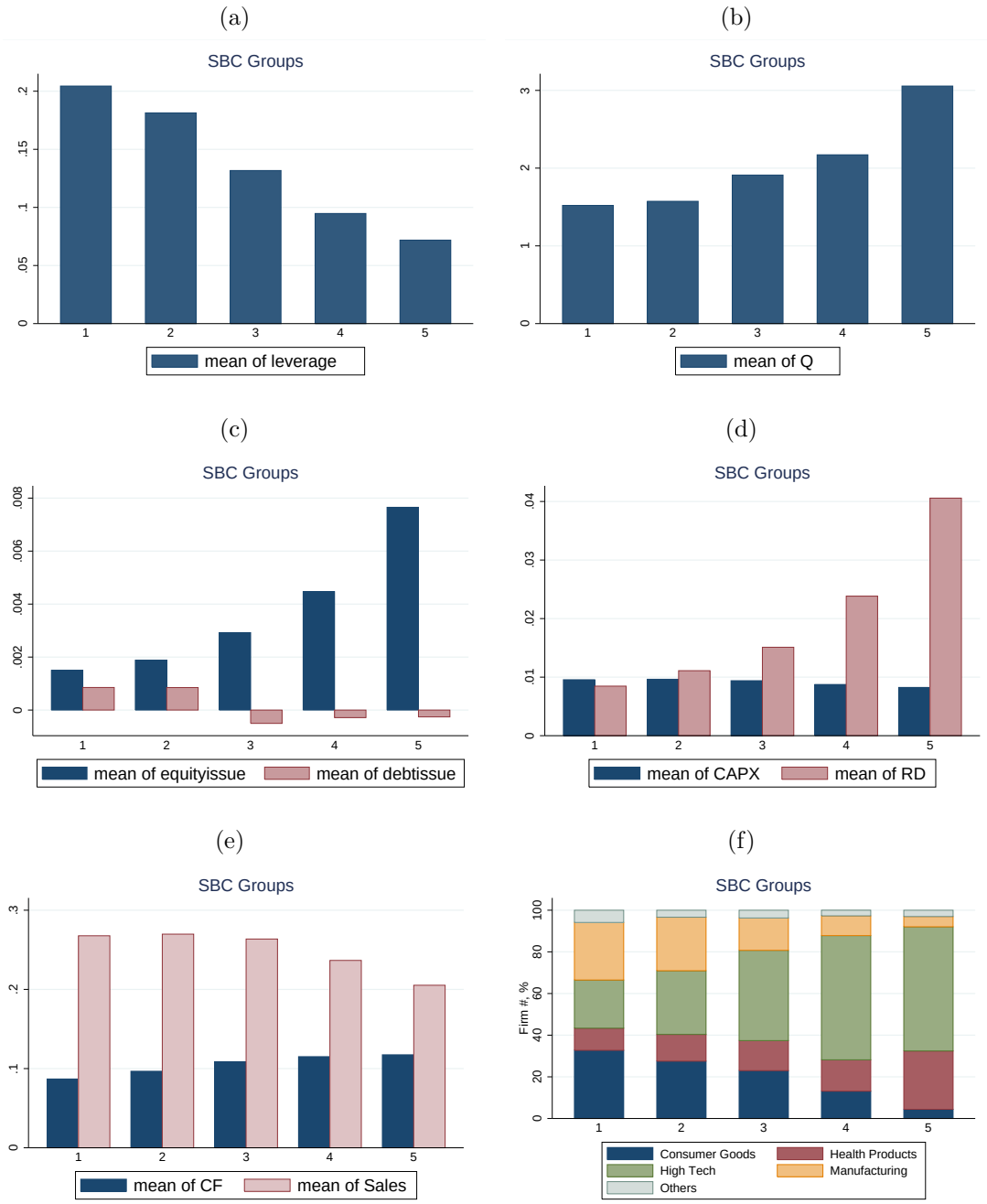


Figure (a) to (e) show the average leverage, Tobin's Q, equity issuance ($\frac{\text{SSTKQ}}{\text{ATQ}}$), debt issuance ($\frac{\text{DLTISQ-DLTRQ+DLCCHQ}}{\text{ATQ}}$), investments, sales, and cash flows within each SBC-to-assets quintile. Figure (f) shows the percentage of firms in different industries 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 2006q1–2014q1. A detailed description of the variables can be found in Appendix B.1.

groups fall into intangible-intensive industries.

2.3 Time Series

In time series, the average firm-level intangible investment (R&D expenses) is highly correlated with stock-based employee compensation (defined as SBC). In Figure 4(c), we show that in the full sample, on average, R&D investment comoves with SBC with a correlation coefficient of 0.59. The correlation between R&D investment and regular financing activity of the firm, including both equity issuance (0.27) and debt issuance (0.03), is much lower (see Figure 4 (a)(e)). Notice that, as documented in the literature, debt issuance and equity issuance are both correlated with physical investment (see Figure 4 (b)(f)).

We then 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. Figure 5 plots the time series of R&D investment and financing activities of firms in high-tech and traditional industries. For a more intangible capital-intensive industry such as high-tech industries, the correlation between R&D investment and SBC is 0.51, while this correlation falls to 0.30 for traditional industries. We also find that the correlations between R&D investment and external finance (debt issuance and regular equity issuance) are significantly negative in high-tech industries.

2.4 Panel Regressions

Last but not least, we confirm the positive correlation between SBC and R&D investment in the panel regressions after controlling for other possible sources of funds. Table 7 reports the regression results of the entire sample. A one standard deviation change in SBC contributes to 18.5% of the change in R&D investment, while the change in debt issuance and the change in regular equity issuance shows negative correlations with R&D investment.

We also examine the firm-level regression results separately for traditional industries and high-tech industries (see Table 8). The change in SBC explains more than 20% of the change

in R&D investment in the high-tech industries, while this impact is less than half among the traditional industries. In terms of the explanatory power of SBC for physical investments (as shown in Table 8, Columns (3) and (4)), we do not find a significant difference between these two industries.

To sum up, our empirical findings are (i) intangible investment is strongly positive correlated with stock-based employee compensation, but not (or weakly negative) correlated with debt issuance and regular equity issuance; (ii) stock-based employee compensation has a stronger relation with intangible investment than that with tangible investment; and (iii) the above two relations are more robust in high-tech industries.

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.

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.[6] The capital accumulation enhances the firm-level human capital and increases the labor productivity.[7]

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 portability is first adopted in Lustig et al. (2011).[8] 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 will 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 refers to 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, 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.

[6] One way to interpret the accumulation of h can be that firms increase h by hiring high skilled labor force.

[7] Firm-level human capital is accumulated while the employee participates in production. Firms invest in workers 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 expenditure is part of selling, general, and administrative expenses as well as research and development expenses.

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

Labor Market Each employee is matched with one firm for production. Employees are risk-averse with preference $u(\cdot)$, where $u'(\cdot) > 0, u''(\cdot) < 0$, and they have no access to the saving technology. The wage contract is the only technology for consumption smoothing. Assume that employees have *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 employees, 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 life-time 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 when 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: $\{c_t,\ \mathbf{m}_{t+1}(z_{t+1}, h_{t+1})\}$.[9] 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 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 determine 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

[9] Appendix A.1 proves the equivalence of the recursive contract and the original contract in detail.

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}. [10]

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.

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

[10] 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 maters for the employee's outside option is the portability η.

"effective" interest rate is $R_t = 1 + (1 - \tau_c)(\tilde{R}_t - 1)$.[11] 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 capital market condition. 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 the following reasons: (i) Intangibles are not effective collateral assets because of the low redeployability, the information asymmetry, and the low liquidation value. (ii) In practice, the output of intangible capital, such as patents, can be used as collateral in debt contracts (e.g., Loumioti (2012)). However, 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), and $\bar{d}$ is set as the steady-state equity 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:

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

[11] 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)).

How does the firm finance investment? In addition to standard financing tools (i.e., debt and public equity issuance), deferring wage compensations to the future serves as another financing channel. 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 compensations $\mathbf{m}_{t+1}$ in the future. In Section 4.1, we will 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 splitting from the match. 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 $\{h, \mathbf{m}, z\} \in \mathcal{H} \times \mathcal{M} \times \mathcal{Z}$:

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

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 enforcement constraint (4) and the tightness of the participation constraints (3). Note that constraints (4) and (3) are not always binding, so we define the slack in constraint (4) $\beta\xi\mathbb{E}(V') - \frac{b'}{R}$ as a *financial buffer*, and the slack in constraint (3) $\beta_w m'(z', h') - \beta_w w(z', h')$ as a *labor-induced operating buffer*.

As the firm accumulates h, it must also increase the promised utility to retain the em-

ployee, 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 debt enforcement constraint (4).

4 Properties of Optimal Policies

In this section, we define employee financing and then describe the solution properties and dynamic interactions between the financial contract and the labor contract by deriving the first-order equations and Euler equations (see Appendix A.2 for the derivation).

4.1 Financing through Wage Contracts and Implementation

The optimal 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. In our model, this is particularly important when firms have constrained access to the capital market.

Under the assumptions of employees' limited commitment and risk aversion, the exact financing mechanism works as follows: First, when the firm delays wage payments to the future to facilitate the retention of employees, 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 need to increase with investment. So the employee's deferred claim is positively correlated with investment. Second, the insurance provided by the optimal wage contract also facilitates financing. To obtain consumption smoothing, risk-averse employees pay an insurance premium, which also implicitly relaxes the budget constraint.

To link the promised utility $\mathbf{m}_t$ to the empirical measurement of employee compensation contracts, we first express the employee's promised utility into its equivalent wealth. Denote the present monetary value of the lifetime consumption stream from the wage contract as:

$$\tau_t(h_t, \mathbf{m}_t, b_t; z_t) = c_t + \beta_w \mathbb{E}_t[\tau_{t+1}(h_{t+1}, \mathbf{m}_{t+1}, b_{t+1}; z_{t+1}|z_t)], \tag{6}$$

where τ_t is the employees' claim on their future income. Given τ_t is the *stock* of total surplus allocated to the employee, we define the employee financing through the wage contract as $\Delta\tau_t = \mathbb{E}_t[\tau_{t+1}] - \tau_t$, which is the *change (flow)* of employee claims.

Implementation 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).[12] 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:

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

$$\tau_{t+1}(z_{L,t+1}) = a_t + s_t P_{t+1}(z_{L,t+1}), \tag{8}$$

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

[12] 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.

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.

Dynamics of Employee Financing To gain some insights into the properties of the optimal financial and wage contracts, it is helpful to exploit 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). The solution of the optimization problem can be completely captured by the system of equations in Appendix A.2.

Define 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 $= \frac{\lambda}{u'(c)}$. The ratio captures the marginal value of external equity financing λ ($\lambda = \frac{1}{\phi'(d)}$) in terms of the marginal utility $u'(c)$. Notice that the first-order condition of consumption gives the static rule for allocation between dividends and wages:

$$\frac{\lambda}{u'(c)} = \theta, \tag{9}$$

where θ is 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:

$$\frac{\lambda_t}{u'(c_t)} + \gamma_t(z_t) = (1 + \mu_t \xi)\frac{\lambda_{t+1}}{u'(c_{t+1})}. \tag{10}$$

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 (9), we obtain the implications on employee financing which are summarized in the following proposition.

Proposition 1 (Dynamics of Employee Financing) *Given the firm's optimization problem $\mathcal{P}$, whenever the employees' participation constraint* (3) *is not binding, the shadow price of expected deferred employee claim θ' decreases over time if $\mu > 0$; θ' remains unchanged if $\mu = 0$; θ' increases when the participation constraint is sufficiently tight ($\gamma(z', h') > \mu\xi\theta$).*

Proof: See Appendix A.2.

Table 1: The shadow price of employee financing θ'

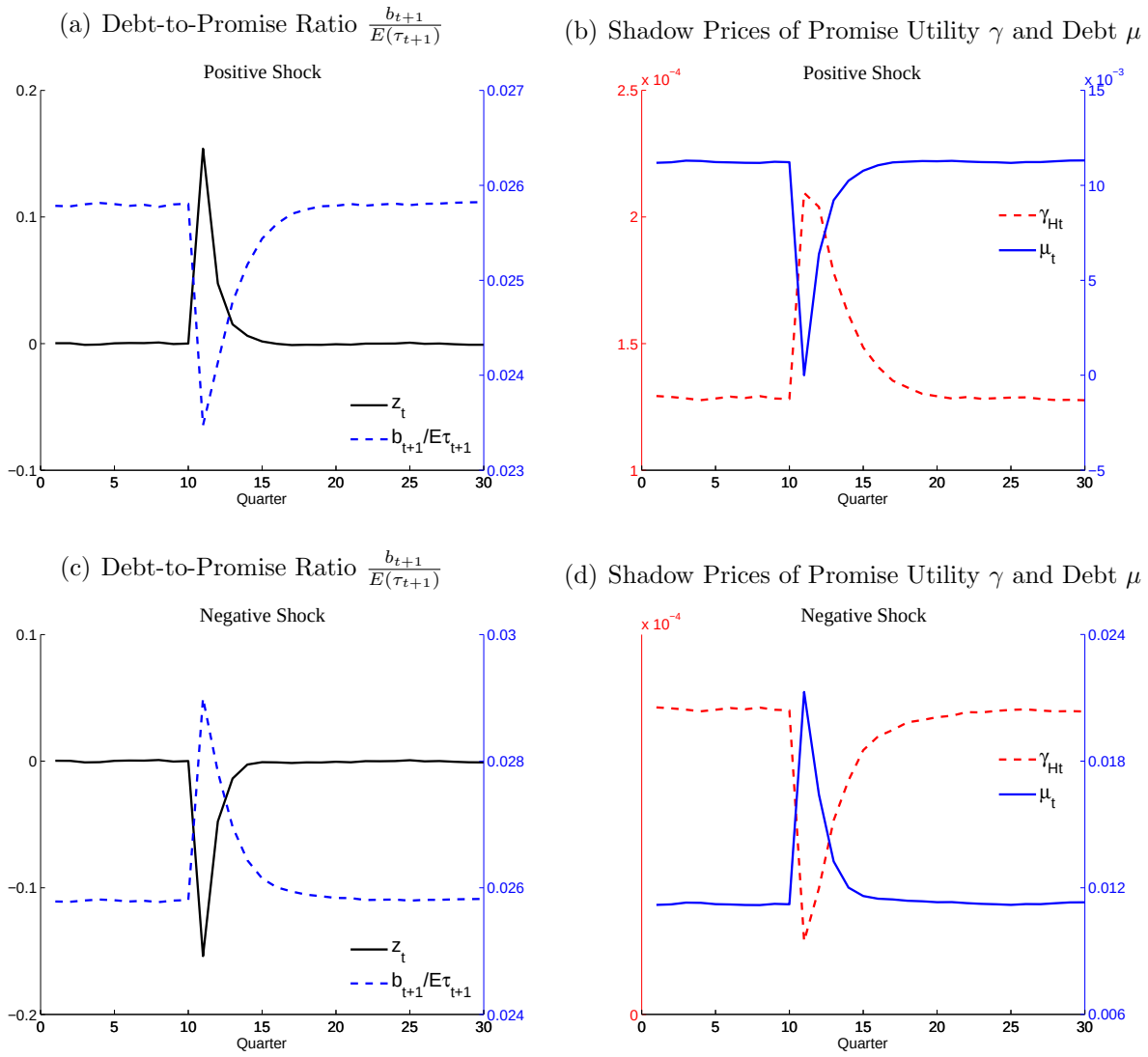
	$\mu > 0$	$\mu = 0$
$\gamma(z', h') > 0$	undetermined	$\theta' \uparrow$
$\gamma(z', h') = 0$	$\theta' \downarrow$	$\theta' \rightarrow$

The intuition of the proposition is straightforward: Based on Proposition 1, the dynamics of θ' is key to understanding the optimal timing of wage payments. The increase in the shadow price of the next period's expected deferred employee claim θ' indicates that it is optimal to defer wage payments to the future period, and vice versa. Proposition 1 shows the conditions of θ' dynamics, and Table 1 summarizes the *four* different scenarios.

Figure 2 demonstrates the impulse response of financing activities to the productivity shock z_t. Given a positive productivity shock, the firm increases investment and accumulates intangible capital. In the meanwhile, employees face better outside options. The contingent wage contract offers higher deferred compensation in order to satisfy the participation constraints. An increase in deferred employee claims shrinks the debt capacity in the future periods, so the firm can either save debt buffers by reducing the debt financing ($\mu = 0$), or the firm can reduce the current wage payment c when the economic state precludes the firm 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

2, Panels (a) and (b) reflect the case in the upper right corner of Table 1. The relative debt-to-promise ratio, defined as $\frac{b_{t+1}}{E_t(\tau_{t+1})}$, responds negatively.

Figure 2: **Impulse responses.**



This figure plots the non-linear impulse response functions calculated under the set of parameter values from the benchmark estimation (Table 3). The x-axis represents the quarter, and 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. Subfigures (a) and (b) report the impulse responses of a positive shock, while Subfigures (c) and (d) report the impulse responses of a negative shock.

When a negative productivity shock is realized, the investment motive is low. An em-

ployee's outside option is 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 when the firm saves enough buffers ($\mu = 0$) to provide full insurance to the employee. However, in a phase 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 2, Panels (c) and (d) show that as the shadow price of employee financing declines, the debt-to-promised ratio increases. 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. The dynamics implied by the model are consistent with our reduced-form empirical findings.

Debt Liability and Employee Financing Quantitatively, the optimal allocation of liability capacity, financial debt versus deferred employee claims, is determined by equalizing their intertemporal marginal rate of substitution.

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

Proof: See Appendix A.3.

Recall the multipliers on the debt enforcement constraint (4) and on the participation constraint (3) as μ and $\gamma(z', h')$, respectively. From the optimality conditions, we obtain the trade-offs between the debt contract and the wage contract:

$$R\frac{E[V_b'|z]}{V_b + \mu} = \frac{1}{\beta_w}\frac{V_{m'}'}{V_m - \gamma(z', h')} \ \forall z', h'. \tag{11}$$

The above equation illustrates the quantitative relationship between the firm's debt financing decision (b') and the employee financing decision (m'). The inter-temporal substitution rate of debt contracts and of wage contracts are held equal to pin down the liability structure of the firm. Intuitively, the marginal rate of return on the financial debt should equal the marginal

rate of return on the deferred employee claim. From (11), the trade-off is affected not only by the relative borrowing costs of the debt contract and that of the employee contract, but also by the curvature of the value function of the equity holder with respect to b and m.

Intangible Capital Overhang Effect The negative correlation between investment and debt financing is due to the interaction between participation constraint (3) and enforcement constraint (4). When the firm increases investment in h today, the deferred employee claim must increase in order 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. We name this endogenous determinant of debt capacity as the *intangible capital overhang effect*. This overhang effect is a key contrasting driving force behind the correlation between investment and debt capacity. This differs from the standard investment model with collateral constraints in which the debt capacity increases in investment opportunity. In our model, the intangible overhang channel crowds out debt capacity because investment opportunity co-moves with the employee's outside option.

The overhang effect in our model arises from the assumption that intangible capital is treated as the "collateral" used to borrow from employees. Intangibles are low in collateral rates when pledged to debt holders, but they can also 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. In the structural estimation, we estimate the implicit collateral rate η across industries to quantify the degree of the overhang effect.

Treating intangible capital as implicit collateral for employee financing also leads to an endogenous adjustment cost for investment.[13] The adjustment cost is on the intangible capital

[13]Given the properties of optimal policies, our endogenous adjustment cost of intangible investment is non-convex and lumpy.

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. To the best of our knowledge, we are also the first to connect employee financing dynamics to investment activity, both theoretically and empirically. We will use the structural estimation to obtain the unobserved shadow prices in order to make further quantitative statements in Section 5.

4.2 Equity Financing and Debt Financing

The dynamics of equity financing costs are correlated with that of debt financing. It is costly for the firm to borrow up to the debt limit, but debt contracts generate tax shields, add value to the firm, and help relax the budget constraint. The following proposition summarizes the dynamics of equity financing cost and debt financing cost:

Proposition 3 *Given the firm's optimization problem $\mathcal{P}$, the shadow price of equity payout λ' increases, on average, whenever the debt enforcement constraint* (4) *is not binding ($\mu = 0$); while λ' decreases when the debt enforcement constraint is tight enough: $\mu > \frac{(1-\beta R)\lambda}{(1+\xi\beta R\lambda)}$.*

Proposition 3 describes the standard result of the relationship between the enforcement constraint and the cost of equity issuance. The optimal choice of debt and equity financing is determined by the interactions between the cost of debt financing and cost of equity issuance. Negative productivity shocks reduce the net worth of the firm, hence debt capacity shrinks. The declining leverage ratio leads to more usage of equity contracts for financing ($\lambda \uparrow$). On the other hand, positive productivity shocks relax the debt enforcement constraint, and the firm issues debt contracts to finance investment and pay out more dividends ($\lambda \downarrow$). The tightness of the debt enforcement constraint drives the payout dynamics.

To sum up, 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 liability allocation. More employee financing is used when portability of intangible capital is higher and when the firm increases the investment. Also, 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, the marginal rate of substitution $\frac{\lambda_t}{u'(c_t)}$ may decrease over time even if the employee's participant constraint is binding. This occurs when the firm's financial tightness cost dominates the marginal benefit of employees' consumption smoothing (i.e., when $\mu\xi\theta > \gamma(z', h')$).

5 Structural Estimation

5.1 The Model Solution

We assume that employees are endowed with log utility $u(c) = \log(c)$ and the production function is linear $y = zh$. 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 is equal to 1. This adjustment cost function has been widely used in the investment and production-based asset pricing literature (Jermann (1998)).

We solve the model numerically by normalizing the wage contract with the level of intangible capital h, given the linearity of the model. Details of the computation can be found in Appendix C.

5.2 Parameters and Moments

Because we calculate empirical moments that require repeated observations for each individual firm (e.g., standard deviations and autocorrelations), we drop firms with fewer than eight

quarters of data. To limit the impact of outliers (e.g., mergers and acquisitions), we also winsorize all level variables at the 5% and 95% percentiles. Nominal variables are deflated by the Consumer Price Index. Table 2 provides the definition of variables used in the structural estimation.

Table 2: **Variable Definitions.**

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

In Compustat 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*.

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

Most of the model parameters are estimated with the exception of (1) the shareholders' discount factor β, (2) the effective interest rate R after considering corporate tax τ_c, (3) the employees' discount factor β_w, and (4) 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 can be calculated as $R = 1 + (1/\beta - 1) \cdot (1 - \tau_c) \approx 1.02$. The employees' 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, which is higher than the depreciation rate of tangible capital.

After calibrating the parameters described above, six parameters remain: (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 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; the correlation coefficient between R&D investment and debt issuance; and the correlation coefficient between R&D investment and stock-based compensation. Panel A of Table 3 lists the moments.

The values of the estimated parameters and their associated t-statistics are reported in the bottom section of Table 3. Although t-statistics provide some local identification of the parameters, it is also important to describe the global identification mechanisms. We do this by conducting a sensitivity analysis. The results of this analysis are reported in Figure 6 through Figure 11. Here, we discuss the identification of two key parameters: the debt enforcement parameter ξ and the capital portability parameter η. Although both parameters affect the level of leverage, the capital portability parameter η has a much stronger impact on the correlations between investment and financing variables (i.e., debt and employee financing). Thus, this difference would allow us to separately identify the debt enforcement

parameter ξ and the capital portability parameter η. We discuss the identification details of other model parameters in Appendix E.

In the benchmark estimation, we do not include the moments of the average R&D investment, the average of debt issuance, and the average of stock-based compensation. The main reason is that our model abstracts from the physical capital accumulation. When we use total assets to normalize the firm level variables, the physical capital is missing, and this biases the value of *level* moments. For robustness of the benchmark estimation, we report estimation results by including those three level moments. The empirical moments are computed using variables normalized by total sales, instead of the total book value of assets. The estimation results are reported in Table 9 of Appendix F.

5.3 Estimation Results

Table 3 reports the results of structural estimation. We use the estimation results of high-tech industries as the benchmark, since the theoretical model is better designed to capture the features of these industries.

As shown in Panel A of Table 3, the model fits the data reasonably well, especially in matching the mean of leverage, the standard deviation of R&D investment and SBC. Furthermore, the model does produce a high positive correlation between R&D investment and SBC. It also produces a negative correlation between R&D investment and debt issuance.

The model does not match the autocorrelation of debt issuance. In the data, the autocorrelation of debt issuance is close to zero. However, it is negative in the model. The reason for this lies in the exact mechanism of the model. After a positive shock, the firm raises funds through both debt financing and employee financing. Because employee financing is stickier than debt financing, the debt financing decreases as employee financing continues to increase in subsequent periods. This generates a pattern of debt financing that increases initially but quickly decreases in the later periods. Hence, this explains the negative autocorrelation of debt issuance.

Table 3: **Moments and parameters (high-tech).**

Panel A: Target Moments	*Observed*	*Simulated*
Average leverage	0.092	0.086
Standard deviation of leverage	0.067	0.017
Autocorrelation of leverage	0.854	0.557
Standard deviation of R&D investment	0.007	0.007
Autocorrelation of R&D investment	0.754	0.857
Standard deviation of debt issuance	0.012	0.010
Autocorrelation of debt issuance	0.005	-0.189
Standard deviation of stock-based compensation	0.002	0.002
Autocorrelation of stock-based compensation	0.623	0.219
Correlation between R&D investment and debt issuance	-0.019	-0.093
Correlation between R&D investment and stock-based compensation	0.286	0.401
Panel B: Estimated Parameters	***Point Estimators***	***T-Statistics***
Persistence of productivity shock, ρ_z	0.370	(21.1)
Volatility of productivity shock, σ_z	0.143	(38.1)
Capital adjustment cost, ϕ	0.310	(95.3)
Financing adjustment cost, κ	0.998	(21.2)
Debt enforcement, ξ	0.108	(21.4)
Capital portability, η	0.280	(183.8)

The reported data moments are estimated using data from Compustat Fundamental Quarterly 2006q1–2014q1, with NAICS codes classified as ICT industry. The estimation is conducted using SMM, 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.

The values of the estimated parameters are reported in Panel B of Table 3. The estimation sets the debt enforcement parameter ξ at 0.108 and sets the capital portability parameter η at 0.280. 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 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. Since we are the first to estimate the value of the capital portability parameter η in the corporate finance literature, in order to convey the economic significance of parameter η, we compare it with the results of the structural estimation for traditional industries in the next section.

The estimated value of the standard deviation of the productivity shock lies within the range established in the literature, while the persistence of the shock is relatively low. The estimated capital adjustment cost parameter ϕ is 0.31, which implies that the elasticity of the investment-capital ratio with respect to the marginal q is about 3.2, which is also in the range found in the literature (e.g., Jermann (1998)). The estimated financing adjustment cost parameter is 0.998, while Jermann and Quadrini (2012) report a value of 0.146 when using U.S. *aggregate* data.

5.4 Cross-industry Estimation

In order to examine the effects of wage contracts on the financial leverage of firms that are homogeneous *ex ante*, we also conduct a structural estimation for the traditional industries. Panel A of Table 4 reports the observed and simulated moments of interest. The average leverage ratio in the traditional industries is 0.178, which is double the ratio of 0.092 found in the high-tech industries. In the column of simulated moments, we see that the model conforms well to the average leverage and the standard deviation of financial leverage. As expected, the model generates a lower correlation between R&D investment and employee financing than the correlation found in the high-tech industries.

Panel B of Table 4 reports the estimated parameters. The debt enforcement parameter ξ in traditional industries now is 0.611, higher than that of the high-tech industries, which is 0.108. This is consistent with the fact that the collateral rate of assets is lower in high-tech industries, but relatively higher in traditional industries. The capital portability parameter $\eta = 0.222$ is lower in traditional industries than the capital portability found in high-tech

Table 4: **Moments and parameters (traditional industries).**

Panel A: Target Moments	*Observed*	*Simulated*
Average leverage	0.178	0.181
Standard deviation of leverage	0.064	0.040
Autocorrelation of leverage	0.832	0.714
Standard deviation of R&D investment	0.004	0.003
Autocorrelation of R&D investment	0.797	0.876
Standard deviation of debt issuance	0.017	0.019
Autocorrelation of debt issuance	-0.029	-0.012
Standard deviation of stock-based compensation	0.002	0.002
Autocorrelation of stock-based compensation	0.430	0.591
Correlation between R&D investment and debt issuance	-0.020	-0.085
Correlation between R&D investment and stock-based compensation	0.147	0.075
Panel B: Estimated Parameters	***Point Estimators***	***T-Statistics***
Persistence of productivity shock, ρ_z	0.509	(29.2)
Volatility of productivity shock, σ_z	0.238	(76.4)
Capital adjustment cost, ϕ	0.266	(119.9)
Financing adjustment cost, κ	0.819	(23.7)
Debt enforcement, ξ	0.611	(39.1)
Capital portability, η	0.222	(71.3)

The reported data moments are estimated using data from Compustat Fundamental Quarterly 2006q1–2014q1, with NAICS codes classified as the manufacturing and consumer goods industry. The estimation is conducted using SMM, 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.

industries ($\eta = 0.280$), which is in line with the intuition that firms in high-tech industries are more intangible-intensive.

5.5 Counterfactual Exercises

5.5.1 Model without Employee Financing

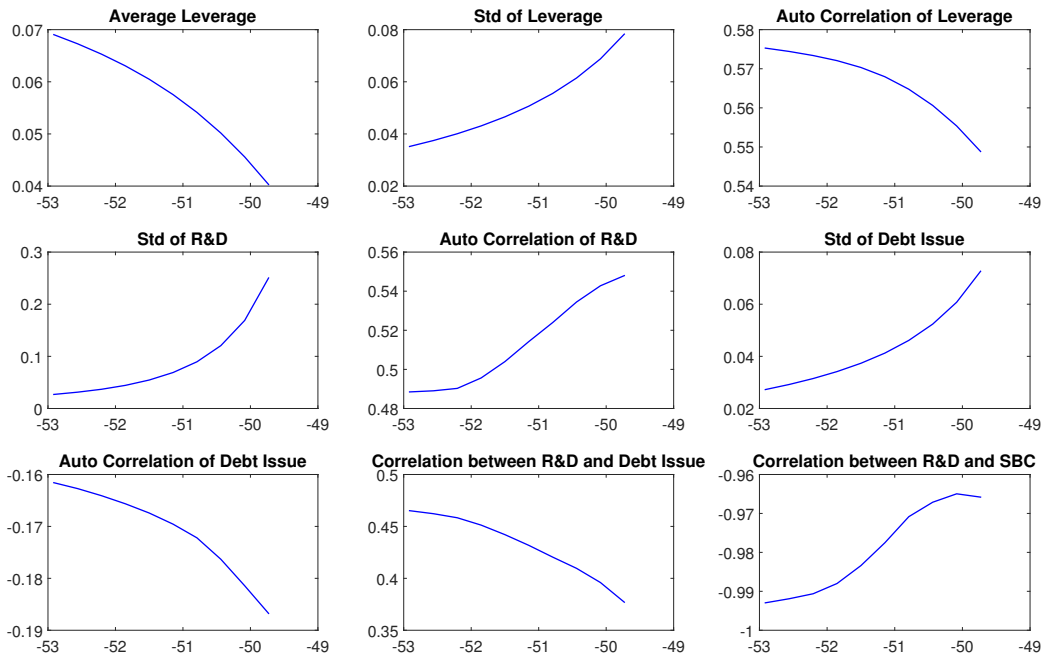
In this section, we compare our model to a typical dynamic investment model with financial frictions, *but without* employee financing. Specifically, to disable the employee financing channel while keeping the model comparable to the literature, we modify our benchmark model in two aspects. First, we set the promised utility $\mathbf{m}_{t+1}$ as a fixed number, and thus a constant wage c_t to satisfy the promise-keeping constraint (2). Second, we choose the fixed promised utility such that the employee's participation constraint (3) always holds. The modified problem 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). Thus, if we define the firm's cash flows by subtracting the 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)).

In the modified problem, when we exogenously change the level of the employee's promised utility, the firm's leverage choice is affected as well as its financing decisions. The interaction between the employee's promised utility and the firm's leverage decision is purely driven by the debt enforcement constraint: an increase in the promised utility reduces the equity value of the firm, and thus tightens the debt capacity. On the other side, since the promised utility is fixed, the firm cannot adjust/delay wage payments to spare internal funds for investment. The employee financing channel is completely closed.

Figure 3 plots the simulated results of the modified model. Consistently, we find that average leverage decreases with the promised utility. However, the modified model cannot generate the negative correlation between R&D investment and debt issuance observed in the data. That is, if we shut down the employee financing channel, the counterfactual result contradicts the empirical evidence. Thus, the employee financing channel identified in our paper can not be simply achieved by re-interpreting tangible capital as intangible capital in

the typical dynamic investment models.

Figure 3: **The modified model without employee financing.**



The x-axis is the exogenous level of promised utility m, and the y-axis represents the simulated moments. All the variables are normalized by total assets, before calculating the moments. To make sure the participation constraint is always satisfied, we set the lower bound of the promised utility as $\tilde{m}_{min} = \frac{\log(z_H)}{1-\beta\rho_z}$, where z_H denotes the highest state of the productivity shock, and ρ_z is the persistence of the shock.

In the modified model, the long-term wage contract provides perfect insurance to employees, but does not adjust according to the size of intangible capital. Thus, the correlation between normalized R&D investment and normalized employee claim τ is driven by the denominator, i.e., total assets. An increase in the investment leads to a larger size of the firm in terms of total assets, so the overall employee claim as a fraction of total assets declines if the overall employee claim is constant. The correlation between normalized R&D investment and the normalized employee claim is then close to -1 in the modified model.

5.5.2 Decomposition of the Financial Effects of Wage Contracts

In this section, we decompose the financial effects of wage contracts. The accumulation of intangible capital imposes an overhang effect on firms' debt capacity, while, for precautionary

purposes, firms are motivated to maintain low leverage to avoid future financial tightness. The precautionary effect can be identified by examining the financial buffers generated from 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. On the other hand, the overhang effect can be identified by demonstrating the changes in the firm's total debt capacity.

We conduct a following counterfactual exercise. First, we report the moments of the model (i.e., capacity and buffers) using the estimated parameters of the traditional industry. Then, we replace the value of the capital portability parameter η with that of the high-tech industries, while keeping other parameters the same as in the traditional industries. In this way, we can quantify the impact of wage contracts on financial decisions.

Table 5: **Decomposing the financial effects of wage contracts.**

	Traditional $\eta = 0.222$	Traditional $\eta = 0.280$	**Changes**
CAPACITY			
Debt capacity, $\frac{\xi\beta\mathbb{E}[V']}{h'}$	0.12	0.08	**-0.04**
Employee financing capacity, $\frac{\beta_w\tau'_H}{h'}$	0.65	0.83	**+0.18**
Employee financing capacity, $\frac{\beta_w\tau'_L}{h'}$	0.63	0.80	**+0.17**
BUFFER			
Financial buffer, $\frac{\xi\beta\mathbb{E}[V']-\frac{b'}{R}}{\xi\beta\mathbb{E}[V']}$	18%	25%	**+7%**
Operating buffer, $\frac{\beta_w m'_H-\beta_w\omega'_H}{\beta_w\lvert m'_H\rvert}$	3%	1%	**-2%**
Operating buffer, $\frac{\beta_w m'_L-\beta_w\omega'_L}{\beta_w\lvert m'_L\rvert}$	57%	45%	**-12%**

The first column uses the parameters estimated from the traditional industries, while the second column replaces the value of portability η with the value found in the high-tech industry. 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.

In Table 5, 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 $\eta = 0.222$) and in the case of high capital portability (traditional industries with $\eta = 0.280$). As shown in the first panel of Table 5, the overhang effect is identified. When the intangible capital portability increases, the debt capacity decreases. At the same time, the firm's capacity for financing from employees increases. Furthermore, the increases in employee financing capacity overturn the decreases in debt capacity. To sum up, our model indicates that the overall financing capacity of the firm increases. 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.

When we consider the precautionary effect, we show that firms have stronger precautionary motives for keeping the financial leverage low as the capital portability η increases. Conversely, firms save fewer labor-induced operating buffers as their employees' outside option improves. The intuition is as follows: Given our estimated value of financing adjustment cost parameter κ, the operating labor buffer is more costly to adjust than the financial debt buffer, therefore, the firm would choose to use debt buffer as the liquidity instrument to maintain flexibility.

6 Conclusion

Firms finance intangible investment using different instruments from financing tangible investment. This paper is the first to document the correlations between employee compensation structure and firms' financing patterns. By identifying the different financing channels, this paper opens a new window to understand the link between the fundamental economic forces and the financial decisions of firms. This paper also provides a new explanation for the contrasting trends in corporate net debt ratios and intangible-to-tangible ratios.

We provide a theory in which firms issue self-enforcing debt contracts to external investors and also offer long-term wage contracts to internal employees who have limited commitment.

The long-term wage contract serves as a financing instrument for shareholders by deferring employee claims to the future. The accumulation of intangible capital in production imposes two effects on the firm's financial structure decisions: the precautionary effect and intangible capital overhang effect. We quantify the sizable intangible overhang effect as a dominant force in explaining cross-industry differences in financial leverage. We argue that rising intangible capital shrinks firms' debt capacity but expands the total borrowing capacity if one takes employee financing into account.

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A Proof

A.1 Equivalence between the Recursive Problem and the Original Problem

We can write down the firm's problem as follows:

$$V_0 = \max_{\{e_t, c_t, b_{t+1}\}_{t=0}^{\infty}} : \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t d_t \right\},$$

subject to:

$$d_t = z_t h_t - c_t - e_t + \frac{b_{t+1}}{R_t} - b_t \geq 0 \tag{12}$$

$$h_{t+1} = (1-\delta)h_t + \phi(e_t/h_t)h_t \tag{13}$$

$$\xi \beta \mathbb{E}_t \sum_{n=0}^{\infty} \beta^n d_{t+1+n} \geq \frac{b_{t+1}}{R_t} \tag{14}$$

$$\beta \mathbb{E}_{t+1} \sum_{n=0}^{\infty} \beta^n u(c_{t+1+n}) \geq \beta \omega(z_{t+1}, h_{t+1}), \ \forall z_{t+1}. \tag{15}$$

Equation (12) is the budget constraint. Equation (13) is the law of motion of intangible capital h. Equation (14) is the debt enforcement constraint. Equation (15) is the employee's participation constraint.

Define $\mathbf{m_{t+1}}(z_{t+1}, h_{t+1}) = \mathbb{E}_{t+1} \sum_{n=0}^{\infty} \beta^n u(c_{t+1+n})$. Then equation (15) is equivalent to the following recursive form:

$$m_t = u(c_t) + \beta \mathbb{E}_t[\mathbf{m_{t+1}}], \tag{16}$$

$$\beta \mathbf{m_{t+1}}(z_{t+1}, h_{t+1}) \geq \beta \omega(z_{t+1}, h_{t+1}), \ \forall z_{t+1}, \tag{17}$$

where equation (16) is the promise-keeping constraint, and equation (17) is the participation constraint. Substituting equation (15) with (16) and (17), we obtain the recursive problem $\mathcal{P}$.

A.2 Proof of Proposition 1

Let λ be the multiplier on the budget constraint, q be the multiplier on the investment constraint, μ be the multiplier on the enforcement constraint, θ be the multiplier on the promise-keeping constraint, and $\pi(z'|z)\gamma(z')$ be the multiplier on the participation constraints.

Write down the Lagrangian of the problem $\mathcal{P}$:

$$
\begin{aligned}
L &= d + \beta E[V(m'(z'), b', h'; z')|z] && (18)\\
&+\lambda\big[zh - c - e + \frac{b'}{R} - b - \varphi(d)\big] && (19)\\
&+q\big[(1-\delta)h + \phi(\frac{e}{h})h - h'\big] && (20)\\
&+\mu\big[\xi\beta E[V(m'(z')', b', h'; z')|z] - \frac{b'}{R}\big] && (21)\\
&+\theta\big[\log(c) + \beta E[m'(z', h')] - m\big] && (22)\\
&+\sum_{z'} \pi(z'|z)\gamma(z')\big[\beta m'(z', h') - \beta\omega(z', h')\big] && (23)
\end{aligned}
$$

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

$$
\begin{aligned}
b' &: \mu = \beta R(1+\mu\xi)E[V_b'|z] + \lambda && (24)\\
m'(z') &: \gamma(z') = -(1+\mu\xi)V'_{m'(z')} - \theta && (25)\\
h' &: q = \beta(1+\mu\xi)E[V_h'|z] + \lambda z - \beta\sum_{z'}\pi(z'|z)\gamma(z')\omega_{h'}(z', h') && (26)\\
d &: \lambda = \frac{1}{\varphi'(d)} && (27)\\
e &: q = \frac{\lambda}{\phi'(\frac{e}{h})} && (28)\\
c &: \theta = \frac{\lambda}{u'(c)} && (29)
\end{aligned}
$$

and the Envelope conditions:

$$
\begin{aligned}
b &: V_b = -\lambda && (30)\\
m &: V_m = -\theta && (31)\\
h &: V_h = \lambda z + q[(1-\delta) + \phi(\frac{e}{h}) - \phi'(\frac{e}{h})\frac{e}{h}] && (32)
\end{aligned}
$$

Equations (24)-(32) completely capture the system.

A.2.1 Cost of Employee Financing

From F.O.C. (25) and Envelope condition (31), we obtain

$$\gamma(z') = -\theta + (1+\mu\xi)\theta' \tag{33}$$

- 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 $\gamma(z') > \mu\xi\theta$.

Define the marginal rate of substitution between dividends and employee's consumption

as $\frac{\lambda}{u'(c)}$. Combine equations (25), (29) and (31) to obtain

$$(1+\mu\xi)\frac{\lambda'(z')}{u'(c'(z'))} = \gamma(z') + \frac{\lambda}{u'(c)} \tag{34}$$

The following statements indicate that 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 $\mu = 0, \gamma(z') > 0$, $\frac{\lambda'(z')}{u'(c'(z'))} = \frac{\lambda}{u'(c)} + \gamma(z') > \frac{\lambda}{u'(c)}$.

A.2.2 Cost of Equity Financing and Debt Financing

From F.O.C (24) and Envelope condition (30), we obtain

$$\mu = \lambda - (1+\mu\xi)\beta R E[\lambda'|z] \tag{35}$$

- When $\mu = 0$, $\lambda = \beta R E[\lambda'|z]$. Thus, λ' increases, on average, since $\beta R < 1$.
- When $\mu > 0$, $\lambda = \mu + (1+\mu\xi)\beta R E[\lambda'|z]$. Thus, λ' decreases on average whenever $\mu > (1-\beta R)\lambda/(1+\xi\beta R\lambda)$.

A.3 Proof of Proposition 2

Recall the systems of optimality conditions (24)-(32). Rearrange terms to obtain Euler equations for m and b:

$$m \;:\; \gamma(z') - V_m = -(1+\mu\xi)V_m' \tag{36}$$
$$b \;:\; \mu + V_b = \beta R(1+\mu\xi)E[V_b'|z] \tag{37}$$

Combining two equations (36) and (37) and substituting out $1+\mu\xi$, we obtain

$$\frac{1}{\beta}\frac{V_m'}{V_m - \gamma(z')} = R\frac{E[V_b'|z]}{V_b + \mu} \tag{38}$$

The ratio $\frac{1}{\beta}\frac{V_m'}{V_m-\gamma(z')}$ is defined as the rate of return on borrowing from the workers m, and the ratio $R\frac{E[V_b'|z]}{V_b+\mu}$ is defined as the rate of return on borrowing from the creditors b. 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 increases m'.

B Data

B.1 Data Construction

All the quarterly variables are from the CRSP/Compustat Merged Database–Fundamentals Quarterly from 2006q1 to 2014q1. 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 4900-4949 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 drop firms with fewer than eight quarters of data, since we need to calculate empirical moments that require repeated observations for each individual firm (such as standard deviations and auto-correlations). 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.

B.2 Variable Definition

- Leverage = Short-Term Debt (DLCQ)+ Long-Term Debt (DLTTQ) / Total Assets (ATQ)
- R&D = R&D Expenses (XRDQ) / Total Assets (ATQ)
- SBC = Stock-Based Compensation Expense (STKCOQ) / Total Assets (ATQ)
- Debt Issuance = (Long-Term Debt Issuance (DLTISQ) - Long-Term Debt Reduction (DLTRQ) + Current Debt Changes (DLCCHQ)) / Total Assets (ATQ)
- Equity Issuance = Sales of Common and Preferred Stocks (SSTKQ) / Total Assets (ATQ)
- Cash Flow = (Operating Income Before Depreciation (OIBDPQ) + XSGAQ) / Total Assets (ATQ)
- Tobin's Q = (Common Shares Outstanding (CSHOQ) * PRCCQ +Total Asset (ATQ) - Common/Ordinary Equity - Total (CEQQ)) / Total Assets (ATQ)

B.3 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 industry 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. The traditional industries in our paper combines the consumer goods and manufacturing industries. To categorize the new economy industries, or highly intangible-intensive industry, we use our definition of high-tech (ICT) industries.

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:

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

subject to:

$$\varphi(\tilde{d}) = z - \tilde{c} - \tilde{e} + g'\frac{\tilde{b}'}{R} - \tilde{b} \tag{39}$$

$$g' = (1-\delta) + \phi(\tilde{e}) \tag{40}$$

$$\xi\beta\mathbb{E}_z[\tilde{V}'] \geq \frac{\tilde{b}'}{R} \tag{41}$$

$$\tilde{m} = \log(\tilde{c}) + \beta\mathbb{E}_z[\tilde{m}'(z')] + \frac{\beta}{1-\beta}\log(g') - \log(\eta) \tag{42}$$

$$\beta\tilde{m}'(z') \geq \beta\frac{\log(z')}{1-\beta\rho_z} \tag{43}$$

We solve the (normalized) contract numerically using the projection method. After writing down 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 nonlinear equations (24)-(32), 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) in estimating the model. However, one issue we encounter when implementing their procedure is that our empirical data consist of a panel of heterogenous firms while the artificial data is generated by simulating one firm over a number of periods. To maintain consistency between the empirical data and simulated data, we demean each variable in the data before calculating the empirical moments.

The estimation procedure consists of the following steps:

1. For each firm i in the data, we first demean the variable: $\tilde{x}_{it} = x_{it} - \bar{x}_{it}$, where $\bar{x}_{it}$ is the within-firm average of x_{it}. The subscripts i and t identify firm and year, respectively. We do not demean the data when we take the sample mean as one of our target moments.

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 the estimated parameters.

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

$$\min_{\theta} \Big[f(x) - f(y, \theta) \Big]' \cdot \Omega \cdot \Big[f(x) - f(y, \theta) \Big],$$

   where $f(x) = \frac{1}{K} \sum_{k=1}^{K} f(x_k)$ and $f(y, \theta) = \frac{1}{S} \sum_{s=1}^{S} f(y_s, \theta)$ are the sample mean of the data and the model, respectively, and Ω is the weighting matrix.

The $M \times M$ optimal weighting matrix is given by

$$\Omega = [\widehat{\Sigma}(1 + K/S)]^{-1},$$

where $\widehat{\Sigma}$ is the $M \times M$ variance-covariance matrix defined as[14]

$$\widehat{\Sigma} = \frac{1}{K} \sum_{k=1}^{K} \big(f(x_k) - f(x) \big) \big(f(x_k) - f(x) \big)'.$$

[14] As a robustness check, we also calculate the variance-covariance matrix accounting for time-series dependence in the data. However, the impact of time-series dependence is not statistically significant.

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

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

where $V = (DWD')^{-1}$, and D' is the $M \times N$ gradient matrix defined as

$$D' = \frac{\partial f(y, \theta)}{\partial \theta'} \approx \frac{f(y, \theta + \Delta\theta) - f(y, \theta - \Delta\theta)}{2\Delta\theta}.$$

The t-statistics of the ith estimator is given by

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

E Identification

Figures 6–11 show the sensitivity analysis. In each figure, the x-axis reports the value of the parameter, and the y-axis reports the moments.

As shown in Figure 6 and 7, the parameters ρ_z and σ_z regarding production shocks are mainly pinned down by the standard deviation and the serial correlation of all four variables in the estimation: leverage, R&D investment, debt issuance, and SBC. Also, we notice that the standard deviation of the shock affects the correlation between investment and financing variables more than that of the persistence of the shock.

The capital adjustment cost parameter ϕ (Figure 8) is fixed down by the autocorrelation of R&D investment, since the capital adjustment cost directly affects the firm's investment timing. 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 investment and financing is also higher.

The financing adjustment cost parameter κ (Figure 9) is pinned down by the autocorrelation of leverage. The firm's leverage becomes more persistent when the financing rigidities are significant. The financing adjustment cost parameter also impacts the correlation between financing and investment.

The debt enforcement parameter ξ is almost uniquely identified by the level of leverage. A higher enforcement rate implies a higher leverage ratio, although the firm may save some unused debt capacity.

The capital portability parameter η also affects the level of leverage, but it has strong impacts on other moments as well, particularly on the correlation between investment and financing variables. Thus, this difference would allow us to separately identify the debt enforcement parameter and the capital portability parameter—which is the primary contribution of our structural estimation.

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 not 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.

F Tables

Table 6: **Summary statistics**

Variable	Obs	Mean	Std. Dev.	P10	P50	P90
MV	37992	3808.745	7357.363	56.0684	673.0886	12339.12
Q	37992	2.0456	1.1676	.917	1.6575	3.8318
Leverage	38089	.1369	.1579	0	.0751	.3875
CAPX	37912	.0091	.0085	.0012	.0063	.0224
R&D Expenses	38089	.0198	.0205	0	.0134	.051
SBC	38089	.0047	.005	.0006	.0027	.0124
Debt Issuance	38089	.0001	.0159	-.0167	0	.0157
Equity Issuance	37671	.0037	.0067	0	.0009	.0106
Sales	38089	.2486	.1413	.0937	.2209	.4668

We use quarterly firm level data from the CRSP/Compustat Merged Database from 2006q1 to 2014q1. Variables in the bottom panel are normalized by the book value of total assets. See Appendix B.1 for the variable definition.

Table 7: **Intangible investment and financing channels: 2006q1—2014q1**

	(1) CAPX	(2) R&D	(3) CAPX	(4) R&D
Debt Issuance	0.026***	-0.001	0.026***	-0.000
	(9.15)	(-0.41)	(9.19)	(-0.05)
Equity Issuance	-0.019***	-0.051***	-0.018**	-0.041***
	(-2.65)	(-3.27)	(-2.48)	(-2.82)
SBC			0.081***	0.706***
			(3.62)	(11.56)
Q	0.001***	0.001***	0.001***	0.000
	(8.61)	(3.07)	(7.92)	(1.01)
CF	0.011***	0.049***	0.011***	0.044***
	(5.54)	(10.20)	(5.23)	(9.74)
L.CF	0.010***	0.014***	0.010***	0.014***
	(5.26)	(3.46)	(5.20)	(3.42)
Const.	0.006***	0.012***	0.006***	0.010***
	(15.57)	(13.12)	(15.05)	(11.49)
Quarter FE	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y
N	34,109	34,124	34,109	34,124
N_clust	1,720	1,720	1,720	1,720
R Square	0.057	0.055	0.058	0.105

t statistics in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The table reports the results of regressing investment on sources of finance. SBC is the stock-based compensation, CF is cash flow, and L.CF is lagged cash flow. All variables are scaled by total book asset (ATQ). The regressions are standard panel regressions with firm and year-quarter fixed effects and with standard errors clustered at the firm level. The sample includes all Compustat firms with required variables from 2006q1 to 2014q1.

Table 8: **Panel regression: Intangible investment and financing channels (industries).**

	(1) R&D Traditional	(2) R&D High-Tech	(3) CAPX Traditional	(4) CAPX High-Tech
Debt Issuance	-0.001	-0.000	0.026***	0.011***
	(-0.39)	(-0.05)	(7.03)	(3.07)
Equity Issuance	-0.043*	-0.043**	-0.034*	-0.004
	(-1.84)	(-2.22)	(-1.91)	(-0.38)
SBC	0.335***	0.756***	0.007	0.082**
	(3.43)	(8.16)	(0.12)	(2.56)
Q	0.000	-0.001**	0.001***	0.001***
	(0.14)	(-2.44)	(5.61)	(4.05)
CF	0.013***	0.084***	0.007*	0.013***
	(3.28)	(11.98)	(1.68)	(4.31)
L.CF	0.008***	0.028***	0.017***	0.005*
	(2.67)	(5.03)	(4.37)	(1.91)
Const.	0.005***	0.013***	0.008***	0.005***
	(6.63)	(10.79)	(8.78)	(8.24)
Quarter FE	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y
N	12,058	14,160	12,056	14,158
N_clust	591	702	591	702
R Square	0.038	0.201	0.089	0.039

t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The table reports the results of regressing investment on sources of finance. Columns (1) and (3) are the regression results for a sample of traditional firms. Columns (2) and (4) are the regression results for the high-tech subsample. SBC is the stock-based compensation, CF is cash flow, and L.CF is lagged cash flow. All variables are scaled by total book asset (ATQ). These regressions are standard panel regressions with firm and year-quarter fixed effects and standard errors clustered at the firm level. The sample includes Compustat firms with required variables from 2006q1 to 2014q1.

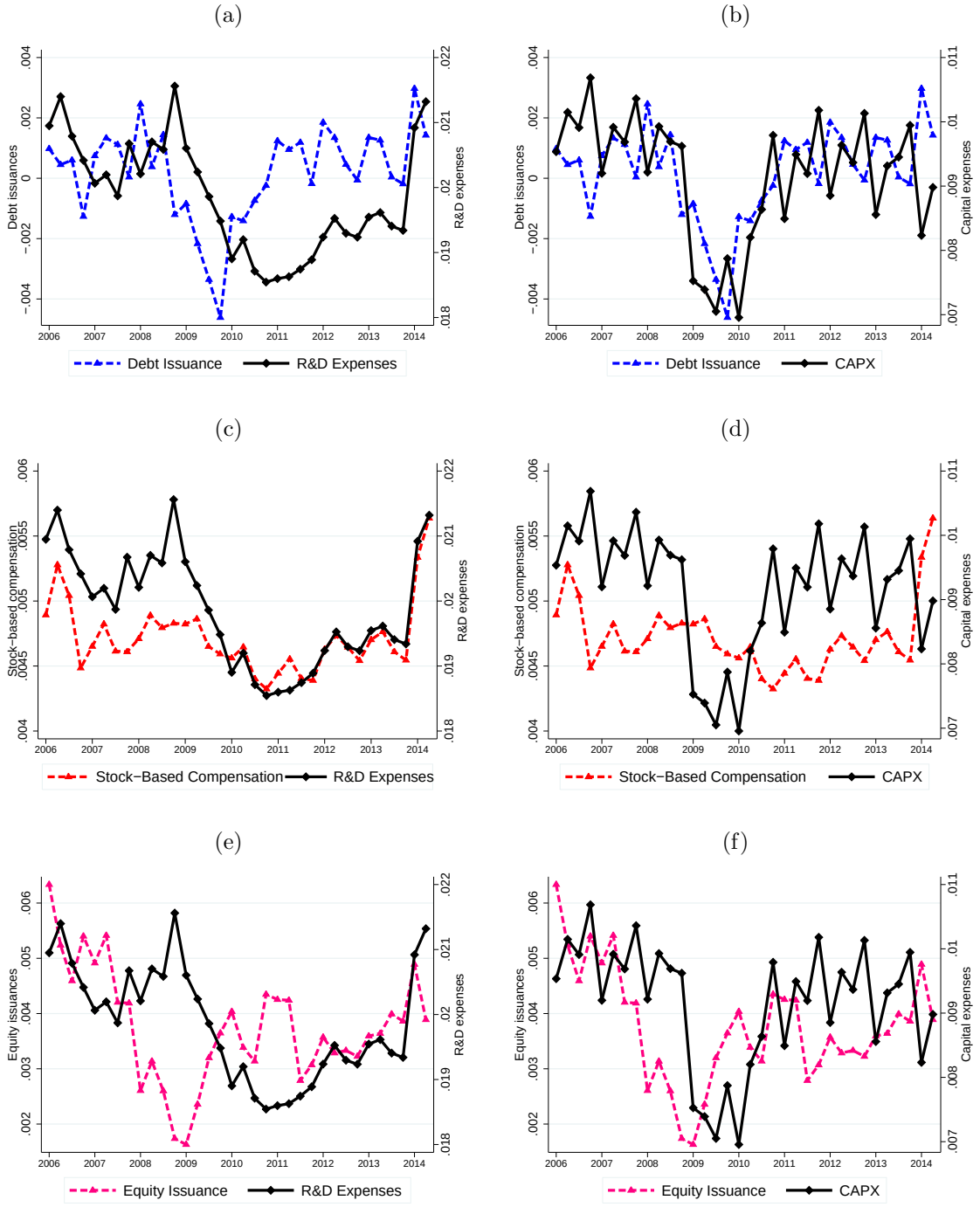
Table 9: **Estimation (robustness).**

Panel A: Target Moments	*Observed*	*Simulated*
Average leverage	0.092	0.076
Standard deviation of leverage	0.067	0.009
Autocorrelation of leverage	0.854	0.555
Average R&D investment	0.157	0.136
Standard deviation of R&D investment	0.055	0.020
Autocorrelation of R&D investment	0.627	0.675
Average debt issuance	-0.002	-0.000
Standard deviation of debt issuance	0.056	0.004
Autocorrelation of debt issuance	0.034	-0.212
Average stock-based compensation	0.035	0.022
Standard deviation of stock-based compensation	0.018	0.004
Autocorrelation of stock-based compensation	0.579	0.543
Correlation between R&D investment and debt issuance	0.025	-0.377
Correlation between R&D investment and stock-based compensation	0.402	0.953
Panel B: Estimated Parameters	*Point Estimators*	*T-Statistics*
Persistence of productivity shock, ρ_z	0.607	(227.7)
Volatility of productivity shock, σ_z	0.242	(24.6)
Capital adjustment cost, ϕ	0.126	(111.8)
Financing adjustment cost, κ	0.095	(0.6)
Debt enforcement, ξ	0.078	(4.9)
Capital portability, η	0.282	(21.3)
Depreciation rate, δ	0.119	(59.8)

In this table, we report the results of estimation including three level moments: the average R&D investment, the average debt issuance, and the average stock-based compensation. To reduce the potential measurement errors of those level moments, we normalize variables by total sales both in the model and in the data. The reported data moments are estimated using data from Compustat Fundamental Quarterly 2006q1–2014q1, with NAICS codes classified as ICT industry. Panel A contains the observed and simulated moments from the estimation. Panel B reports the parameters estimated using SMM.

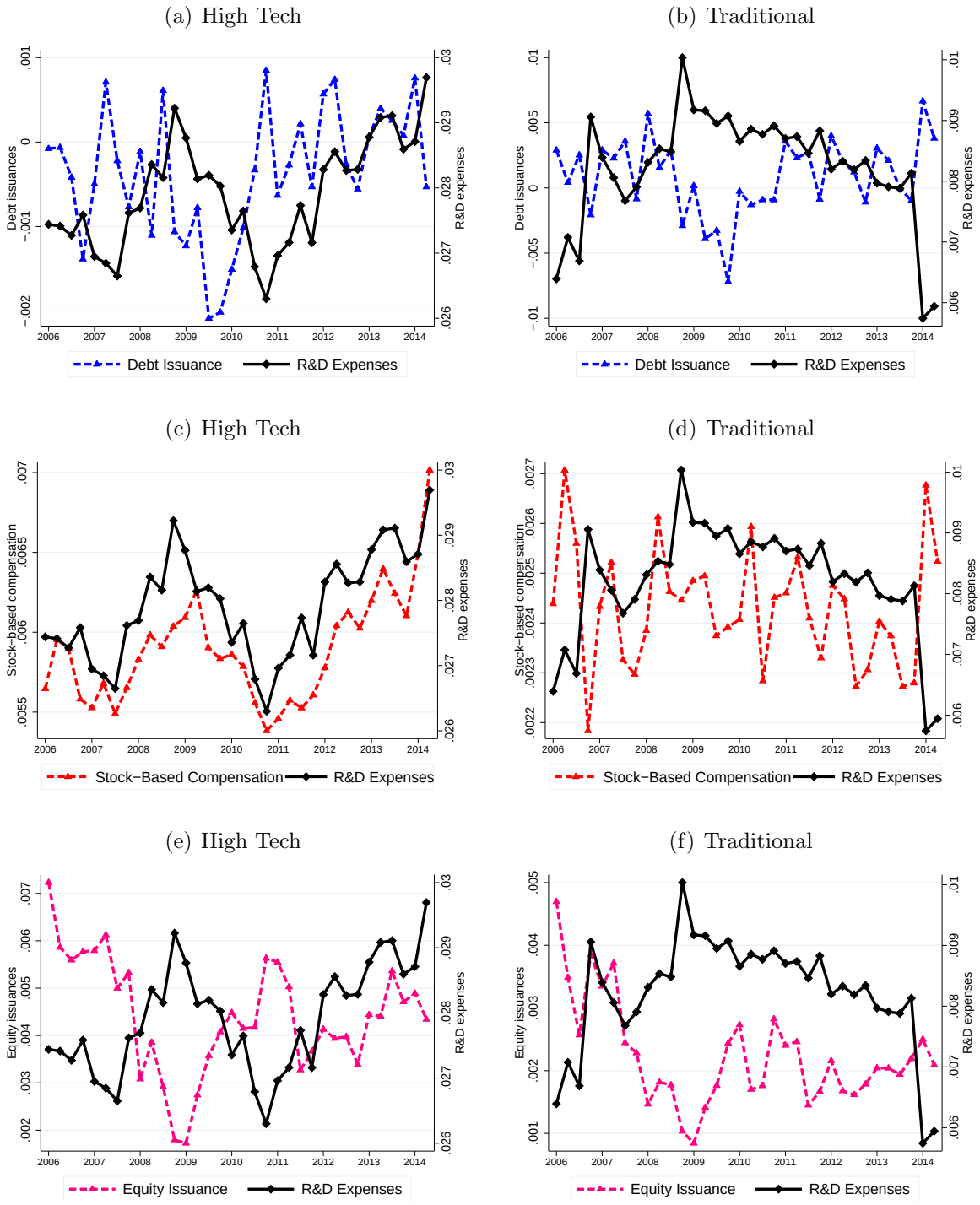
G Figures

Figure 4: **Firm-level time series.**



This figure shows the time series of average firm-level stock-based compensation (SBC), debt issuance, equity issuance, tangible investment (CAPX) and intangible investment (R&D Expenses). All variables are scaled by total book assets, and they are quarterly observations from Compustat Fundamental 2006q1-2014q1.

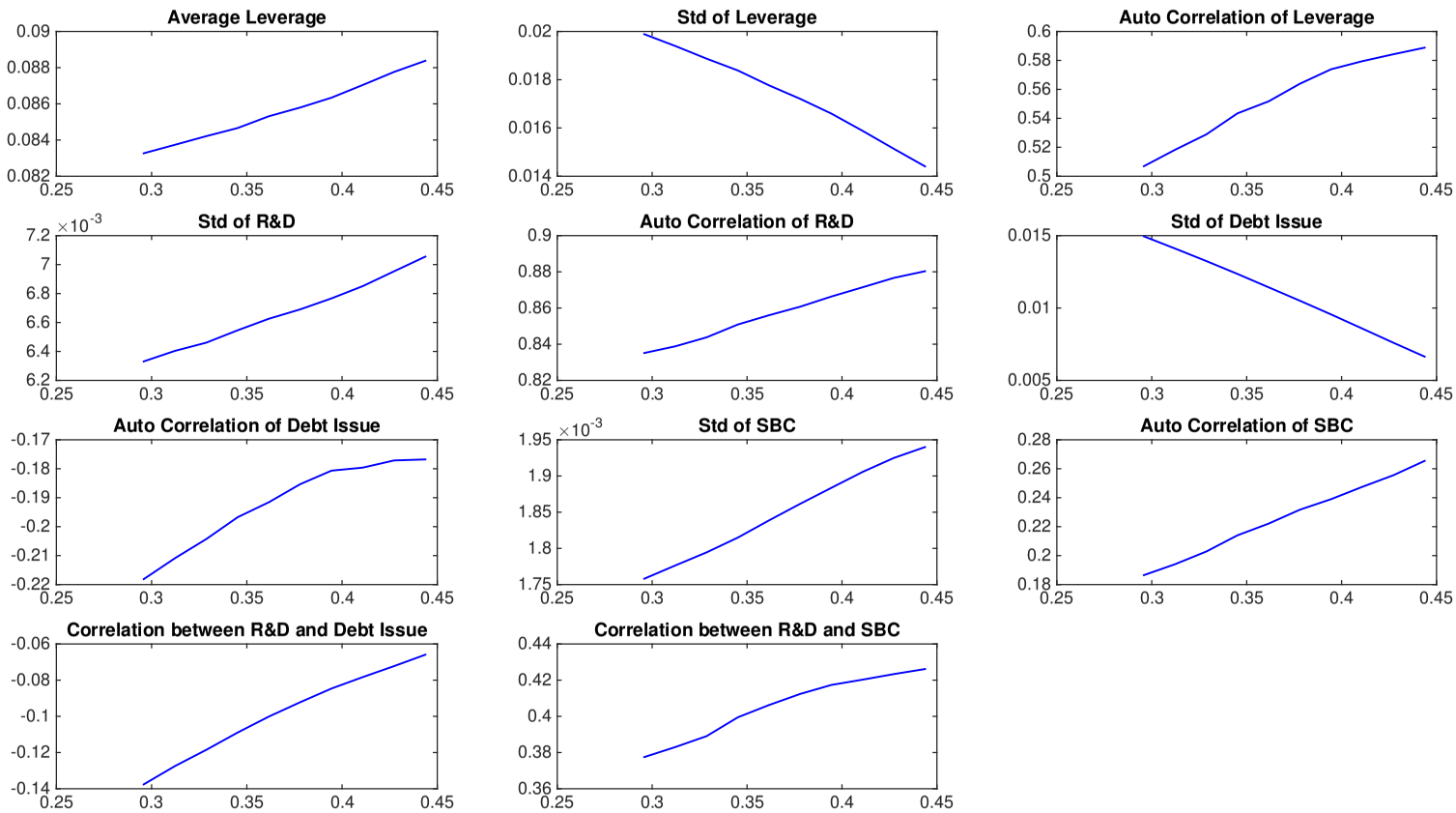
Figure 5: **Firm-level time series (industries).**



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 high-tech and traditional industries. All variables are quarterly observations from Compustat Fundamental 2006q1–2014q1. A detailed description of variable construction can be found in Appendix B.1.

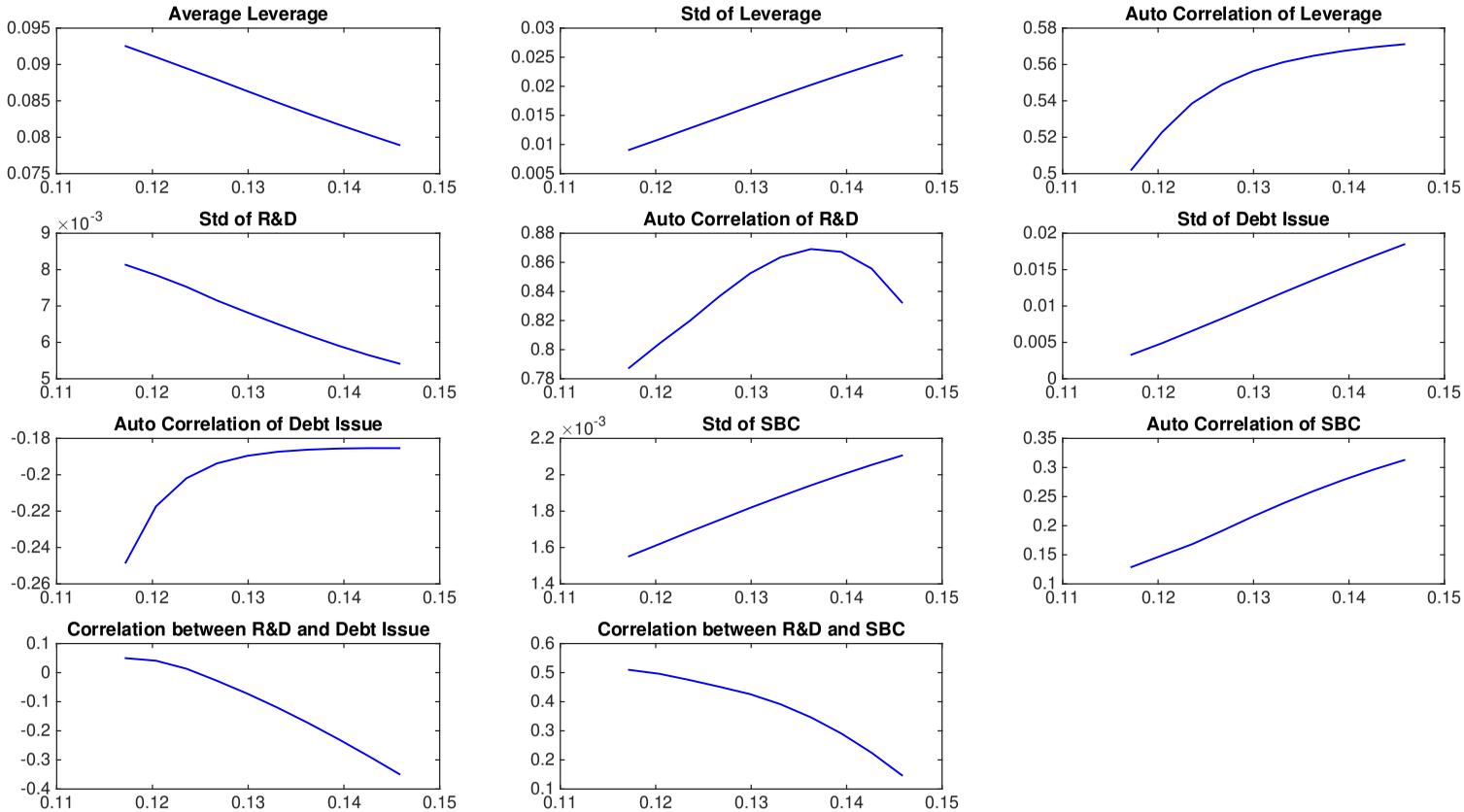
H Sensitivity Analysis

Figure 6: **The persistence of the productivity shock ρ_z.**



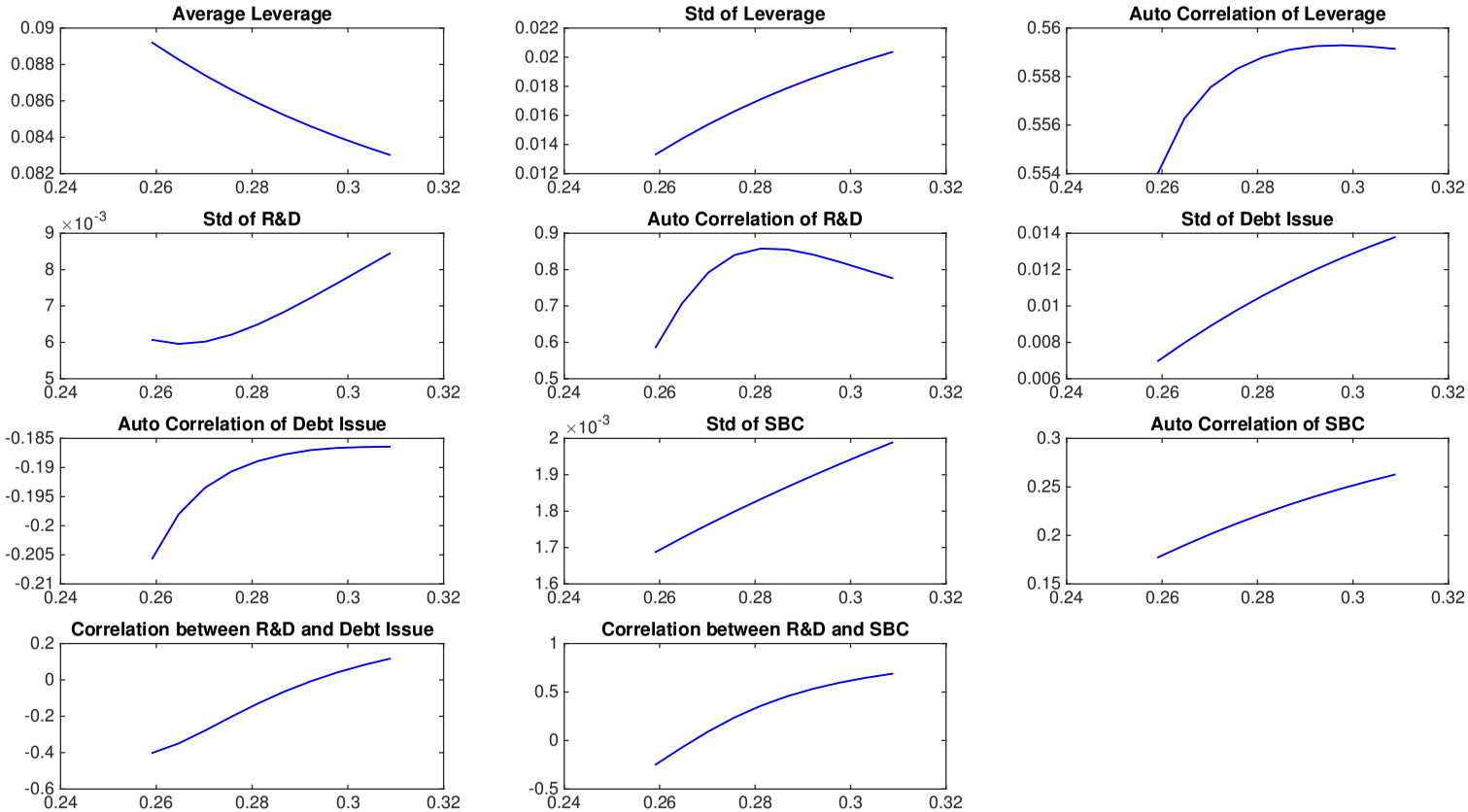
This figure shows the sensitivity of each moment to the change of the persistence of the productivity shock ρ_z. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 7: **The volatility of the productivity shock σ_z.**



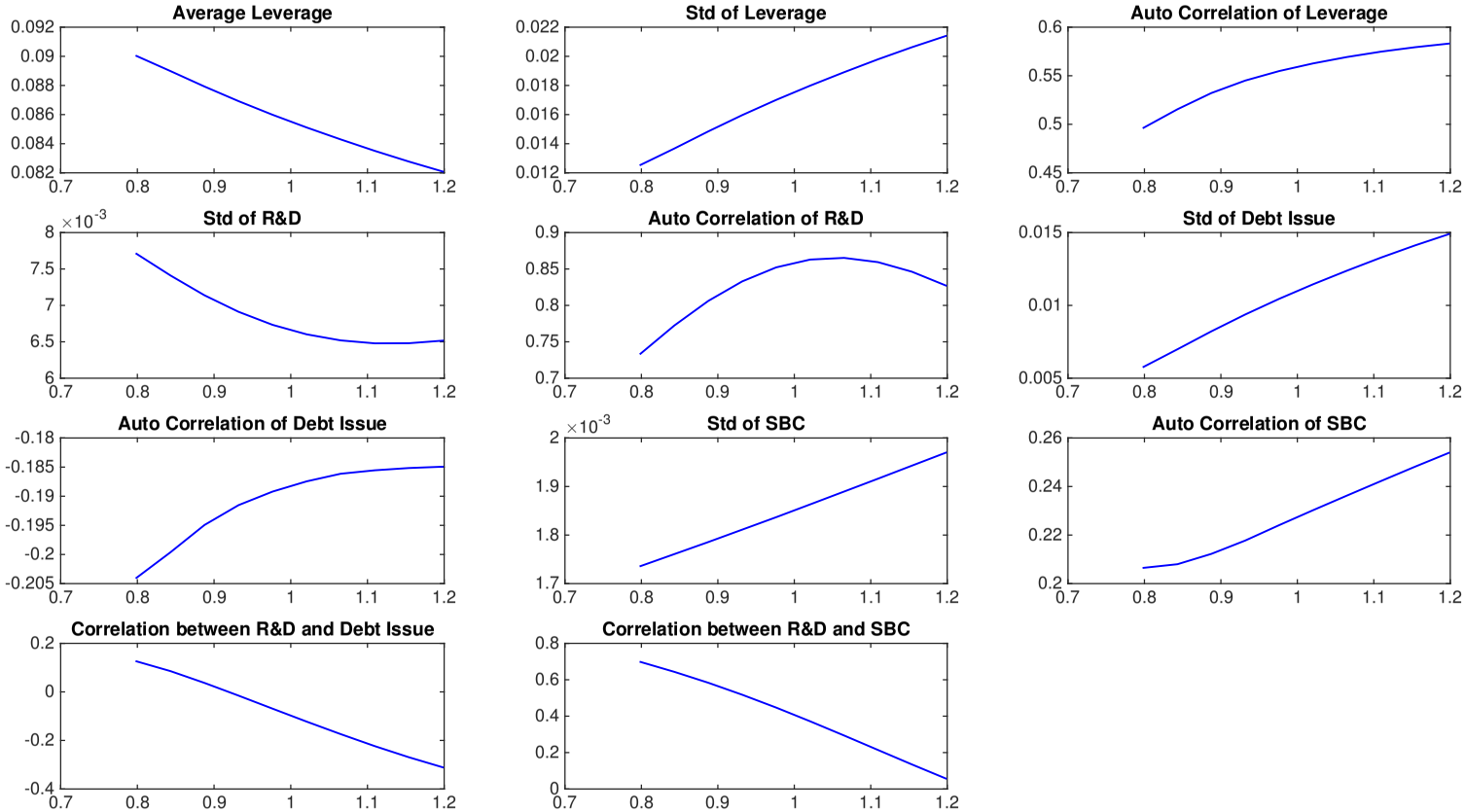
This figure shows the sensitivity of each moment to the change of the volatility of the productivity shock σ_z. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 8: **The capital adjustment cost parameter ϕ.**



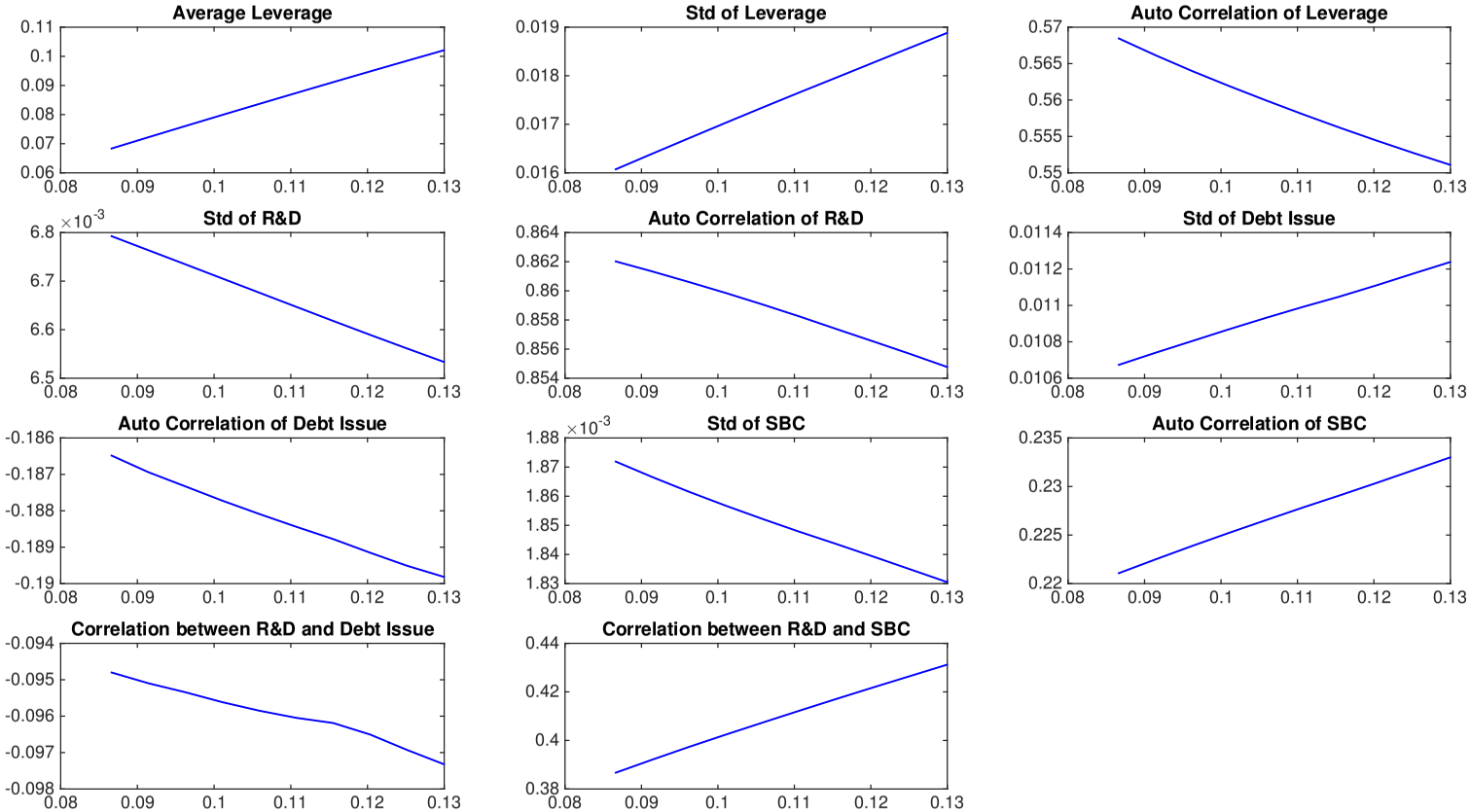
This figure shows the sensitivity of each moment to the change of the capital adjustment cost parameter ϕ. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 9: **The financing cost parameter κ.**



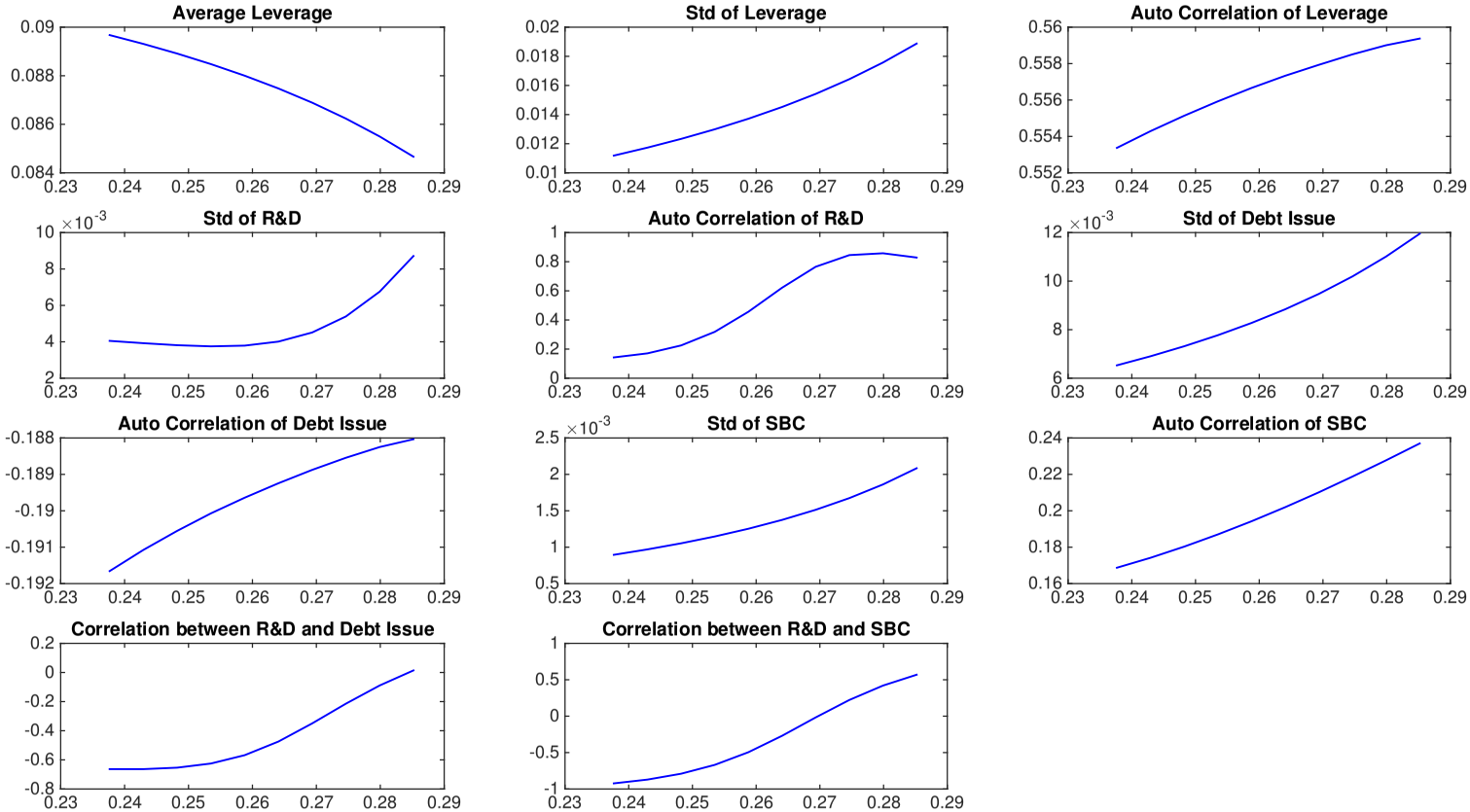
This figure shows the sensitivity of each moment to the change of the financing cost parameter κ. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 10: **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 11: **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.