Online Appendix to

"Financing Intangible Capital"

Not For Publication

Summary

In this document, we include supplement materials to our paper. Section 1 includes an extended version of the model with physical capital investment. Section 2 re-estimates the benchmark model using an alternative identification strategy. Section 3 reports the impulse responses for optimal financing policies, sensitivity tests of all estimated variables in the benchmark estimation, and additional sensitivity tests of η and ξ on the first moments. Section 4 presents additional counterfactual analysis for ξ, in which the traditional industries is treated as the benchmark. Section 5 includes the proofs of some additional theoretical results. Section 6 describes the data sources, data construction and more details on variable definitions. Section 7 includes additional regression tables for robustness checks.

1 The Version of Model with Physical Capital Accumulation

We specify the optimization problem $\mathcal{P}'$ of firms with physical capital in production:

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

subject to:

$$\varphi(d) + c = z k^\alpha h^{1-\alpha} - e + \frac{b'}{R} - b - i_k k \tag{1}$$

$$h' = (1 - \delta)h + \phi(e/h)h \tag{2}$$

$$\xi k + \xi_2 \beta \mathbb{E}_z \left[V(h', \mathbf{m}'(z'), b'; k', z') \right] \geq \frac{b'}{R} \tag{3}$$

$$m = u(c) + \hat{\beta} \mathbb{E}_z [\mathbf{m}'(z')] \tag{4}$$

$$\hat{\beta} \mathbf{m}'(z') \geq \hat{\beta} \omega(z', h') \ \forall z' \tag{5}$$

The variable α is the capital share. The accumulation of physical capital follows $k' = (1 - \delta_k)k + i_k k$, where δ_k is the depreciation rate of capital and i_k is the investment rate of capital. In this model, tangible capital can be used as collateral directly, and we modify the debt enforcement constraint (3). To highlight our employee financing channel, we make the assumption that intangible capital cannot be used as collateral, that is, $\xi_2 = 0$.

We normalize the problem $\mathcal{P}'$ by h as in problem $\mathcal{P}$:

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

subject to:

$$\varphi(\tilde{d}) = z\tilde{k}^\alpha - \tilde{c} - \tilde{e} + g'\frac{\tilde{b}'}{R} - \tilde{b} - i_k\tilde{k} \tag{6}$$

$$g' = (1 - \delta) + \phi(\tilde{e}) \tag{7}$$

$$\xi\tilde{k} \geq g'\frac{\tilde{b}'}{R} \tag{8}$$

$$\tilde{m} = \log(\tilde{c}) + \hat{\beta}\mathbb{E}_z[\tilde{\mathbf{m}}'(z')] + \frac{\hat{\beta}}{1 - \hat{\beta}}\log(g') - \log(\eta) \tag{9}$$

$$\beta\tilde{\mathbf{m}}'(z') \geq \hat{\beta}w_0 + \frac{\hat{\beta}\log(z')}{1 - \hat{\beta}\rho} \tag{10}$$

To reduce the number of state variables, we assume that the tangible-to-intangible ratio $\tilde{k} = \frac{k}{h}$ is exogenous, and follows a two-states Markov process. Given that $\tilde{k}$ is an exogenous state, it's much easier to solve the model. Also, this does not lose the purpose of adding capital — there still exists a production structure of tangible and intangible.

The tangible-to-intangible ratio $\tilde{k}$ determines the leverage ratio. A higher $\tilde{k}$ allows the firm to use more debt financing. However, the tangible-to-intangible ratio $\tilde{k}$ does not affect the employee financing channel directly through the participant constraint or the promise keeping constraint, but indirectly through the level of net cash flows $z\tilde{k}^\alpha - i_k\tilde{k}$.

Before estimating the new model, we set the capital share $\alpha = 0.5$, the quarterly depreciation rate of tangible capital $\delta_k = 0.04$, and the quarterly tangible capital investment rate $i_k = 0.06$. We specify a two-states Markov chain of $\tilde{k}$, with grids $\tilde{k}^H = 1.25$, and $\tilde{k}^L = 0.75$, and transition probability $\pi_{11} = 0.75$ and $\pi_{12} = 0.25$.[1] The steady state value of $\tilde{k}$ is normalized to 1.0.

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[1] Our results are robust to the different calibrated values of α, δ_k, i_k and the Markov chain of $\tilde{k}$.

Table 1: **Estimation (with k, High–Tech)**

PANEL A: TARGET MOMENTS	Data	Simulated	t-Statistics
Average leverage	0.105	0.099	(0.92)
Standard deviation of leverage	0.074	0.023	(9.78)
Autocorrelation of leverage	0.912	0.764	(4.31)
Standard deviation of R&D	0.009	0.007	(2.60)
Autocorrelation of R&D	0.488	0.574	(1.51)
Standard deviation of debt issuance	0.014	0.019	(12.8)
Autocorrelation of debt issuance	0.006	-0.052	(2.28)
Standard deviation of SBC	0.002	0.002	(1.20)
Autocorrelation of SBC	0.366	0.189	(4.94)
Correlation between R&D and debt issuance	-0.014	-0.085	(6.37)
Correlation between R&D and SBC	0.307	0.209	(2.53)

PANEL B: ESTIMATED PARAMETERS	Estimators	t-Statistics
Persistence of productivity shock, ρ_z	0.781	(123.3)
Volatility of productivity shock, σ_z	0.052	(25.8)
Debt enforcement, ξ	0.053	(80.5)
Financing adjustment cost, κ	0.532	(31.2)
Capital adjustment cost, ϕ	0.512	(51.7)
Capital portability, η	0.111	(42.3)

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

Table 2: **Estimation (with k, High–Tech): Robustness**

Moments	Benchmark ($\tilde{k} = 1$)	Robustness ($\tilde{k} = 1.2$)
Average leverage	0.099	0.115
Standard deviation of leverage	0.023	0.023
Autocorrelation of leverage	0.764	0.762
Standard deviation of R&D	0.007	0.004
Autocorrelation of R&D	0.574	0.948
Standard deviation of debt issuance	0.019	0.018
Autocorrelation of debt issuance	-0.052	-0.067
Standard deviation of SBC	0.002	0.001
Autocorrelation of SBC	0.189	0.246
Correlation between R&D and debt issuance	-0.085	-0.076
Correlation between R&D and SBC	0.209	0.206

This table provides a robustness check of the results in Table 2. We increase the steady state level of tangible-to-intangible ratio $\tilde{k}$ from 1.0 to 1.2, and report the moments in the table.

2 Matching the level of R&D

In this section, we take an alternative identification strategy to estimate model. The goal of this exercise is to match the level of average R&D and the average SBC, and conduct a counterfactual exercise of qualifying the size of employee financing channel in the model.

Compared to the benchmark estimation, we make the following changes: (1) We use Compustat annually data 2006-2016, instead of quarterly data 2006q1-2015q1. The measurement of the level of R&D and SBC is more accurate in annual data since there is no seasonality. (2) We add the moments of Q, the level of R&D and SBC in the target moments, but remove the two correlations: the correlation between R&D and debt issuance, and R&D and SBC. The new variable definitions are in Table 3. (3) We specify the capital adjustment cost in a quadratic form $\phi(e) = \phi e^2$, which allows the model to match the level of Q.

In Table 4, we report the estimation results. As can be seen from the table, the model can match the level of R&D and SBC quite well. In column (d), we also do the counterfactual exercise of disabling the channel of employee financing. It shows that without employee financing, the level of R&D decreases from 0.114 to 0.103, and the level of SBC decreases from 0.023 to 0.011. That is, our model (the employee financing channel) can explain about $\frac{0.023-0.011}{0.023} \approx 52\%$ of SBC observed in the data.

Table 3: **Variable Definitions**

	Model	Data	Compustat
Leverage	$\frac{b'}{h}$	$\dfrac{\text{Debt}_t}{\text{Market Value of Assets}_t}$	$\dfrac{\text{dltt+dlc}}{\text{at}}$
Tobin'Q	$\frac{v+b'+\mathbb{E}\tau'}{h}$	$\dfrac{\text{Market Value of Assets}_t}{\text{Book Value of Assets}_t}$	$\dfrac{\text{csho*prccf+(at-ceq-txdb)}}{\text{at}}$
R&D	$\frac{e}{h}$	$\dfrac{\text{R\&D Expenses}_t}{\text{Book Value of Assets}_t}$	$\dfrac{\text{xrd}}{\text{at}}$
Debt Issuance	$\frac{b'-b}{h}$	$\dfrac{\text{Debt Issuance}_t}{\text{Book Value of Assets}_t}$	$\dfrac{\text{dltis-dltr+dlcch}}{\text{at}}$
SBC	$\frac{\mathbb{E}\tau'-\tau}{h}$	$\dfrac{\text{SBC}_t}{\text{Book Value of Assets}_t}$	$\dfrac{\text{stkco}}{\text{at}}$

This table contains definitions of variables and empirical measures. In Compustat Annually, dltt denotes Short-Term Debt, dlc denotes Long-Term Debt, csho denotes Common Shares Outstanding, prccf denotes Stock Price, ceq denotes Common/Ordinary Equity - Total, txdb denotes Deferred Taxes, at denotes Total Assets, xrd denotes R&D Expenses, dltis denotes Long-Term Debt Issuance, dltr denotes Long-Term Debt Reduction, dlcch denotes Current Debt Changes, and stkco denotes Stock-Based Compensation Expense.

Table 4: **Structural Estimation (Matching the Level of R&D)**

TARGET MOMENTS	(a) Empirical data	(b) Estimated model	(c) t-Statistics	(d) Counterfactual fixed m
Average leverage	0.120	0.110	(1.6)	0.043
Standard deviation of leverage	0.085	0.011	(12.3)	0.014
Autocorrelation of leverage	0.803	0.663	(1.7)	0.563
Average Q	1.924	1.889	(0.8)	1.523
Standard deviation of Q	0.636	0.081	(14.7)	0.062
Autocorrelation of Q	0.633	0.352	(5.9)	0.404
Average R&D	0.116	0.114	(0.5)	0.103
Standard deviation of R&D	0.040	0.020	(7.0)	0.010
Autocorrelation of R&D	0.733	0.262	(6.3)	0.329
Average SBC	0.023	0.023	(0.2)	0.011
Standard deviation of SBC	0.011	0.008	(0.6)	0.001
Autocorrelation of SBC	0.623	0.585	(0.5)	0.330

ESTIMATED PARAMETERS		Estimators	t-Statistics
Persistence of productivity shock, ρ_z		0.338	(28.0)
Volatility of productivity shock, σ_z		0.330	(94.4)
Debt enforcement, ξ		0.196	(34.9)
Financing cost, κ		0.267	(96.7)
Capital adjustment cost, ϕ		0.499	(72.5)
Capital portability, η		0.179	(38.5)
Capital depreciate rate, δ		0.093	(124.3)

The table shows the results of the structural estimation. The first panel lists the target moments; Column (a) reports the moments from the data; Column (b) reports the moments generated by the estimated model; Column (c) reports the t-Statistic for the differences between the empirical moments and the moments generated by the estimated model; Column (d) reports the moments generated by the modified model of disabling the employee financing channel. The second panel reports the estimated parameters and the associated t-Statistics. As described in Section 5.5 of the paper, the counterfactual model $\mathcal{P}'$ maximizes the value of shareholders, subject to the law of motion of capital, the promise-keeping constraint with fixed promised utility, the debt enforcement constraint, and the budget constraint.
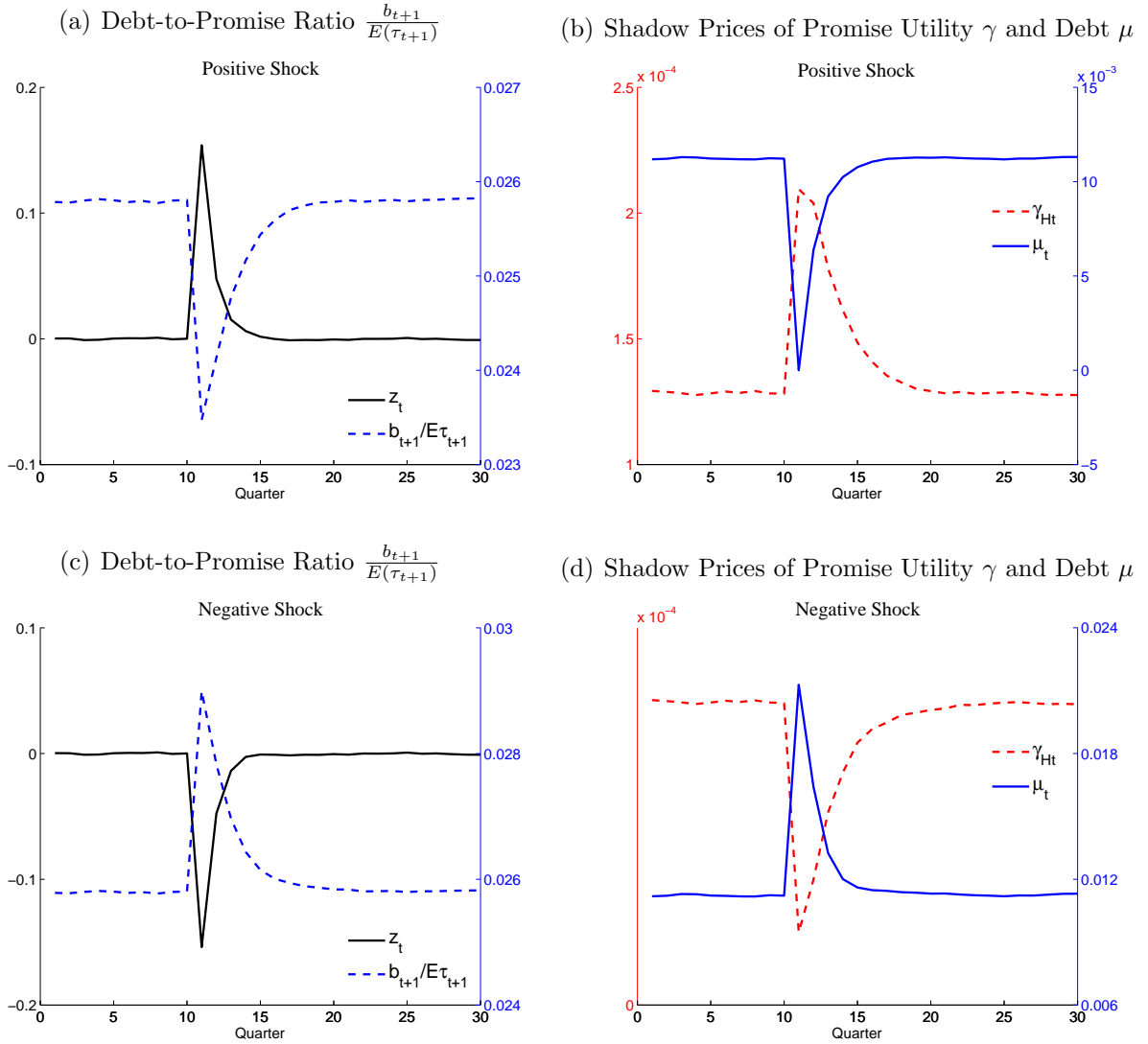
3   Impulse Responses and Sensitivity

3.1   Optimal Financing Policies

Given the benchmark estimation result in Table 4 in the main text, we now illustrate the substitution between debt and employee financing quantitatively. Figure 1 demonstrates the non-linear impulse response functions calculated under the set of parameter values from the benchmark estimation.

Figure 1 panel (a) shows the impulse response of the debt-to-promise ratio ($\frac{b_{t+1}}{E_t(\tau_{t+1})}$) to a one-standard deviation positive productivity shock. The firm increases investment and accumulates intangible capital given a positive productivity shock. In the meantime, the employee faces a better outside option. The contingent wage contract offers higher deferred compensation in order to satisfy the participation constraint (3). An increase in deferred employee claims shrinks the debt capacity in future periods, so the firm can either save debt buffers by reducing debt financing ($\mu = 0$), or it can reduce the current wage payment c when the economic state precludes it from saving debt buffers for precautionary purposes ($\mu > 0$). On average, a positive shock leads to co-movement between investment and deferred employee claims, but leads to zero correlation, or a negative correlation, between investment and debt financing. In Figure 1, the debt-to-promise ratio responds negatively to the positive productivity shock.

When a negative productivity shock is realized, the investment motive is low. An employee's outside options are weak, and the participation constraint is not binding ($\gamma(z', h') = 0$). Given that the employee is risk averse, the contingent wage contract offers a constant deferred compensation to provide full insurance to the employee when the firm saves enough buffers ($\mu = 0$). However, during a period of financial tightness ($\mu > 0$), the firm can use some of its operating buffers to relax the budget constraint by reducing the deferred compensation. In Figure 1, Panels (c) and (d) show that the debt-to-promised ratio increases as the shadow price of employee financing declines. To summarize, a negative shock leads to a positive correlation between investment and deferred employee claims but leads to a negative, or zero, correlation between investment and debt financing.

Figure 1: **Impulse Responses**

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

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

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

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

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

## 3.2   Sensitivity Analysis

Figure 2-7 report the sensitivity tests of all estimated variables in the benchmark estimation.

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Figure 2: **The persistence of the productivity shock ρ_z.**
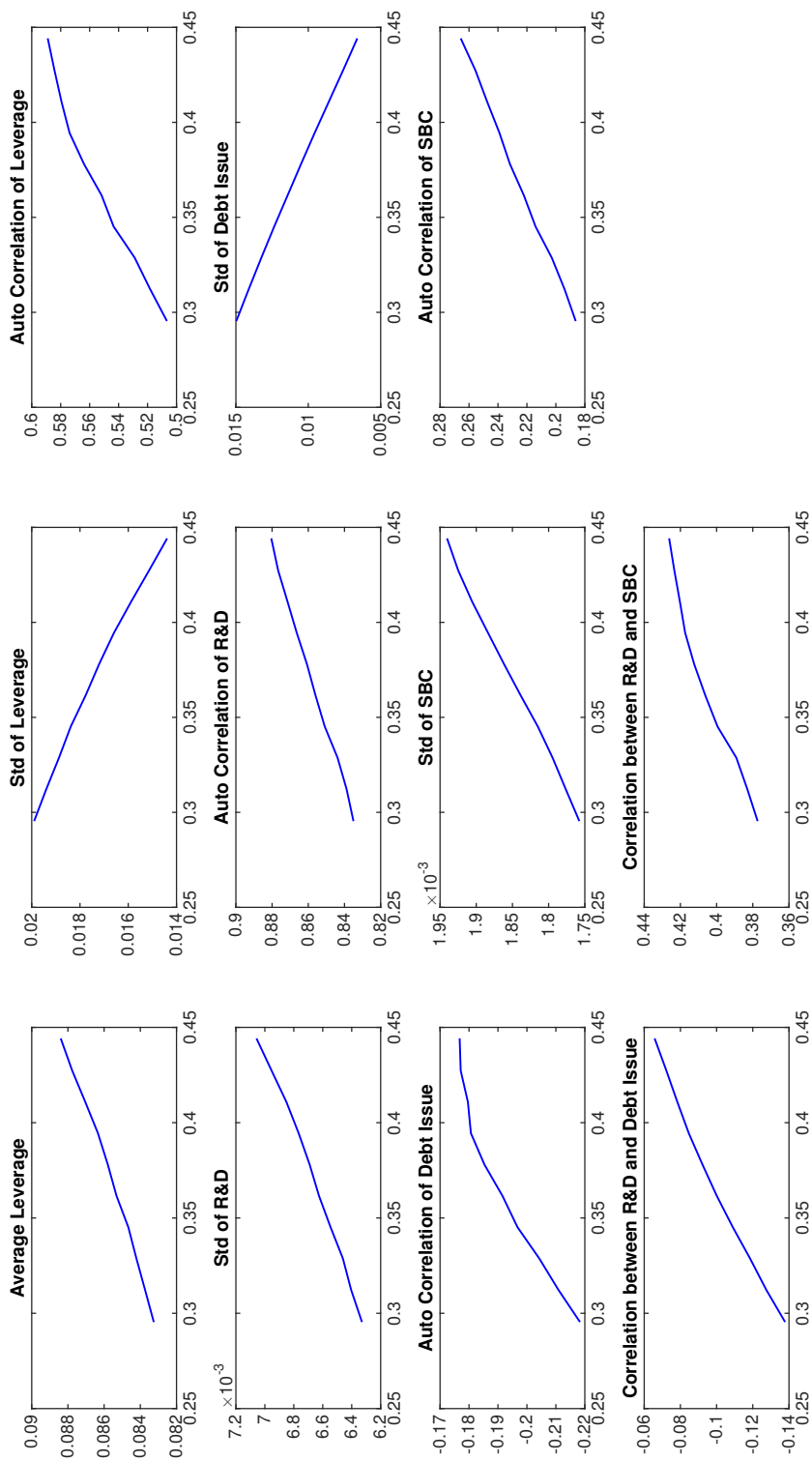
This figure shows the sensitivity of each moment to the change of the persistence of the productivity shock ρ_z. The x-axis is the parameter, and the y-axis represents the simulated moments.

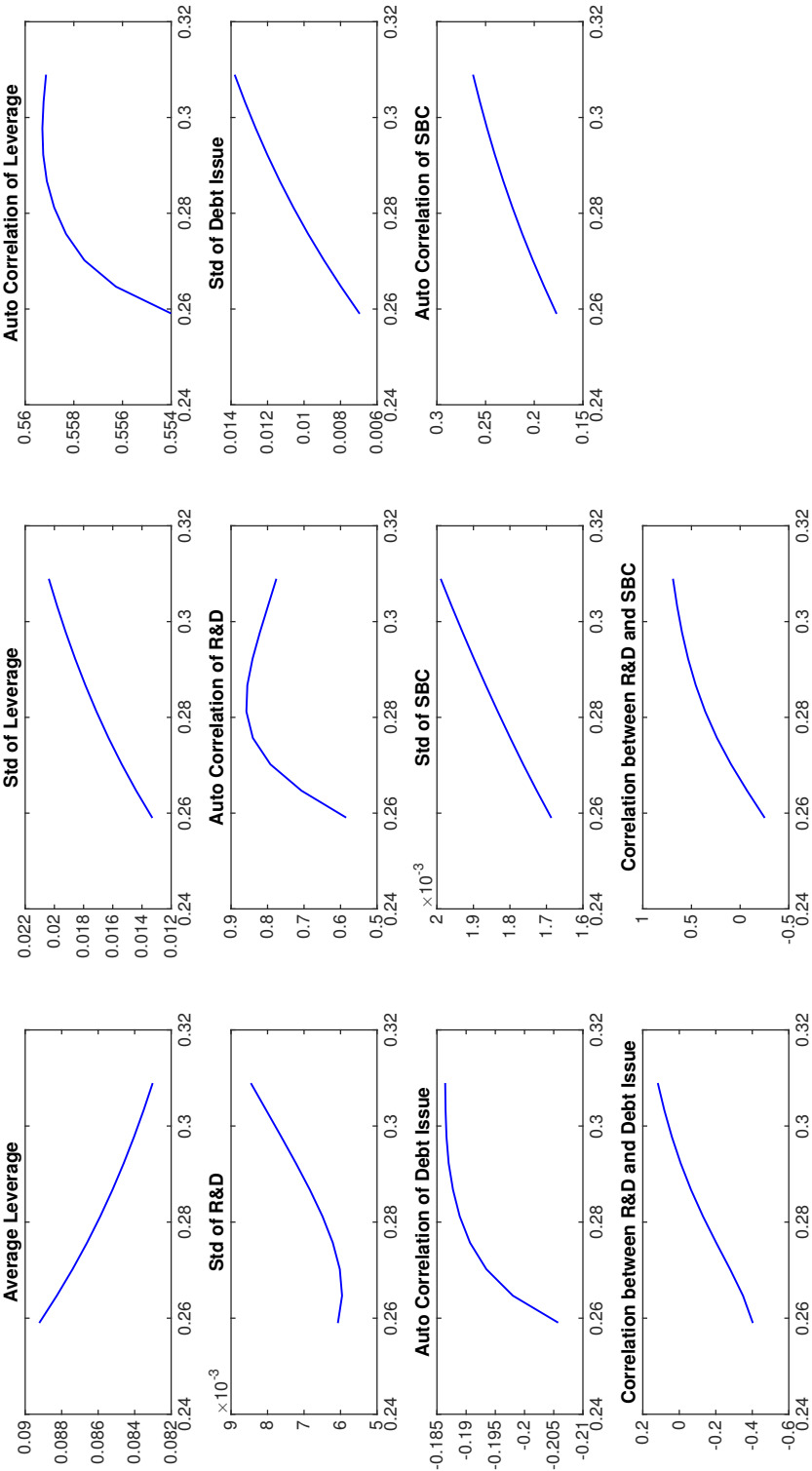Figure 3: **The volatility of the productivity shock σ_z.**
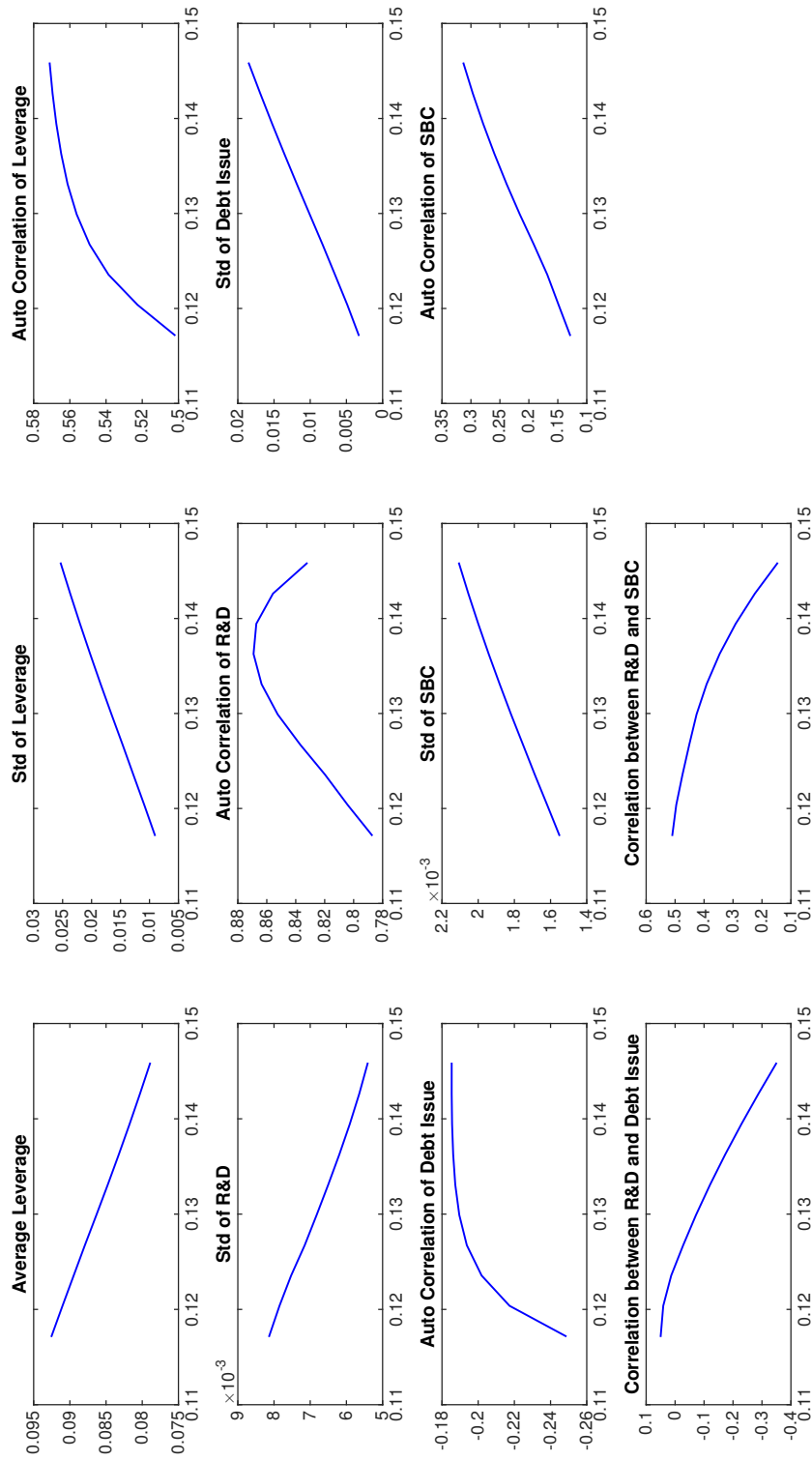
This figure shows the sensitivity of each moment to the change of the volatility of the productivity shock σ_z. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 4: **The capital adjustment cost parameter ζ.**

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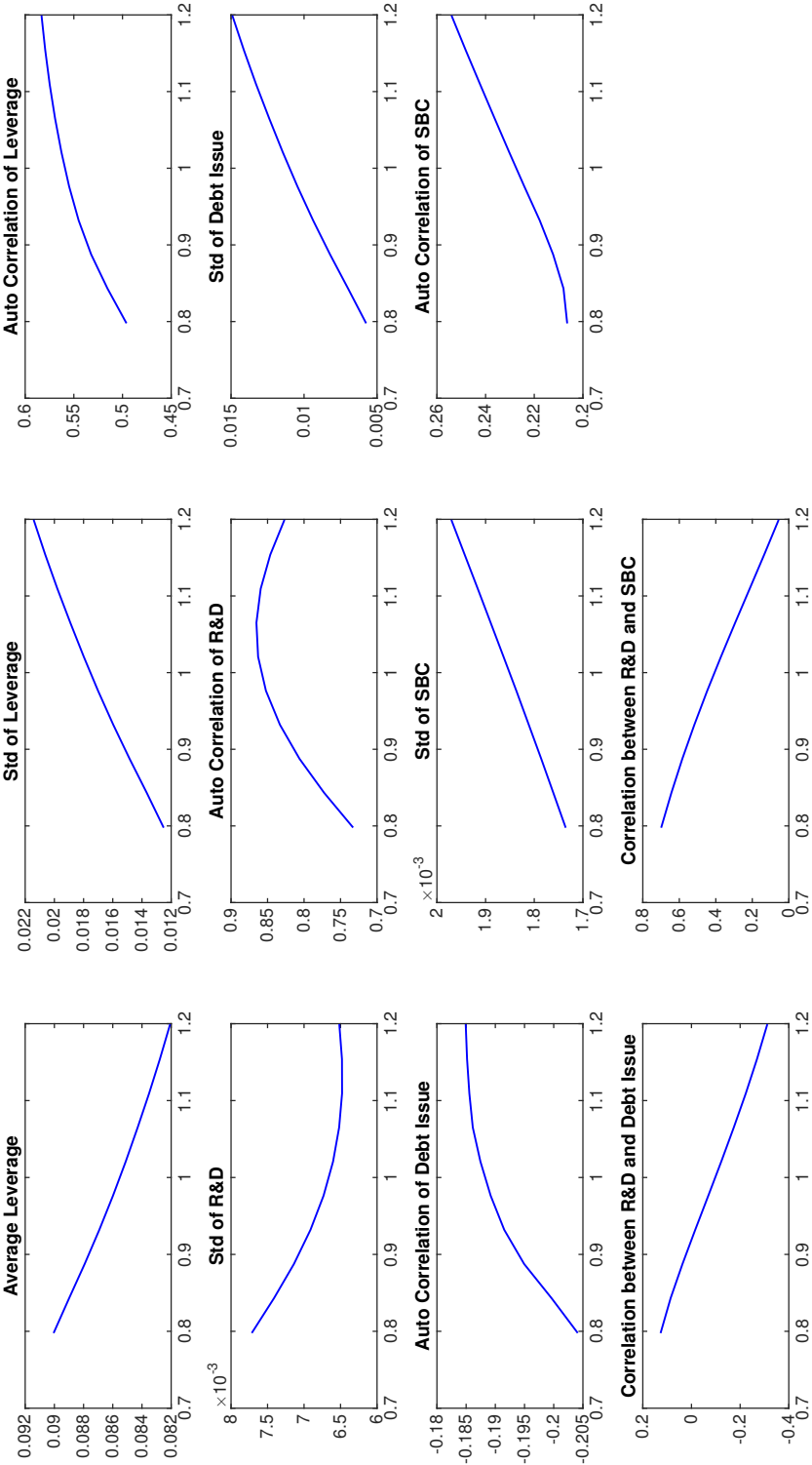
This figure shows the sensitivity of each moment to the change of the financing cost parameter κ. The x-axis is the parameter, and the y-axis represents the simulated moments.

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Figure 6: **The debt enforcement parameter** ξ.
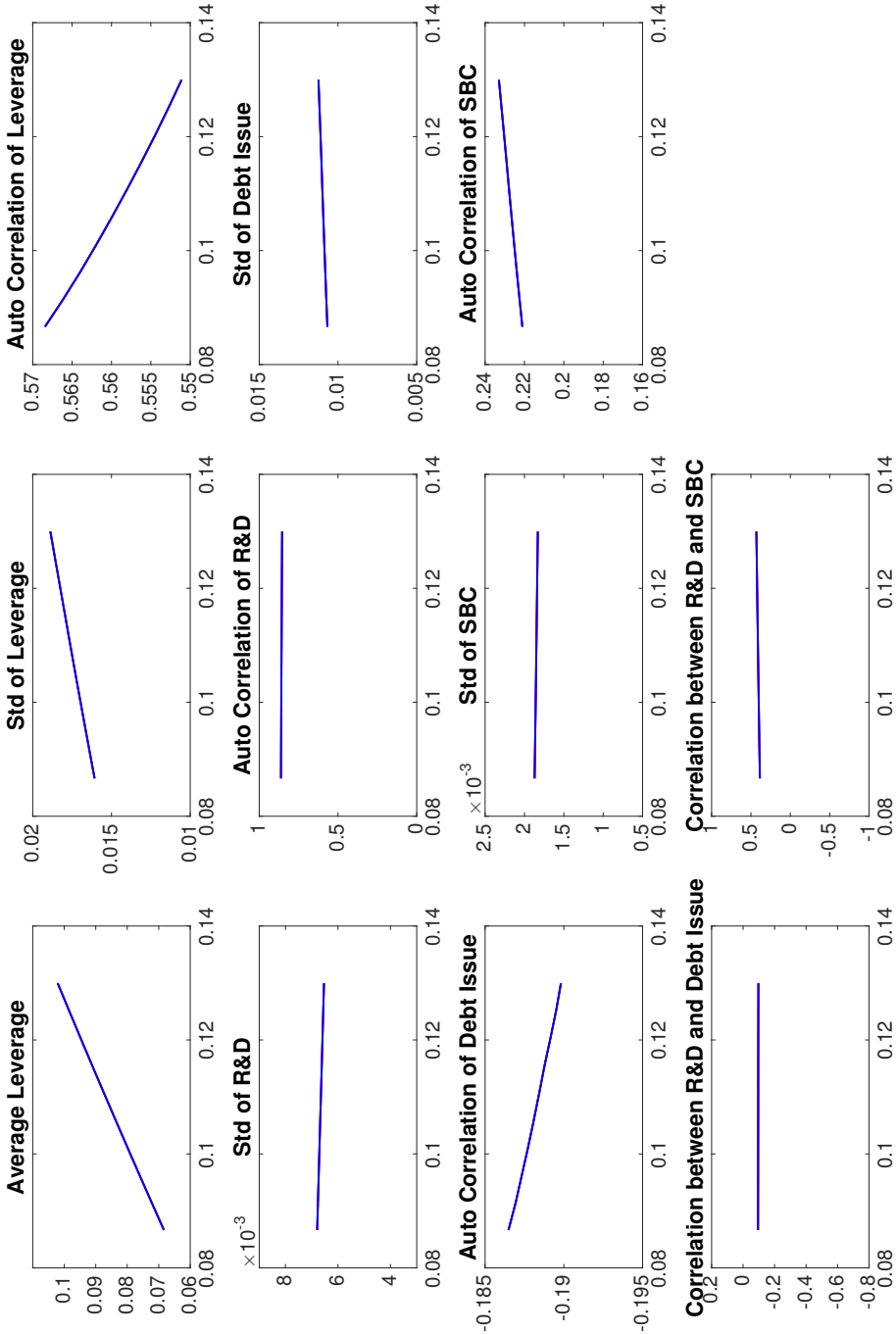
This figure shows the sensitivity of each moment to the change of the debt enforcement parameter ξ. The x-axis is the parameter, and the y-axis represents the simulated moments.

Figure 7: **The portability of intangible capital** η.
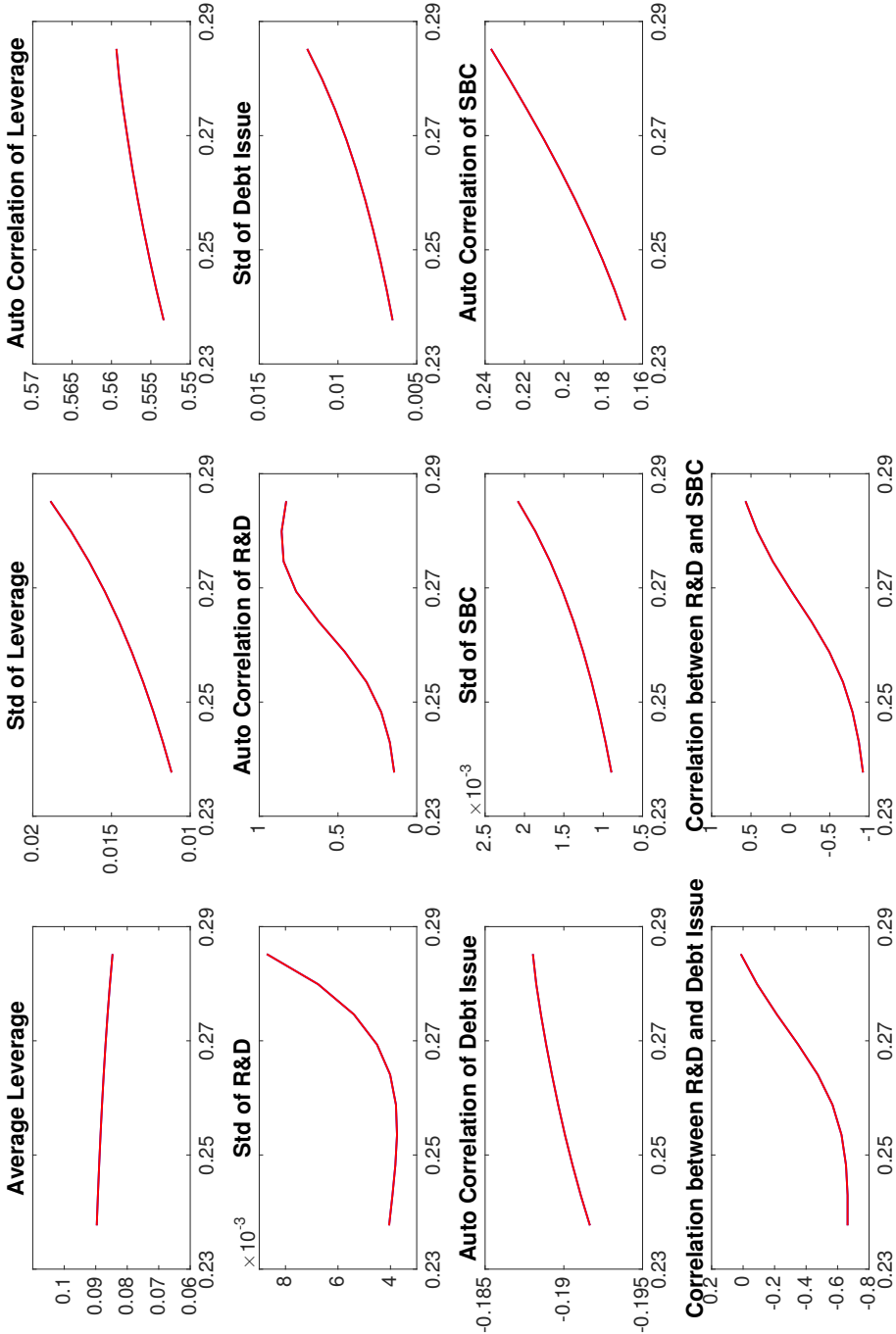
This figure shows the sensitivity of each moment to the change of the portability of intangible capital η. The x-axis is the parameter, and the y-axis represents the simulated moments.

Table 5: **Sensitivity of η and ξ**

Panel A: Simulated Moments	benchmark	$\eta \searrow$	$\xi \searrow$
Average leverage	0.098	0.102	0.088
Standard deviation of leverage	0.022	0.016	0.021
Autocorrelation of leverage	0.626	0.617	0.629
Average R&D investment	0.3335	0.2439	0.3339
Standard deviation of R&D investment	0.008	0.005	0.008
Autocorrelation of R&D investment	0.907	0.328	0.907
Average debt issuance	0.0006	0.0004	0.0006
Standard deviation of debt issuance	0.012	0.008	0.012
Autocorrelation of debt issuance	-0.153	-0.157	-0.153
Average stock-based compensation	0.0083	0.0061	0.0083
Standard deviation of stock-based compensation	0.002	0.001	0.002
Autocorrelation of stock-based compensation	0.337	0.304	0.335
Correlation between R&D investment and debt issuance	-0.118	-0.600	-0.116
Correlation between R&D investment and stock-based compensation	0.395	-0.782	0.390

In this table, we show the sensitivity of the simulated moments of our model with respect to the change in parameters η and ξ. We report the simulated moments of our model by reducing the value of parameters η and ξ from the benchmark value by 10%, respectively. Column (1) reports the simulated moments from our benchmark estimation. Column (2) shows the simulated moments with the value of η lowered by 10% while keeping other parameters unchanged. Column (3) shows the simulated moments with the value of ξ lowered by 10% while keeping other parameters unchanged. Although in this dynamic model, all moments change as we shift parameters, we can see that 1) the leverage ratio is very sensitive to the change in ξ and 2) the correlation between R&D investment and SBC is most sensitive to the change in η.

4 Counterfactual: Financial Effects of Debt Enforcement

In this section, we investigate the effect of change of ξ on the firm's financing activities and investment. In Table 6, we report the value of financing capacity, financial buffers, investment rate, as well as firm value in the case of high debt enforcement rate (traditional industries with $\xi = 0.226$) and the case high debt enforcement rate (traditional industries with $\xi = 0.129$). As in Section 5.7 in the main paper, we keep other parameters the same as for the traditional industries. The counterfactual is interpret what the consequential impact on the financial leverage and value of a firm in the traditional industries if there is a negative shock to the capital market condition for traditional firms.

Panel A of Table 6 shows that ξ has a direct and sizable effect on the firm's leverage. The debt capacity decreases by 38% as ξ drops to 0.129. Debt enforcement rate ξ directly affects the debt capacity $\xi\beta\mathbb{E}[\tilde{V}']$. The higher the enforcement rate, the higher the debt capacity. The financial buffer is tighter after the negative shock to ξ.

Unlike the changes of the portability parameter η which has impacts on both the debt capacity and employment financing capacity, the change of enforcement rate ξ does not have significant impacts on the employee financing capacity. This is because that the change of capital market condition is independent of the productivity shock of the firm and the labor market conditions, which both drive the usage of employee financing. Employee financing does increase slightly but not enough to compensate the loss of debt capacity. This key result distinguishes our channel from the internal credit market channel in the existing literature (**?**, **?**) which emphasize the importance of financial constraint on the usage of employee financing. Our "collateral" constraint mechanism highlights that firms optimally seek for financing through wage contracts even if they are not financially constrained. The importance of intangible capital in the production function put the employee financing in the first order due to the retention motive. Hence, tightening the financial condition is not necessarily lead to more employee financing.

In Panel C, we find the intangible investment rate does not deviate significantly from the depreciation rate because the counterfactual exercise compares two stationary means of the investment rate. In Panel D, we find that both equity value and employee equity value increases when debt enforcement rate decreases, with equity value increases by the amount that compensates the decline in the outstanding debt value. The total firm value remains insignificant change because the reduction in outstanding liability is transferred to the equity holders.

Table 6: **Employee Financing and Debt Enforcement**

	(1)	(2)	(3)	(4)
	Traditional $\xi = 0.226$	Traditional $\xi = 0.129$	**Changes**	**Changes** %
PANEL A: CAPACITY				
Debt capacity, $\xi\beta\mathbb{E}[\tilde{V}']$	0.0897	0.0551	-0.0341	-38%
Employee financing capacity, $\beta_w\tilde{\tau}'_H$	0.6501	0.6587	+0.0086	+1%
Employee financing capacity, $\beta_w\tilde{\tau}'_L$	0.6196	0.6216	+0.0020	+0.3%
PANEL B: FINANCIAL BUFFER				
Debt capacity, $\xi\beta\mathbb{E}[\tilde{V}']$	0.0897	0.0551	-0.0341	-38%
Debt outstanding, $\frac{\tilde{b}'}{R}$	0.0872	0.0548	-0.0324	-37%
Debt buffer, $\frac{\xi\beta\mathbb{E}[V']-\frac{b'}{R}}{\xi\beta\mathbb{E}[V']}$ (relative to debt capacity)	0.0278	0.0054	-0.0224	-81%
PANEL C: INVESTMENT				
Investment rate, $\tilde{e}$	0.0864	0.0863	-0.0001	-0.1%
PANEL D: FIRM VALUE				
Equity value, V	0.4107	0.4407	+0.0300	+7%
Employee equity value, τ	0.6577	0.6594	+0.0017	+0.3%
Debt value, b	0.0884	0.0556	-0.0328	-37%
Total firm value, $V + \tau + b$	1.1568	1.1557	-0.0011	-0.1%
Employee equity ratio, $\frac{\tau}{V+\tau}$	0.62	0.60	-0.02	-3%

This table reports the value of financing capacities, buffers (slack of the constraints), as well as investment and equity value, in the case of high debt enforcement rate (traditional industries with $\xi = 0.226$) and in the case of low debt enforcement rate (traditional industries with $\xi = 0.129$) while keeping the other parameters the same as for the traditional industries. Column (1) uses the parameters estimated from the traditional industries. In Column (2), the value of debt enforecement rate ξ is replaced by the value found for the high-tech industries group. All variables are expressed in units of cash flow. All variables $\tilde{x} = \frac{x}{h}$ from the normalized model (See appendix **??**).

5   More Proofs

5.1   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:

$$d_t = z_t h_t - c_t - e_t + \frac{b_{t+1}}{R_t} - b_t \geq 0 \tag{11}$$

$$h_{t+1} = (1-\delta)h_t + \phi(e_t/h_t)h_t \tag{12}$$

$$\xi\beta\mathbb{E}_t\sum_{n=0}^{\infty}\beta^n d_{t+1+n} \geq \frac{b_{t+1}}{R_t} \tag{13}$$

$$\beta\mathbb{E}_{t+1}\sum_{n=0}^{\infty}\beta^n u(c_{t+1+n}) \geq \beta\omega(z_{t+1}, h_{t+1}), \ \forall z_{t+1}. \tag{14}$$

Equation (11) is the budget constraint. Equation (12) is the law of motion of intangible capital h. Equation (13) is the debt enforcement constraint. Equation (14) 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 (14) is equivalent to the following recursive form:

$$m_t = u(c_t) + \beta\mathbb{E}_t[\mathbf{m_{t+1}}], \tag{15}$$

$$\beta\mathbf{m_{t+1}}(z_{t+1}, h_{t+1}) \geq \beta\omega(z_{t+1}, h_{t+1}), \ \forall z_{t+1}, \tag{16}$$

where equation (15) is the promise-keeping constraint, and equation (16) is the participation constraint. Substituting equation (14) with (15) and (16), we obtain the recursive problem $\mathcal{P}$.

5.2 Capital Structure Dynamics: Debt and Equity

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 A 1 *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: $\mu > \frac{(1-\beta R)\lambda}{(1+\xi\beta R\lambda)}$.*

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

$$b' \quad : \quad \mu = \beta R(1 + \mu\xi)E[V_b'|z] + \lambda \tag{17}$$

$$m'(z') \quad : \quad \gamma(z') = -(1 + \mu\xi)V_{m'(z')}' - \theta \tag{18}$$

$$h' \quad : \quad q = \beta(1 + \mu\xi)E[V_h'|z] + \lambda z - \beta\sum_{z'}\pi(z'|z)\gamma(z')\omega_{h'}(z',h') \tag{19}$$

$$d \quad : \quad \lambda = \frac{1}{\varphi'(d)} \tag{20}$$

$$e \quad : \quad q = \frac{\lambda}{\phi'(\frac{e}{h})} \tag{21}$$

$$c \quad : \quad \theta = \frac{\lambda}{u'(c)} \tag{22}$$

and the Envelope conditions:

$$b \quad : \quad V_b = -\lambda \tag{23}$$

$$m \quad : \quad V_m = -\theta \tag{24}$$

$$h \quad : \quad V_h = \lambda z + q[(1 - \delta) + \phi(\frac{e}{h}) - \phi'(\frac{e}{h})\frac{e}{h}] \tag{25}$$

Equations (17)-(25) completely capture the system.

From F.O.C (17) and Envelope condition (23), we obtain

$$\mu = \lambda - (1 + \mu\xi)\beta RE[\lambda'|z] \tag{26}$$

- 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 $\mu > (1 - \beta R)\lambda/(1 + \xi\beta R\lambda)$.

Proposition 1 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.

6 Data

6.1 Data Construction

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

firm (such as standard deviations and auto-correlations), we drop firms with fewer than eight quarters of data.

6.2 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 = (Sales (SALEQ) - Cost of Goods Sold (COGSQ)) / Total Assets (ATQ)

- Tobin's Q = (Common Shares Outstanding (CSHOQ) * PRCCQ +Total Asset (ATQ) - Common/Ordinary Equity - Total (CEQQ)) / Total Assets (ATQ)

7 Tables

This section includes additional regression tables for robustness checks.

Table 7: **Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1**

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

The table reports the results of regressing investment on sources of finance. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). CF is the cash flow defined as Sales (saleq) - Cost of Goods Sold (cogsq). Q is defined as the market value of assets (cshoq*prccq+atq-ceqq) divided by the book value of Assets (atq). All variables are scaled by total book asset (atq). Data source: Compustat Fundamentals Quarterly 2006q1-2015q1. t-statistics in parentheses. $* p < 0.10$, $** p < 0.05$, $*** p < 0.01$.

Table 8: Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1 (High Tech and Health Product Industries)

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: High Tech			Panel B: Health Product		
	CAPX	RD	SGA	CAPX	RD	SGA
Debt Issuance	0.011***	0.007	0.000	0.030***	-0.016	-0.007
	(3.41)	(1.53)	(0.09)	(5.00)	(-1.41)	(-0.81)
Equity Issuance	-0.009	-0.017	-0.033**	-0.013**	-0.062***	-0.046*
	(-1.12)	(-0.94)	(-2.07)	(-2.02)	(-2.88)	(-1.82)
SBC	0.061**	0.927***	1.327***	0.129***	1.330***	1.334***
	(2.11)	(9.82)	(12.92)	(4.23)	(11.16)	(10.26)
CF	0.016***	0.099***	0.180***	0.004	-0.019*	0.097***
	(5.34)	(10.72)	(18.28)	(1.40)	(-1.88)	(8.22)
Q	0.001***	0.000	-0.000	0.000***	0.003***	0.002***
	(5.92)	(0.00)	(-1.44)	(3.92)	(7.74)	(4.42)
_cons	0.004***	0.013***	0.022***	0.005***	0.031***	0.031***
	(6.47)	(10.36)	(17.63)	(8.80)	(16.04)	(16.67)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y	Y	Y
N	21,009	21,009	20,543	12,963	12,963	8,363
N_clust	1,006	1,006	996	631	631	471
r2_a	0.039	0.167	0.322	0.039	0.147	0.197

t statistics in parentheses

The table reports the results of regressing investment on sources of finance. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). CF is the cash flow defined as Sales (saleq) - Cost of Goods Sold (cogsq). Q is defined as the market value of assets (cshoq*prccq+atq-ceqq) divided by the book value of Assets (atq). All variables are scaled by total book asset (atq). Panel A reports regression results in *High Tech*, or *Information, Computer, and Technologies (ICT)* industries. Panel B reports regression results in *Health Product* industries. Data source: Compustat Fundamentals Quarterly 2006q1-2015q1. t-statistics in parentheses. $* p < 0.10$, $** p < 0.05$, $*** p < 0.01$.

Table 9: **Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1 (Scaled by h)**

	(1) CAPX	(2) RD	(3) SGA	(4) CAPX	(5) RD	(6) SGA
Debt Issuance	0.008***	0.004***	0.002***	0.008***	0.004***	0.001***
	(6.05)	(3.54)	(4.49)	(5.85)	(3.35)	(4.22)
Equity Issuance	0.010*	0.012***	0.002	0.009*	0.011***	0.001
	(1.95)	(3.01)	(1.50)	(1.75)	(2.71)	(1.04)
SBC				0.107***	0.071***	0.057***
				(5.38)	(3.42)	(8.62)
CF	0.001*	-0.002	0.001***	0.000	-0.003**	0.001**
	(1.65)	(-1.60)	(4.10)	(0.50)	(-2.47)	(2.39)
Q	0.009***	0.002***	0.001***	0.009***	0.002***	0.001***
	(13.36)	(4.05)	(4.08)	(12.92)	(3.22)	(3.21)
L.Debt Issuance	0.002	0.002**	0.002***	0.002	0.002**	0.002***
	(1.40)	(2.23)	(5.36)	(1.41)	(2.11)	(5.29)
L.Equity Issuance	0.024***	0.008**	0.005***	0.023***	0.006	0.004***
	(4.57)	(2.07)	(3.87)	(4.34)	(1.46)	(3.24)
L.CF	0.002*	0.011***	0.000	0.001	0.009***	-0.000
	(1.84)	(9.12)	(0.56)	(1.08)	(8.32)	(-0.94)
L.SBC				0.021	0.128***	0.015***
				(1.10)	(6.43)	(3.07)
Const.	0.060***	0.087***	0.044***	0.058***	0.084***	0.043***
	(22.83)	(45.19)	(58.42)	(22.21)	(44.05)	(57.26)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y	Y	Y
N of Obs.	31,843	31,843	31,843	31,843	31,843	31,843
ID	1,589	1,589	1,589	1,589	1,589	1,589
Adj. R^2	0.052	0.302	0.140	0.055	0.318	0.160

The table reports the results of regressing investment on sources of finance. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). Variables in this table are normalized by the book value of empirical estimates of h, which we follows **?**.[2] Data Source: CRSP/Compustat Merged Database Quarterly from 2006q1 to 2015q1. t-statistics in parentheses. $* \ p < 0.10, \ ** \ p < 0.05, \ *** \ p < 0.01$.

Table 10: **Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1 (Traditional and High-Tech: Scaled by h)**

	Traditional R&D	High-Tech R&D	Traditional CAPX	High-Tech CAPX	Traditional SGA	High-Tech SGA
Debt Issuance	0.001	0.006***	0.008***	0.007***	0.001	0.002***
	(0.65)	(3.41)	(4.73)	(3.61)	(1.64)	(4.19)
Equity Issuance	0.010	0.013***	0.004	0.013**	-0.001	0.003*
	(1.47)	(2.61)	(0.46)	(2.06)	(-0.68)	(1.81)
SBC	-0.020	0.132***	0.037	0.172***	0.020***	0.082***
	(-0.70)	(4.38)	(1.37)	(6.03)	(2.65)	(8.18)
CF	-0.003*	-0.004*	-0.000	0.003**	0.001	0.001***
	(-1.67)	(-1.67)	(-0.53)	(2.07)	(1.28)	(2.96)
Q	0.003**	0.001**	0.013***	0.008***	0.001*	0.001**
	(2.17)	(2.12)	(8.68)	(9.66)	(1.69)	(2.55)
L.SBC	0.120***	0.138***	0.032	0.017	0.006	0.025***
	(3.99)	(4.64)	(1.13)	(0.67)	(1.00)	(3.03)
L.Debt Issuance	0.001	0.003*	0.001	0.003	0.001	0.003***
	(0.69)	(1.83)	(0.66)	(1.45)	(1.41)	(5.92)
L.Equity Issuance	0.003	0.005	-0.008	0.036***	0.002	0.005***
	(0.34)	(1.24)	(-0.96)	(5.52)	(0.92)	(3.23)
L.CF	0.009***	0.011***	0.001	0.000	-0.000	-0.000
	(6.31)	(5.30)	(0.97)	(0.11)	(-0.14)	(-1.21)
Const.	0.079***	0.084***	0.040***	0.063***	0.035***	0.045***
	(18.82)	(39.40)	(8.57)	(20.31)	(26.74)	(49.56)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y	Y	Y
N of Obs.	7,681	23,582	7,681	23,582	7,681	23,582
ID	395	1,159	395	1,159	395	1,159
Adj.R^2	0.287	0.339	0.085	0.052	0.132	0.176

The table reports the results of regressing investment on sources of finance for both the traditional industries group and ICT and health product industries group. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). Variables in this table are normalized by the book value of empirical estimates of h, which we follows **?**. Data Source: CRSP/Compustat Merged Database Quarterly from 2006q1 to 2015q1. t-statistics in parentheses. $* p < 0.10$, $** p < 0.05$, $* * * p < 0.01$.

Table 11: **Intangible Investment and Financing Channels: Firm Level 2006q1—2015q1 (Traditional and ICT: Scaled by h)**

	Traditional R&D	ICT R&D	Traditional CAPX	ICT CAPX	Traditional SGA	ICT SGA
Debt Issuance	0.001	0.005***	0.008***	0.006***	0.001	0.002***
	(0.65)	(2.95)	(4.73)	(2.58)	(1.64)	(3.56)
Equity Issuance	0.010	0.009	0.004	0.021**	-0.001	0.002
	(1.47)	(1.42)	(0.46)	(2.51)	(-0.68)	(1.06)
SBC	-0.020	0.173***	0.037	0.164***	0.020***	0.091***
	(-0.70)	(4.78)	(1.37)	(4.34)	(2.65)	(7.09)
L.SBC	0.120***	0.125***	0.032	-0.006	0.006	0.019**
	(3.99)	(3.79)	(1.13)	(-0.20)	(1.00)	(1.98)
CF	-0.003*	-0.001	-0.000	0.004***	0.001	0.002***
	(-1.67)	(-0.23)	(-0.53)	(2.80)	(1.28)	(3.97)
Q	0.003**	-0.000	0.013***	0.008***	0.001*	0.000
	(2.17)	(-0.51)	(8.68)	(8.00)	(1.69)	(0.92)
L.Debt Issuance	0.001	0.004*	0.001	-0.001	0.001	0.003***
	(0.69)	(1.94)	(0.66)	(-0.51)	(1.41)	(5.98)
L.Equity Issuance	0.003	0.000	-0.008	0.037***	0.002	0.003*
	(0.34)	(0.06)	(-0.96)	(4.21)	(0.92)	(1.81)
L.CF	0.009***	0.009***	0.001	0.000	-0.000	-0.001*
	(6.31)	(4.40)	(0.97)	(0.14)	(-0.14)	(-1.67)
Const.	0.079***	0.086***	0.040***	0.068***	0.035***	0.044***
	(18.82)	(37.76)	(8.57)	(19.89)	(26.74)	(46.70)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Y	Y	Y	Y	Y	Y
N of Obs.	7,681	17,493	7,681	17,493	7,681	17,493
ID	395	839	395	839	395	839
Adj. R^2	0.287	0.427	0.085	0.059	0.132	0.213

The table reports the results of regressing investment on sources of finance for both the traditional industries group and the high-tech industries group. R&D Expenses (xrdq), SBC is the stock-based compensation (stkcoq), Debt Issuance is defined as Long-Term Debt Issuance (dltisq) - Long-Term Debt Reduction (dltrq) + Current Debt Changes (dlcchq). Equity Issuance is Sales of Common and Preferred Stocks (sstkq). SGA is our robustness measure of intangible investment, which is calculated as xrdq+0.3*(xsgaq-xrdq). Variables in this table are normalized by the book value of empirical estimates of h, which we follows **?**. Data Source: CRSP/Compustat Merged Database Quarterly from 2006q1 to 2015q1. t-statistics in parentheses. $*$ $p < 0.10$, $**$ $p < 0.05$, $***$ $p < 0.01$.