Asset Collateralizability and the Cross-Section of Expected Returns*

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Abstract

This paper studies the implications of credit market frictions on the cross-section of stock returns. Theory implies that the tightness of financial constraint is countercyclical. As a result, collateralizable capital, that relaxes financial constraint in economic down turns, provides insurance against aggregate shocks, therefore this type of capital demands lower returns. We present a production-based general equilibrium model to quantify the effect of the above mechanism on the cross-section of expected returns, where firms are subject to collateral constraint. Consistent with the predictions of our model, we find that in the data firms with more non-collateralizable capital have average annualized returns that are 4.8% higher than firms with more collateralizable capital.

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1 Introduction

A large volume of literature in economics and finance emphasizes the importance of credit market frictions in affecting macroeconomic fluctuations.[1] Although models differ in details, a common prediction is that financial constraints exacerbate economic downturns because they are more binding in recessions. As a result, theories of financial frictions predict that assets that relax financial constraints should provide insurance against aggregate shocks. We evaluate the implication of this mechanism on the cross-section of equity returns.

To formalize the above observation, we present a dynamic stochastic general equilibrium (DSGE) model with financial constraints and the production involving the heterogeneity in assets based on their collateralizability. The entrepreneurs borrow risk-free bond from the workers, and invest into the production technology of the non-financial firms. In the same spirit of Kiyotaki and Moore (1997), the credit constraint is motivated by a limited enforcement story, and it provides a need for entrepreneurs to use collateral to obtain loans. In order to study the cross-sectional asset pricing implications, we allow for two types of assets as the inputs of the production technology. The major difference of them lies in that one asset can be used as collateral against debt, while the other type cannot. We argue that different collateralizability is the key driver of the cross-sectional return pattern that we observe in the data. Comparing with non-pledgable asset, the collateralizable asset not only produces output, but also helps to relax the credit constraint. Since the constraint tends to bind more severely in the bad times, collateralizable asset's value of loosening the constraint is counter-cyclical and thus makes it to be less risky. Calibrated to the aggregate moments from the aggregate production side, we use this model framework to explicitly quantify such a channel on the cross-section of asset returns across assets with different collateralizability.

In order to study the empirical relation between asset collateralizability and risk premia, we construct a measure of collateralizability based on asset tangibility. We use intangible capital as a proxy for non-collateralizable capital at firm level. By the nature of intangible capital, it is hard to quantify its value, therefore intangible capital can hardly be pledged as collateral[2].

Consistent with our theory, we document that firms with more collateralizable capital have on average lower stock returns in the data. We construct a high minus low portfolio by long firms with more non-collateralizable capital and short firms with less

[1] Quadrini (2011) and Brunnermeier et al. (2012) provide comprehensive reviews of this literature.

[2] We call collateralizable asset as physical capital, non-collateralizable as intangible capital interchangeably through this paper.

non-collateralizable capital. The portfolio has average annualized return 4.8% per year. The spread is still significant even after controlling for market portfolios, size, value, momentum, profitability risk factors.

When calibrated to standard statistics of the dynamics of macroeconomic quantities, our model is able to reproduce the key features of asset returns data, including the equity premium and, more importantly, the difference in the average return on assets with different collateralizability. Our model generates a high equity premium 3.5% per year with a relative risk aversion of 10 and a low and smooth risk-free interest rate. The simulated aggregate quantities are comparable to those obtained by the standard real business cycle models in terms of the second moments of aggregate output, consumption, as well as tangible and intangible investments. Furthermore, the model generates annualized return on collateralizable capital 5.1% higher than that on non-collateralizable capital, in line with the data.

In summary, our work emphasizes the credit market frictions have strong implications on cross-section of expected returns. From the perspective of shareholders, investing in firms with more non-collateralizable assets is risky than firms with more pledgeable physical assets, because unlike the physical capital, non-collateralizable capital does not offer benefits from the countercyclical value of relaxing the credit constraint. Consequently, it has risk characteristics distinct from those of physical capital, and the risk inherent in this type of capital requires significant risk premia.

This paper builds on the growing literature of macroeconomic models focusing on the role of credit market frictions, but we do not attempt to summarize it here. A partial list of papers most related to ours include Kiyotaki and Moore (1997), Kiyotaki and Moore (2012), Gertler and Kiyotaki (2010), He and Krishnamurthy (2014), and Brunnermeier and Sannikov (2014), where financial frictions plays an important role of exacerbating the negative aggregate shocks to the economy, because the financial constraints are more binding in recessions. Our paper differs from the prior literature by emphasizing the implications of credit market frictions on the cross-section of asset returns, rather than macroeconomic quantities and the aggregate stock market. To study the cross-section, we introduce two different types of capital into this economy, one is collateralizable while the other one is not. our theory predicts that collateralizable assets that relax financial constraints should provide insurance against aggregate shocks and therefore earn lower average return. We document the consistent empirical evidence, and quantify the implications of this mechanism.

Our paper connects to the production based asset pricing literature, which was surveyed by Kogan and Papanikolaou (2012). Our study differs from previous literature in two important dimensions. First, our model generates the equity premium puzzle, as does the rest of the literature, but more importantly we study the return spread between assets with different collateralizability. Second, we focus on the interplay of financial frictions and collateralizability. In particular, the endogenous countercyclical tightness of the collateral constraint makes the collateralizable asset to be an insurance for aggregate shocks, and therefore less risky than the non-collateralizable asset.

This study builds on the intangible capital literature. The measure of non-collateralizable capital is based on intangible capital. We measure intangible capital following Falato et al. (2013), Peters and Taylor (2016), Eisfeldt and Papanikolaou (2013). Falato et al. (2013) documents that only 3% of total loan value have patents or brands as collateral, and they show that when firms have more intangible capital, they have less physical capital as collateral, this will decrease their debt capacity, therefore firms will increase cash holding to preserve their financial flexibility. Our paper differs from Falato et al. (2013), as we are focusing on the implications of cross-section of stock returns. Additionally, our empirical finding suggests that firms with more intangible capital have higher returns is in line with previous empirical asset pricing literature as in Chan et al. (2001), Li (2011) and Eisfeldt and Papanikolaou (2013). Chan et al. (2001) shows that firms with higher R&D expenditure to market value have higher stock returns. Li (2011) shows that if firms are more constrained, then firms with more R&D capital[3] have higher stock return. Eisfeldt and Papanikolaou (2013) interprets organizational capital as human capital, the firms key talents' outside option will make the firm more risky, therefore investors demand higher risk premium. Our study has a different interpretation on the risk profile of intangible capital, based on the fact that it cannot easily serve as collateral.

The rest of the paper is organized as the following, section 2 introduces our model, section 3 explores the predictions of the model, section 4 concludes.

2 The Model

We introduce collateral constraint in the spirit of Gertler and Kiyotaki (2010) into an otherwise standard neoclassical growth framework, where the entrepreneurs hold two types of assets, one type of which cannot be used as collateral. The economy is of infinite horizon and time is discrete.

[3]Accumulation of past 5 years R&D expenditure net of depreciation rate 20%.

2.1 Households

There is a continuum of identical households of measure one in this economy. Each household is consist of two members, worker and entrepreneur. Workers supply labor inelastically to firms and obtain wage payments each period. Entrepreneurs are operating the firms and transfer earnings to the household. Within each household, there is perfect consumption insurance between two members. Workers do not have access to the asset markets, where state contingent securities are traded, they can only save through the bond issued by the entrepreneurs. The workers do not invest the entrepreneur which belongs to the same household. Only entrepreneurs get access to the asset market in this economy.

The households in this economy is endowed with recursive preference as Epstein and Zin (1989),

$$U_t = \left\{ (1-\beta) C_t^{1-\frac{1}{\psi}} + \beta (E_t[U_{t+1}^{1-\gamma}])^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}, \tag{1}$$

where β is the time discount rate, ψ is the intertemporal elasticity of substitution, γ is the relative risk aversion.

The household receives wages W_t and payout from the ownership of firms Π_t^B each period, the budget constraint reads,

$$C_t + B_t = R_{t-1}^f B_{t-1} + W_t L_t + \Pi_t^B.$$

Let M_{t+1} be the stochastic discount factor, or intertemporal marginal rate of substitution, between time period t and $t+1$, from the optimal choice of household, we arrive

$$M_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\psi}} \left(\frac{U_{t+1}}{E_t[U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma}$$

$$R_t^f = \frac{1}{E_t[M_{t+1}]}.$$

2.2 Firms

Final goods producers are equipped with constant return to scale technology with capital and labor as inputs. Entrepreneurs hold the capital, firms only make static labor choice, and pay all the remaining cash flow net of wage bill to entrepreneurs. The production technology is specified as

$$Y_t = A_t (K_t^{\phi} H_t^{1-\phi})^{\alpha} L_t^{1-\alpha}, \tag{2}$$

where K_t is collateralizable capital, H_t is non-collateralizable capital, ϕ is the share of collateralizable capital in production. Hereafter, we will call collateralizable asset as physical capital, non-collateralizable as intangible capital interchangeably. In this economy, we assume learning by doing, TFP is augmented by the capital stock of the economy, which is

$$A_t = \tilde{A}_t (K_t^{\phi} H_t^{1-\phi})^{1-\alpha}.$$

The exogenous component of TFP process $\tilde{a}_t = \log \tilde{A}_t$, follows an autoregressive process,

$$\tilde{a}_t = (1-\rho^A)\bar{a} + \rho^A \tilde{a}_{t-1} + \varepsilon_t^A,$$

where $\bar{a}$ is the productivity in steady state. The optimization problem of the firm is

$$\max_{L_t} Y_t - W_t L_t.$$

Thanks to the assumption of constant return to scale production technology, profits generated by two types of assets paid out to the entrepreneur per unit can be represented by marginal productivity of capital.

$$MPK_t^K = \frac{\partial Y_t}{\partial K_t} = \alpha\phi \frac{Y_t}{K_t} \tag{3}$$

$$MPK_t^H = \frac{\partial Y_t}{\partial H_t} = \alpha(1-\phi)\frac{Y_t}{H_t}. \tag{4}$$

At the end of each period t, firm sells the depreciated capital to the competitive market at price q_t for collateralizable asset and p_t for non-collateralizable asset. Therefore the total returns on the two types of capital paid to the entrepreneurs are

$$R_{t+1}^K = \frac{MPK_{t+1}^K + q_{t+1}(1-\delta_K)}{q_t} \tag{5}$$

$$R_{t+1}^H = \frac{MPK_{t+1}^H + p_{t+1}(1-\delta_H)}{p_t}. \tag{6}$$

2.3 Capital Goods Producer

After production taken place, at the end of each period t, capital goods producer convert investment goods into new capital goods and then repair depreciated capital to form new capital for production in period $t+1$. Let I_t and J_t be the investment of collateralzible and non-collateralizable asset respectively. The optimization problems of collateralizable capital goods producer reads

$$\max_{I_t} \quad q_t G^K \left(\frac{I_t}{K_t} \right) K_t - I_t,$$

where q_t is the value of a unit of new capital, by solving the static problem we obtain

$$q_t = 1/G^{K'}(\frac{I_t}{K_t}).$$

The flow budget constraint of collateralizable capital is $K_{t+1} = (1-\delta_K)K_t + G^K \left(\frac{I_t}{K_t}\right) K_t$

The production of non-collateralizable capital goods is similar,

$$\max_{J_t} \quad p_t G^H \left(\frac{J_t}{H_t} \right) H_t - J_t,$$

where p_t is the value of a unit of new capital, the solution to the optimization problem yields

$$p_t = 1/G^{H'}(\frac{J_t}{H_t})$$

The flow budget constraint of non-collateralizable asset is $H_{t+1} = (1-\delta_H)H_t + G^H \left(\frac{J_t}{H_t}\right) H_t$.

The functional form of capital goods producers' technology is specified as

$$G_t^K \left(\frac{I_t}{K_t} \right) = \frac{a_1^K}{1 - 1/\xi^K} \left(\frac{I_t}{K_t} \right)^{1-1/\xi^K} + a_2^K \tag{7}$$

$$G_t^H \left(\frac{J_t}{H_t} \right) = \frac{a_1^H}{1 - 1/\xi^H} \left(\frac{J_t}{H_t} \right)^{1-1/\xi^H} + a_2^H. \tag{8}$$

We use non-collateralizable capital and intangible, collateralizable capital and physical capital interchangeably in this paper.

2.4 Entrepreneur

Entrepreneurs finance their asset position through net worth and loans obtained from households. They operate firms with survival rate λ, with probability $1-\lambda$ they are forced to be liquidated, paying remaining net worth to households as dividends. This assumption creates borrowing incentive for the entrepreneurs, it excludes the equilibrium where entrepreneurs accumulate enough wealth such that they become financially autarky.

At the end of each period t, entrepreneur j purchases two types of capital, K^j_{t+1} and H^j_{t+1}, from the competitive market and supply them to firms. Firms take the capital into production in $t+1$ and then pay back all the cash flow generated by capital, which is profits plus the value of depreciated capital, to the entrepreneurs. Therefore entrepreneurs receive returns R^K_{t+1} and R^H_{t+1} from capital each period.

Let N^j_t denote net worth, or the equity, at the end of period t, B^j_t denote the bond they issued, q_t and p_t are the prices of collateralizable and non-collateralizable asset respectively. The net worth of entrepreneur j is given by

$$N^j_t = q_t K^j_{t+1} + p_t H^j_{t+1} - B^j_t. \tag{9}$$

The entrepreneur receives capital returns after production take place, she pays back the debt with interest R^f_t. The evolution of net worth is

$$\begin{aligned} N^j_{t+1} &= R^K_{t+1} q_t K^j_{t+1} + R^H_{t+1} p_t H^j_{t+1} - R^f_t B^j_t \\ &= (R^K_{t+1} - R^f_t) q_t K^j_{t+1} + (R^H_{t+1} - R^f_t) p_t H^j_{t+1} + R^f_t N^j_t. \end{aligned} \tag{10}$$

The entrepreneurs share the same stochastic discount factor as the workers given the consumption insurance assumption. Entrepreneur j is maximizing the discounted dividends by optimally choosing capital and bond next period subject to the flow budget constraints equation (9), (10) and collateral constraint as equation (12)

$$V^j_t = \max_{K^j_{t+1}, H^j_{t+1}, B^j_t} E_t \left[M_{t+1} \{ (1-\lambda) N^j_{t+1} + \lambda V^j_{t+1} \} \right], \tag{11}$$

where the right hand side represents the discounted dividend payment and the continuation value of the entrepreneur, weighted by survival probability.

They key assumption in the model is that only collateralizable asset, or we call it physical capital, can be pledged as collateral, whereas non-collateralizable asset has zero value to the lender. To acquire loans B^j_t from the market, at the end of each period t, the entrepreneur can pledge all the collateralizable asset $q_t K^j_{t+1}$ to the lender, therefore the collateral constraint in this economy reads,

$$B^j_t \leq \zeta q_t K^j_{t+1}, \tag{12}$$

where ζ reflects the fact that only a fraction of the value of collateral can be recovered upon default. Latter we will see that in equilibrium, no entrepreneur will default.

This assumption makes collateralizable capital more valuable in the bad states of the world. The intuition follows the literature of economies with collateral constraint, e.g. Kiyotaki and Moore (1997) and Kiyotaki and Moore (2012), where the tightness of collateral constraint is counter cyclical. In the bad state, the collateral constraint is more binding, because the asset prices are very low, if an entrepreneur has more collateralizable capital, she can use more collateral to acquire additional loans to relax the collateral constraint, this makes collateralizable capital more valuable in bad states of the world. More collateralizable asset can provide the entrepreneur an insurance to hedge the bad state of the world. On the other hand, one additional unit non-collateralizable asset cannot alleviate the collateral constraint, therefore it is less favorable, especially in the bad states.

As in Gertler and Kiyotaki (2010), we assume that entrepreneurs' net worth can be freely traded at the end of each period, it implies that all the entrepreneurs' net worth is the same by the end of every period. This implies that all the equity return of different entrepreneurs are the same, therefore the choice of leverage is the same across different entrepreneurs. The assumption allows us to do a simple aggregation of the entrepreneurs.

2.5 Aggregation and Markets Clear

At the beginning of each period $t+1$, there is a group of new entrepreneurs entering the economy with measure $1-\lambda$, they replace the liquidated entrepreneurs, therefore the population of the economy remain unchanged over time. They are funded by household, using a fraction of the value of assets from the liquidated entrepreneurs, $\chi(1-\lambda)(q_t K_{t+1} + p_t H_{t+1})$. The aggregate law of motion of entrepreneurs' net worth is

$$N_{t+1} = \lambda \left\{ \left(Q_{t+1} - R_f q_t\right) K_{t+1} + \left(P_{t+1} - R_f p_t\right) H_{t+1} + R_f N_t \right\} + \chi(1-\lambda)(q_t K_{t+1} + p_t H_{t+1}). \tag{13}$$

The variables without superscript denote the aggregate quantities. We assume that consumption goods and investment goods can be converted one to one without any friction, therefore the market clearing condition for this economy is

$$Y_t = C_t + I_t + J_t. \tag{14}$$

2.6 Model Solution

Given the fact that the objective and the budget constraint of the entrepreneur is linear, we conjecture the value function can be summarized by one state variable, $V(N_t) = \mu_t N_t$, where μ_t is the marginal value of net worth. We can rewrite the entrepreneurs' problem as

$$\begin{aligned} \mu_t N_t^j &= \max_{K_{t+1}^j, H_{t+1}^j, B_t^j} E_t M_{t+1} \left[\lambda \mu_{t+1} N_{t+1}^j + (1-\lambda) N_{t+1}^j \right] \\ & \quad \text{s.t.}(9), (10) \text{ and } (12). \end{aligned} \tag{15}$$

Take first order condition with respect to B_t, K_{t+1}, H_{t+1}, we arrive the optimality conditions

$$E_t \left\{ M_{t+1}[\lambda \mu_{t+1} + (1-\lambda)] \right\} R_t^f = \mu_t - \eta_t \tag{16}$$
$$E_t\{M_{t+1}[\lambda \mu_{t+1} + (1-\lambda)](R_{t+1}^K - R_t^f)\} = \eta_t (1-\zeta) \tag{17}$$
$$E_t\{M_{t+1}[\lambda \mu_{t+1} + (1-\lambda)](R_{t+1}^H - R_t^f)\} = \eta_t, \tag{18}$$

where η_t is the Lagrangian multiplier associated with collateral constraint. As one could see from the optimality conditions, if the collateral constraint is never binding, then $\eta_t = 0$ for any time period t, then the non-arbitrage condition of the two types of capital will be exactly the same. If η_t is not zero in this economy, that is when the constraint is binding, the non-arbitrage conditions for the two types of capital are not the same. This will imply different dynamics of the two asset returns. As later we will see that physical capital provides insurance for bad state, therefore it has lower returns.

2.7 Asset Market

In this economy, the entrepreneurs are the marginal investors of risky assets, they are trading collateralizable and non-collateralizable asset. We assume that the equity is freely traded by the end of each period, the market equity return is effectively the equity return of entrepreneurs. Let $\tilde{M}_{t+1}$ be the effective stochastic discount factor of the entrepreneur. Assuming we are in equilibrium, dividing both sides of equation (15) by $\mu_t N_t$, we arrive

$$E_t[\tilde{M}_{t+1} R_{t+1}^M] = 1,$$

where the market return is defined as $R^M_{t+1} \equiv \frac{N_{t+1}}{N_t}$. Please note that the definition of market equity return is a levered position between assets and risk free debt. To see this,

$$R^M_{t+1} \equiv \frac{N_{t+1}}{N_t} = \frac{R^K_{t+1} q_t K_{t+1} + R^H_{t+1} p_t H_{t+1} - R^f_t B_t}{q_t K_{t+1} + p_t H_{t+1} - B_t}.$$

Therefore in order to do fair comparisons, in our quantitative results, we also lever the returns on two types of assets R^K_t and R^H_t correspondingly, using the leverage in the economy. The effective stochastic discount factor of the entrepreneur,

$$\tilde{M}_{t+1} = \frac{M_{t+1}[\lambda \mu_t + (1-\lambda)]}{\mu_t}, \tag{19}$$

should also price the two types of capital, by rearranging the equations (16), (17) and (18)

$$E_t[\tilde{M}_{t+1} R^K_{t+1}] = 1 - \zeta \frac{\eta_t}{\mu_t} \tag{20}$$

$$E_t[\tilde{M}_{t+1} R^H_{t+1}] = 1. \tag{21}$$

The intuition of equation (20) and (21) is that the effective stochastic discount factor of entrepreneur prices the two types of asset. Following the intuition of standard consumption saving problem, when the investment in collateralizable capital is constrained, $\eta_t > 0$, the Euler equation does not neccessary to hold, since one additional unit of this type of asset can provide additional value by relaxing the constraint, which is on top of marginal utility of consumption. The investment in non-collateralizable capital is not constrained, therefore the corresponding Euler equation should hold in every state of the world.

Additionally, we assume there is a one period inter-entrepreneur loan traded among the entrepreneurs, because every entrepreneur is ex ante identical, in equilibrium this loan is not traded. The shadow rate of return R^I_t is priced by the stochastic discount factor of the entrepreneurs,

$$E_t[\tilde{M}_{t+1}] R^I_t = 1.$$

Latter we will see in calibration part, by introducing this inter-entrepreneur loan, we can discipline the behavior of $\tilde{M}$. Workers invest in risk free asset, therefore their stochastic discount factor price the risk free asset,

$$E_t[M_{t+1}] R^f_t = 1.$$

2.8 Model Predictions

Our model predicts that physical (collateralizable) asset have lower returns than intangible (non-collateralizable) asset. The intuition is the following: when a bad shock hits the economy, asset prices go down, the collateral constraint becomes more binding, one additional unit of physical asset can provides more collaterals to the entrepreneur such that she can borrow more in the bad states, hence it is more valuable in bad states of the world. For intangible asset, it cannot be used as collateral, one additional unit of it would not relax the collateral constraint. Therefore, physical capital can be seen as an insurance against the states when the collateral is binding, it is less risky compare to intangible asset from the perspective of entrepreneurs.

We can derive the analytical form of the return spread in the model, by combining equation (21) and (20).

$$E_t[\tilde{M}_{t+1}(R^H_{t+1} - R^K_{t+1})] = \zeta \frac{\eta_t}{\mu_t} \tag{22}$$

$$E_t[R^H_{t+1} - R^K_{t+1}] = \underbrace{\frac{\zeta}{E_t[\tilde{M}_{t+1}]} \frac{\eta_t}{\mu_t}}_{\text{liquidity premium}} \underbrace{- \frac{1}{E_t[\tilde{M}_{t+1}]} Cov_t(\tilde{M}_{t+1}, R^H_{t+1} - R^K_{t+1})}_{\text{risk premium}} . \tag{23}$$

We call the first component as the liquidity premium, since it is associated with the collateral constraint. When the collateral constraint is more binding, which is higher η_t in our case, the illiquid asset is more risky, the liquidity premium increases. When more fraction of collateralizable capital can be pledged, controlled by parameter ζ, it will make collateralizable capital more liquid compare to non-collateralizable capital, it will also increase the liquidity premium. Investors demand positive liquidity premium because illiquid asset is more risky.

The second component has the form of standard risk premium, defined by the covariance between return spread and stochastic discount factor. Given our intuition, the collateralizable capital is more valuable in the bad time, and stochastic discount factor is counter cyclical, therefore the covariance between SDF and return on collateralizable capital should be less negative than the one with non-collateralizable capital, hence the risk premium component should also be positive.

From the discussion above, our model predicts that both of the two components of the expected return spread are positive. Additionally by the definition of non-collateralizable capital, more of this type of capital will decrease debt capacity and lower financial leverage.

3 Quantitative Results

In this section, we calibrate our model and explore its predictions in the data. We show that our model can match both the asset prices and macroeconomics variables in the data.

3.1 Calibration

We calibrate our model at quarterly frequency, the parameters are listed in Table 1. Our calibration procedure is divided into three steps, and and the parameters are divided into three groups. The first group (top panel) are the ones which can be directly determined by previous literature or directly measured in the data, including household's relative risk aversion γ, intertemporal elasticity of substitution (IES) ψ, the capital share in firm production α, and the depreciation rates of tangible and intangible capitals, δ_K and δ_H, respectively. We set the relative risk aversion $\gamma = 10$, intertemporal elasticity of substitution $\psi = 1.5$, in line with the long-run risks literature. Capital share in production α is set to 0.33, as in standard RBC literature. The depreciation rate of physical capital δ_K is 0.025, corresponding to a 10% annual depreciation rate. The depreciation rate of non-collateralizable capital is set to 0.0375, which is 15% at the annual rate, and this number is in line with Peters and Taylor (2016), Falato et al. (2013) and Li and Hall (2016). Li and Hall (2016) estimates the depreciation rates of R&D capital for different industries, when the depreciation rate is not estimated for an industry, 15% is recommended.

The second group of parameters can be directly pinned down by matching a set of first moments at the deterministic steady state to the counterparts in the data. These parameters are listed in the middle panel of Table 1, and they include the mean productivity level as $E(\tilde{a})$, discount factor β, the liquidation value of collateral, ζ, survival rate of entrepreneurs, λ, share of physical capital, ϕ, and transfer to entering entrepreneurs, χ. We set $E(\tilde{a})$ to match a mean growth rate of U.S. economy of 2% per year. We set β to match the real risk free rate of 1% per year. We calibrate the remaining four parameters to jointly match a non-financial corporate sector leverage ratio of 2.3, an consumption to investment ratio,$E(C/I)$, of 5, a ratio of two investments, $E(J/I)$, of 0.7, and the TED spread of 0.7% per year. The leverage ratio we target is roughly in line with the asset to book equity ratio of non-financial firms in COMPUSTAT with mean 2.8 and median 2.2. The investment ratio $E(J/I)$ we target is also consistent with the data. The two depreciation rates δ_k and δ_H together with the investment ratio $E(J/I)$ used here can determine the capital ratio between the two capital in steady state, $E(H/K)$, at 41%, which is in close to data counterpart of 40%. As we discuss in Section 2.7, we introduce a shadow inter-entrepreneur loan. Because ex-ante all entrepreneurs are identical, therefore the loan is not traded but its shadow price can be determined by the Euler equation. We set the annual shadow rate of return of this loan to be 0.08% per annum, which is roughly the same as interbank borrowing rate. This is due to the fact that, in our economy, the entrepreneurs can be considered as the combination of non-financial and financial sector. In steady state, the shadow rate of return is $1/E[\tilde{M}]$, given our definition $\tilde{M}_{t+1} = \frac{M_{t+1}[\lambda\mu_{t+1}+(1-\lambda)]}{\mu_t}$, therefore this condition is very informative on the survival probability λ. We calibrate λ to be 0.986, it implies an average firm survives around 20 years.

The last group of parameters (bottom panel) are not related to the deterministic steady states of the economy, instead they need to be determined by the second moments in the data. The persistence parameter ρ and the standard deviation σ^A is chosen to match the first-order autocorrelation and the volatility of the aggregate output growth. The elasticity parameters of the adjustment cost functions, ξ_K and ξ_H are set to target the volatilities of the tangible and intangible investments, respectively.

Based on our calibrated parameters, the collateral constraint is binding at the steady state. Therefore, following the macroeconomic literature, for instance, Gertler and Kiyotaki (2010), we assume the constraint is binding on the narrow region around the steady state, and the local approximation solution method is a good approximation. We therefore solve the model using a second-order local approximation computed using the `dynare` package.

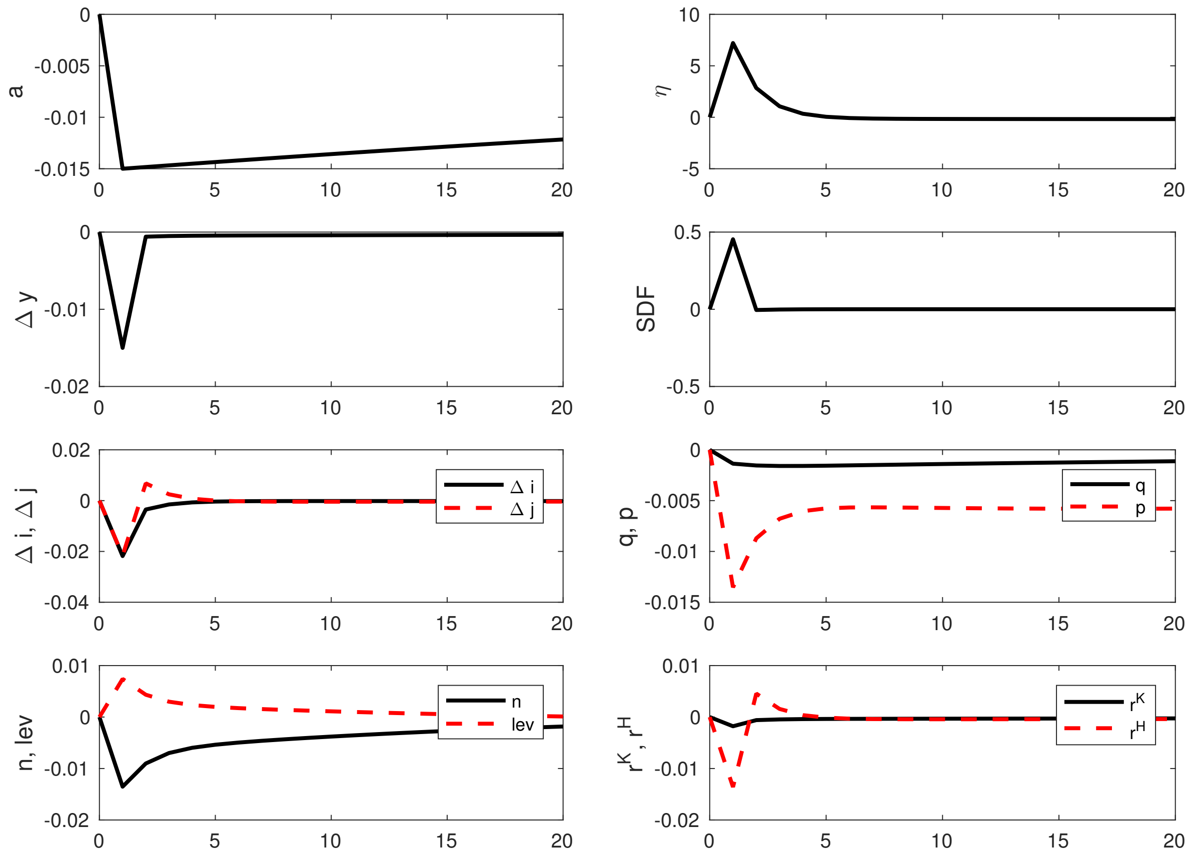
3.2 Impulse Responses

In order to understand the mechanism in the model, we plot the impulse responses with respect to a one-standard deviation negative shock to the aggregate productivity in Figure 1. The horizontal axis is the quarters after the shock, and the vertical axis represents the percentage deviations of quantities (left column) and prices (right column) from the steady state.

We make several observations. First, with respect to a negative productivity shock, both physical and intangible investments (third row, left column) decrease on impact. The intangible investment decreasing by slightly less, consistent with the evidence that intangible capital investment is less volatile that that of the physical investment. Second, the Lagrangian multiplier of the collateral constraint (first row, right column) increases with a negative productivity shock. This reflects a general prediction of this type of the model: the constraint becomes more binding in the bad time. Since the phys-

Figure 1: Impulse Responses to TFP shock

This figure shows the log-deviations from the steady state with respect to a one-standard deviation negative shock to aggregate productivity. The frequency is at quarterly. All parameters are calibrated as in Table 1.



ical capital can serve as the collateral, and the countercyclical value of the Lagrangian multiplier implies that collateralizable asset's marginal value relaxing the constraint is also countercyclical, and makes it to be a good hedge for the aggregate shock. This intuition is reflected in the third row of the right column, which shows that the prices of physical capital reduces much less than that of the intangible capital, since the latter does not provide benefit of relaxing the collateral constraint. Third, the realized return of these two types of capital inherits their price dynamics, that is, the return on the intangible capital responds more negatively to the negative aggregate shock than that of the physical capital, and is more risky due to a higher covariance with the stochastic discount factor.

3.3 Model Predictions

Our model suggests that firms with more non-collateralizable asset have lower debt capacity, and the collateralizable capital is more valuable in the bad times, hence it provides a counter cyclical value to the firm, firms with more collateralizable capital have lower returns. In the next few sessions, we show empirical evidence that firms with more non-collateralizalbe capital have higher stock returns, they have lower financial leverage due to lower debt capacity. More importantly, we test the key mechanism of our model, the price of collateralizalbe is less exposed to macroeconomic conditions than non-collateralizable capital, is true in the data.

3.3.1 Measuring Non-collaterlizable Capital

Collateralizable asset of a firm may consist of different assets, such as real estate, machine, long lasting equipment, etc. There is no consensus in the literature on how to measure collateralizability of a firm precisely, we proxy non-collateralizable asset as intangible asset. Intangible capital can hardly be used as collateral, Falato et al. (2013) document that only 3% of total loan value is written on intangibles like patents or brands, they directly assume that intangible capital is non-collateralizable asset in their model. The intangible capital measure in this paper may not be the precise measure of the total value of non-collateralizable assets of a firm, since a certain fraction book assets of a firm is not collateralizable, but our measure can capture most of the non-collateralizable capital.

The measure of intangible capital is following Falato et al. (2013) and Peters and Taylor (2016). The total amount of intangible capital of a firm is consist of three parts, externally purchased intangible capital, internally generated R&D and organizational capital.

Firms balance sheet data is from CRSP/Compustat Merged Database Annual Industrial Files, monthly stock returns are from CRSP. Since 1975, FASB requires firms to report their R&D expenditures, therefore the sample starts from 1975. We exclude utility (SIC code between 4900 and 4999) and financial firms (SIC between 6000 and 6999). Additionally, we keep common stocks that are traded on NYSE, AMEX and NASDAQ. Firms with negative book value of assets, book equity or sales are excluded. Delisting bias is corrected following Shumway (1997). Details can be found in the appendix.

In order to compare the composition of intangible capital among firms, we define intangible ratio as intangible capital over book value of total asset (COMPUSTAT item

AT). It measures the share of non-collateralizable asset in a firm.

As our model predicts that firms with more non-collateralizable assets have higher returns, because non-collateralizable assets are more risky, especially in the economic down turns. Additionally less collateralizable assets will reduce firms ability of obtaining loans from creditors, therefore they will have lower financial leverage. In this section, we sort portfolios based on intangible to book asset ratio, a high-minus-low portfolio will yield 4.8% spread annually. We also show that firms with more non-collateralizable capital have lower financial leverage.

3.3.2 Firm Characteristics

The key assumption in our model is that intangible capital cannot be used as collateral, if a firm has more non-collateralizable asset, the firm will have less asset to be pledged as collateral, therefore they have lower debt capacity, and their financial leverage should also be lower. Table 2 reports the firm characteristics across five quintiles of firms sorted on intangible ratio. It shows that financial leverage monotonically decreases as intangible ratio increases, the result is robust to different measures of financial leverage. The definitions of measures can be found in Table 2.

Firms in the fifth quintile have the lowest book to market ratio, but they have the highest returns as shown in Table 3. However, if we include intangible capital when calculating firms' book equity[4], then the firms with higher intangible adjusted book to market ratio have higher returns. This implies, if we take into account intangible capital when measure book to market ratio, firms with more intangible capital will look like value firms. This can also be confirmed in the investment rates. According to neoclassical q theory, q can be approximated by investment rates, higher investment rates imply more investment opportunities. As we see the physical investment rate, it decrease across five quintiles, which means firms with most intangible capital invest least, it implies they are actually value firms with less investment opportunities. Intangible investment rates suggest the same intuition.

Additionally, indices of financial constraints are showing different interpretations. WW and SA indices show that tightness of financial constraint is increasing monotonically as intangible ratio increases. As pointed out by Hadlock and Pierce (2010), KZ index should be used with caution and it does not correlate strongly with WW or SA index. WW and SA indices have some degree of correlation, they are both indicating firms with more intangible capital are more financially constrained. This also provides evidence that more intangible capital increase the tightness of constraints, which is in

[4] Adjusted BE = AT + Intangible - LT

line with our model prediction.

3.3.3 Portfolio Sorts

At the end of each June of year t (1975-2015), stocks are allocated into five quintiles based on intangible ratio (intangible to book asset ratio) in year $t-1$ and portfolios are formed from July of year t to June of year $t+1$. The portfolios are hold for one year and rebalanced at the end of each June. Therefore, portfolio 5 (1) contains firms with highest (lowest) intangible ratio. Table 3 shows the summary statistics of monthly stock returns of 5 quintiles portfolios. The 5-1 portfolio earns an annualized return of 4.8% for both value-weight and equal-weight returns.

As for robustness, Table 4 reports standard empirical asset pricing test using Carhart four factor model and Fama French five factor model. To take into account serial correlation, the t-statistics in parentheses are computed using Newey-West estimator allowing for three lags. As one can see that the anomaly can not be explained by these two models, because alphas are statistically significant. GRS tests reject that the alphas are jointly zero for both four factor model and five factor model, with p-values 0.001 and 0.003 respectively. Additionally, the alphas of fifth quintile portfolios are significantly larger than the alphas of the first quintile portfolios both of the models.

This section shows that firms with more non-collateralizable assets have higher expected returns, a long-short strategy can earn annualized return of 4.8%, the spread is also significant after risk adjustment, controlling for popular factor models. This verifies our theory that firms with more non-collateralizable capital have higher returns.

3.3.4 Predictability of Intangible Ratio

Portfolio sorts show us that on average, portfolios of firms with more non-collateralizable capital have higher expected returns, in order to test the predictability of intangible ratio at firm level, we perform Fama-Macbeth regressions in the following form with six lags to take into account autocorrelations, the specifications is following Li (2011).

$$R_{i,t+1} = \alpha^i + \beta_1 log(ME_{it}) + \beta_2 log(BM_{it}) + \beta_3 Mom_{it} + \beta_4 ROA_{it} + \beta_5 Intangible\ Ratio_{it} + \varepsilon_{it}$$

where $R_{i,t+1}$ is individual stocks' cumulative returns from July of year t to June of each year $t+1$, $log(ME_{it})$ is the nature log of firms' market capitalization at the end of June of each year t, $log(BM_{it})$ is the firms' book to market ratio at the end of June of each year t, Mom_{it} is the prior six month returns with a one-month gap between holding period and current month, ROA_{it} is income before extraordinary (IB) divide by total asset (AT) at June of year t, $Intangible\ Ratio_{it}$ is intangible capital divide by total asset at June of year t. Book leverage is financial debt (FD) divided by total asset. To avoid using future information, all the balance sheet variables measured at June of year t is using the value of fiscal year $t-1$, which is already known by investors.

Table 5 reports the results of Fama-Macbeth regression. The model indicates a significantly positive slope on intangible ratio. This slope is significant at 1% level, after controlling for size, book-to-market ratio, etc. It implies 1% increase in intangible ratio will predict 0.05% increase in return in the following year for an average firm, the magnitude is comparable to book-to-market ratio, which is considered to be one of the most prominent determinants of stock returns. This evidence supports our theory that if a firm has more non-collateralizable capital, it bears more risks, then it demands higher returns.

3.3.5 Capital Structure and Intangible Capital

Our model also has testable implications on financial leverage, since more non-collateralizable capital will shrink firms debt capacity, then the financial leverage will decrease. In order to study the effect of intangible capital on debt capacity of a firm as suggested by the model, we test whether more intangible capital is associated with lower financial leverage. Table 6 shows that 1% increase in intangible ratio will lead to $0.04 \sim 0.05\%$ increase in financial leverage. The result is statistically significant, standard errors are adjusted for clustering by firm and year, as suggested by Petersen (2009). The effect of intangible capital on financial leverage is comparable to size effect, robust to different financial leverage measures. Account payable denominated by total asset is included in the regression, because some short term debt is not included either in long-term debt or current debt (Welch (2011)), but are included in account payable. The results remain significant if we include other control variables. Detailed definitions of variables can be found in the comments of Table 6. The empirical findings on the negative correlation between intangible capital and financial leverage supports our theory that more non-collateralizable asset reduce the firms ability to acquire loans, therefore they have lower financial leverage.

3.3.6 Marginal Q

Our theory relies on the assumption that collateralizable capital is more valuable in the bad states of the world. In our model setup, it is when the aggregate productivity is low. In this section, we show the price of non-collateralizable capital is more responsive to aggregate fluctuations. Since there is no good measure of (non)collaterelizable capital, therefore we use the price of structural and intellectual capital as proxies for prices of collateralizable and non-collateralizable capital, respectively. Structure capital is consist of buildings, power plants, heavy machines the firms need for production, etc, most items included in structures are highly collateralizable. Intellectual capital is consist of software, R&D, entertainment products, which are hardly collateralizable. Therefore their price dynamics should be in line with the dynamics of collateralizable and non-collateralizable capital.[5] The prices of capital goods are from NIPA table 1.1.9 at quarterly frequency. We extract the cyclical component of the prices using HP filter, with penalty parameter λ 1600.

We calculate the regression coefficients of the cyclical component of marginal price of non-collateralizable and collateralizable capital on the cyclical component of aggregate GDP, they are denoted as $\beta(q, y)$ and $\beta(p, y)$ respectively. The results in Table 7 show that price of non-collateralizable (intellectual) capital is more responsive to aggregate output than collateralizable (structure) capital. It implies when the economy is in economic down turn, the price of collateralizable capital decreases less. It is a direct evidence that the price of collateralizable capital is more valuable in bad times, the value provided by the collateralizable capital is less cyclical. The results suggest that collateralizable capital is less risky than non-collateralizable capital, because its value is less exposed to aggregate economic conditions. This empirical evidence verifies our key mechanism.

3.4 Model Simulation and Quantitative Results

To understand the quantitative implications of the model, we simulate the model for long series of 12000 quarters and discard the first 2000 quarters; we aggregate the quarterly quantities in the remaining part of the simulation into annual quantities; and we compute moments for annualized quantities. In order to highlight the important implications of the credit market frictions on asset prices, we simulate two specifications of the model. The first specification is the benchmark model, the calibration of which is described in Section 3.1. In the second specification, we shut down the collateral con-

[5] Capital equipment is more complicated than structures and intellectuals. Part of equipment capital is short lasting equipments, software, part of it is long lasting transportation equipment like trucks, aircrafts. Therefore it is hard to classify equipment capital as collateralizable or not. Additionally, from the investment shocks literature, we know that price of equipment capital is counter cyclical. NIPA only offer deflators at structure, equipment and intellectual property level, we cannot get detailed price composition of equipment capital, and there is no guidance which part of equipment capital can be used collateral, we cannot re-construct the price deflators of collateralizables and non-collateralizables.

straint and study a frictionless world by assuming the borrowing and lending between entrepreneurs and workers are frictionless and no requirement for collateral. For a fair comparison, we recalibrate the adjustment cost parameters for both types of capital to maintain the volatilities of investments to be of the comparable magnitudes, and focus on the different implications on asset returns between these two specifications.

We report the moments of macroeconomic quantities (top panel) and those of asset returns (bottom panel) of two model specifications, namely "Benchmark" and "Frictionless" respectively in Table 8. Both specifications of the model are consistent with the basic features of the aggregate economy in terms of volatilities of consumption, physical and intangible investments, and the relative magnitude of two types of capital. It is noteworthy that we calibrate the adjustment cost parameters to be asymmetric between two capitals, with higher adjustment cost elasticity parameter for intangible capital, in order to respect the empirical fact that intangible investment is less volatile than its counterpart. The model generated volatility of physical investment is still a bit on the lower side; this reflect the typical tension in the production-based asset pricing model with adjustment cost: higher adjustment cost required by delivering volatile asset prices tend to make the investment to be smoother than that in the data.

Focusing on the asset pricing moments of the benchmark specification, our model is reasonably successful in generating asset pricing moments both at the aggregate level and more importantly in the cross-section. Our model replicates a low and smooth risk free rate, with mean 0.8% and volatility 0.8%. This is consistent with long run risks literature with a recursive preference of high intertemporal elasticity of substitution (IES). The equity premium in this economy is 3.5%, comparable to 5.7% in the data. The return on entrepreneurs equity is a levered position between risky assets and a risk free asset as discussed in section 2.7, therefore the risky asset returns we reported here are levered returns. Our calibration targets a leverage ratio of 2.3, in line with the nonfinancial corporate sector's leverage ratio in the data. The spread between intangible and physical capital return is 5.1%, quantitatively close to its data counterpart of 4.8%.

In order to highlight the intuition on the key model ingredient that delivers the quantitative success on asset prices, we compare the moments with the frictionless model specification. In the frictionless model without collateral constraint, only unlevered returns are simulated. For a fair comparison, we multiply the return spreads by a factor of 2.3, the targeted corporate leverage ratio. We make several observations in the comparison. First, the aggregate equity market premium in the frictionless model only accounts roughly one-half of that in our benchmark model. This is due to lack of the amplification prorogation mechanism of the financial frictions. As emphasized in

Li (2016), this mechanism will increase the effective risk aversion of the entrepreneurs through the augmented component in the stochastic discount factor, and make it much more volatile. Second, the frictionless specification delivers a return spread between intangible and tangible assets of 1.65%, only about one-third of the magnitude of our benchmark model. This mild amount of return spread is generated by the asymmetric adjustment costs. Recall that we calibrate a lower elasticity parameter in the adjustment cost function for intangible capital, this makes the price of intangible capital to be more volatile than that of the physical capital. However, as we show in the comparison, asymmetric capital adjustment costs alone cannot quantitatively generate enough return spread. More importantly, we need the countercyclical tightness of the collateral constraint to provide the physical capital a strong hedging role in relaxing the constraint, where physical capital provides additional counter cyclical value of relaxing the constraint, and this channel is the main contributor of the cross-sectional stock return spread.

4 Conclusion

In this study, we present a general equilibrium asset pricing model with collateral constraint and two types of assets which differ in their collateralizability. Our model predicts that the collateralizable asset provides an insurance against aggregate shocks and therefore is expected to earn lower expected return, because it relaxes the countercyclical collateral constraint. We measure non-collateralizabile capital based on intangible capital, and document the empirical evidence which is consistent with the predictions of our model. In particular, we find in the data that stock of firms with a larger share of non-collateralizable capital earn on average 4.8% higher return annually than those of firms with a lower share. When calibrate our model to standard statistics of the dynamics of macroeconomic quantities, we show that the credit market friction channel is quantitatively important at determining the cross-section of asset returns. Our model is able to reproduce the key features of asset return data, including an annualized 5.1% return spread between assets with different collateralizability and high equity premium, while maintain the success of matching the moments on the aggregate quantities as compared to those the standard real business cycle models.

Tables

Table 1: Calibration

We calibrate the model at quarterly frequency. This table reports the moments we used to calibrate the parameters of the model, or the corresponding literature. Note that ζ, λ, ϕ and χ are jointly determined by matching the moments, details can be found in section 3.1.

Parameter	Symbol	Value	Target/Source	Moments (Annual)
Relative risk aversion	γ	10	Bansal and Yaron (2004)	-
IES	ψ	1.5	Bansal and Yaron (2004)	-
Mean productivity growth rate	$E(\tilde{A})$	0.005	Mean GDP growth rate	2%
Capital share	α	0.33	Gertler and Kiyotaki (2010)	-
Depreciation rate of collateralizable	δ_K	0.025	Gertler and Kiyotaki (2010)	10%
Depreciation rate of non-collateralizable	δ_H	0.0375	Li and Hall (2016)	15%
Time discount rate	β	0.997	Risk-free rate	1%
Liquidation value of collateral	ζ	0.844	Corporate leverage	2.3
Survival rate of entrepreneurs	λ	0.986	TED spread	0.8%
Share of collateralizable	ϕ	0.58	E(J/I)	0.7
Transfer to entering entrepreneurs	χ	0.385	E(C/I)	5
Persistence of TFP shock	ρ^A	0.989	Autocorrelation of GDP growth	0.49
Standard deviation of TFP shock	σ^A	0.015	Volatility of GDP growth	3.30
Invest. adj. cost of collateralizable	ξ^K	9	$\sigma(\Delta i)$	10.30
Invest. adj. cost of non-collateralizable	ξ^H	2	$\sigma(\Delta j)$	3.88

Table 2: **Firm Characteristics**

This table shows the firm characteristics of the five portfolios sorted on intangible to total asset. Intangible ratio is measured by intangible to total asset (AT), financial debt (FD) is defined as long-term debt (DLTT), plus debt in current liability (DLC). Book equity (BE) is stockholder's book equity (SEQ), plus balance sheet deferred taxes and investment tax credit (TXDITC) if available, minus the book value of preferred stock (PSTK/PSTKRV/PSTKL depends on availability). Market equity (ME) is defined as the price of stock times share outstanding (SHROUT). Intangible investment is the combination of R&D expenditure, plus 30% of SGA.
Book leverage denominated by book asset is defined as FD/AT, book leverage denominated by book equity is defined as FD/(BE+FD), market leverage is FD/(FD+ME), book to market ratio (BM) is BE/ME. Asset turnover is defined as sales (SALES) to book assets (AT), return on assets is net income (NI) to total asset (AT). Tangible investment rate is defined as physical investment (CAPX) denominated by total asset (AT), intangible investment rate is intangible investment to intangible capital. Firm age is the years since a firm has record in COMPUSTAT. KZ, WW and SA indices are financial constraint measures, they are from Kaplan and Zingales (1997), Whited and Wu (2006) and Hadlock and Pierce (2010), respectively. The firms are more financially constrained when the KZ, WW and SA index are assigned with higher values.

	1	2	3	4	5
Intangible Ratio	0.099	0.344	0.570	0.827	1.416
FD/AT	0.267	0.213	0.198	0.162	0.058
FD/(BE+FD)	0.347	0.290	0.269	0.219	0.083
FD/(FD+ME)	0.281	0.209	0.174	0.127	0.032
BM	0.752	0.665	0.612	0.543	0.437
BM(account for intangible)	0.863	1.140	1.288	1.372	1.674
Physical investment rate (%)	8.121	5.034	3.990	3.593	3.196
Intangible investment rate (%)	18.232	18.128	18.010	17.573	16.937
log(ME)	5.672	5.302	5.384	5.135	4.023
Firm age	9.000	9.000	9.000	8.000	6.000
KZ	0.493	-0.531	-1.461	-1.936	-2.142
WW	6.656	3.809	4.229	5.982	10.262
SA	-3.226	-3.105	-3.097	-2.942	-2.389

Table 3: **Portfolios Sorted on Intangible to Book Asset Ratio**

This table reports the monthly excess stock returns and their statistics. At the end of June each year t, we sort all the firms into five quintiles based on intangible ratio, where intangible ratio is measured as intangible over total asset at the end of year $t-1$. The portfolios are reformed every June. This table reports monthly average excess returns R^e, standard errors σ, t-statistics (t), and Sharpe ratios SR across portfolios.

Panel A: Value-weighted Portfolios

	1	2	3	4	5	5-1
$R^e(\%)$	0.51	0.65	0.71	0.66	0.91	0.40
(t)	2.39	2.68	3.25	3.17	3.95	2.32
$\sigma(\%)$	4.64	5.30	4.77	4.54	5.00	3.72
SR	0.11	0.12	0.15	0.15	0.18	0.11

Panel B: Equal-weighted Portfolios

	1	2	3	4	5	5-1
$R^e(\%)$	0.56	0.76	0.90	0.95	0.97	0.40
(t)	2.15	2.90	3.44	3.37	2.84	2.03
$\sigma(\%)$	5.71	5.74	5.71	6.11	7.41	4.34
SR	0.10	0.13	0.16	0.15	0.13	0.09

Table 4: **Asset Pricing Tests**

This table shows asset pricing test for five value weighted portfolios sorted on intangible ratio. In Panel A, I regress the five quintile portfolios on Fama French three factor model, in Panel B I regress five portfolios on Carhart four factor model. To take in to account serial correlation, the t-statistics in parentheses are computed via Newey-West estimator allowing for three lags. All values reported here are in monthly frequency..

Panel A: Carhart Four Factor Model

	1	2	3	4	5	5-1
α	-0.12	0.11	0.17	0.14	0.33	0.45
(t)	-1.34	1.45	2.81	1.66	2.74	2.61
β_{MKT}	1.00	1.07	0.99	0.92	0.92	-0.08
(t)	41.67	42.00	69.05	35.22	29.95	-1.61
β_{HML}	0.15	-0.22	-0.15	-0.15	-0.17	-0.32
(t)	3.18	-4.64	-5.29	-2.88	-2.64	-3.57
β_{SMB}	-0.14	0.08	0.04	-0.05	0.16	0.31
(t)	-2.65	1.78	1.49	-1.73	3.28	3.60
β_{MOM}	0.02	-0.08	-0.03	0.03	0.05	0.03
(t)	0.67	-2.17	-1.64	1.01	0.88	0.37
R^2	0.84	0.91	0.92	0.84	0.78	0.15

Panel B: Fama-French Five-Factor Model

	1	2	3	4	5	5-1
α	-0.19	0.13	0.16	0.03	0.42	0.61
(t)	-2.04	1.59	2.09	0.36	3.70	3.51
β_{MKT}	1.02	1.05	1.02	0.96	0.94	-0.08
(t)	40.97	42.99	65.49	38.24	29.70	-1.69
β_{SMB}	-0.09	0.05	0.02	-0.03	0.34	0.43
(t)	-2.22	1.40	0.47	-0.90	7.81	6.59
β_{HML}	0.10	-0.05	-0.25	-0.29	-0.42	-0.52
(t)	1.58	-0.89	-6.36	-4.53	-6.97	-4.89
β_{RMW}	0.18	-0.06	-0.01	0.19	-0.42	-0.60
(t)	3.06	-1.07	-0.35	3.75	-7.18	-5.73
β_{CMA}	0.11	-0.27	0.10	0.29	0.25	0.14
(t)	1.40	-2.49	1.43	3.19	2.44	0.85
R^2	0.85	0.91	0.92	0.84	0.86	0.42

Table 5: **Return Spread: Multivariate Regression Analysis**

$R_{i,t}$ is individual stocks' cumulative return from July of year t to June of year $t+1$, $log(ME)$ is the nature log of firms' market capitalization at the end of June of year t, $log(BM)$ is the firms' book to market ratio at the end of June of year t, Mom is the prior six month returns with a one-month gap between holding period and current month, ROA is income before extraordinary (IB) divide by total asset (AT) at June of year t, *Intangible Ratio* is intangible capital divide by total asset at June of year t. Book leverage is financial debt (FD) divided by total asset. All the balance sheet variables measured at June of year t is using the value of fiscal year $t-1$. Values in parenthesis are t-statistics estimated by Newey-West estimator allowing for 6 lags.

$$R_{i,t+1} = \alpha^i + \beta_1 log(ME_{it}) + \beta_2 log(BM_{it}) + \beta_3 Mom_{it} + \beta_4 ROA_{it} + \beta_5 Intangible\ Ratio_{it} + \varepsilon_{it}$$

	(1)	(2)	(3)	(4)
log(ME)	-0.0114	-0.00649	-0.0117	-0.00831
	(-1.80)	(-0.95)	(-1.83)	(-1.23)
log(BM)	0.0440***	0.0533***	0.0436***	0.0513***
	(5.20)	(5.89)	(5.61)	(5.93)
Mom	0.0646**	0.0617**	0.0632**	0.0593**
	(2.82)	(2.88)	(2.78)	(2.87)
Leverage	-0.0250	0.00242	-0.0171	0.0177
	(-0.56)	(0.06)	(-0.38)	(0.47)
Intangible Ratio		0.0456***		0.0545***
		(3.25)		(3.67)
ROA			0.0524	0.113***
			(1.40)	(3.38)
Observations	109520	109520	109502	109502
R^2	0.0384	0.0438	0.0430	0.0484

Table 6: **Capital Structure Regressions - Fixed Effects**

This table shows capital structure panel regression with firm fixed effects. I use intangible ratio instead of tangibility in standard literature. Robust standard errors are adjusted for clustering by firm and year, as suggested by Petersen (2009). BM is book to market ratio, profitability is operating income before depreciation (OIBDP) divide by total asset (AT), cash ratio is cash and short-term investments (CHE) divide by total asset. AP/AT is account payable (AP) denominated by total asset. Numbers reported in parenthesis are t-statistic, ***, ** and * indicate statistical significance at 1%, 5% and 10% level.

	FD/AT	FD/(FD+ME)	FD/(BE+FD)
BM	-0.00369**	0.0103**	-0.00671**
	(-2.29)	(2.44)	(-2.48)
CF	-0.0874***	-0.0987***	-0.112***
	(-19.18)	(-15.91)	(-18.01)
Intangible Ratio	-0.0228***	-0.0476***	-0.0282***
	(-11.48)	(-11.65)	(-11.39)
log(ME)	-0.0227***	-0.0757***	-0.0351***
	(-24.24)	(-36.48)	(-24.06)
AP/AT	-0.264***	-0.234***	0.0328**
	(-26.52)	(-15.62)	(2.18)
Cash ratio	-0.290***	-0.286***	-0.362***
	(-77.74)	(-69.14)	(-74.75)
R^2	0.136	0.317	0.145

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: **Capital Prices and Aggregate Output**

$\beta(q, y)$ and $\beta(p, y)$ represent the regression coefficients of regressing the cyclical component of marginal price of collateralizable and non-collateralizable capital on cyclical component of aggregate GDP, respectively.

Variable	Data	Model
$\beta(q, y)$	0.26 (0.07)	0.11
$\beta(p, y)$	0.68 (0.12)	0.49

Table 8: **Model Simulations and Quantitative Results**

This table presents the moments from the simulated economy. All returns are levered except for risk free rate. $R^{L,K}$, $R^{L,H}$ denotes the levered returns. The leverage is 2.3 as determined in the economy. We simulate the economy at quarterly frequency, then calculate the moments on the annualized quantities and prices. Number in parenthesis are standard errors of the calculated moments. Benchmark: $\xi^K = 9$, $\xi^H = 2$; Case 1: $\xi^K = \xi^H = 4$; Frictionless: No collateral constraint

Moments	Data	Benchmark	Frictionless
$\sigma(\Delta y)$	3.30 (0.60)	3.29	3.38
$\sigma(\Delta c)$	2.53 (0.56)	2.98	3.04
$\sigma(\Delta i)$	10.30 (2.36)	4.72	4.96
$\sigma(\Delta j)$	3.88 (1.45)	3.40	3.06
$AC_1(\Delta c)$	0.49 (0.15)	0.25	0.26
$E(H/K)$	0.40 (0.09)	0.42	0.44
$\sigma(\tilde{M})$		104.59	94.31
$E[R^f]$	1.20 (0.16)	0.83	1.14
$\sigma(R^f)$	0.97 (0.31)	0.81	0.84
$E[R^{L,K} - R^f]$		1.58	1.26
$\sigma(R^{L,K})$		2.34	1.65
$E[R^{L,H} - R^f]$		6.73	2.91
$\sigma(R^{L,H})$		4.66	2.61
$E[R^{L,H} - R^{L,K}]$	4.80 (2.04)	5.15	1.65
$E[R^M - R^f]$	5.71 (2.25)	3.50	1.79

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5 Appendix

5.1 Details on Constructing Intangible Capital

5.1.1 Externally Acquired Intangible Capital

The externally acquired capital is defined as item *INTAN* in COMPUSTAT. It reflects the amount of intangible capital a firm purchases in a given fiscal year. Firms typically capitalize this type of asset on the balance sheet as part of intangible assets. For an average firm, *INTAN* is only 19% of total intangible capital, meanwhile the median value is just 3%, consistent with Peters and Taylor (2016). I set INTAN to zero when missing.

Internally created intangible capital has two components, R&D and organizational capital, we discuss the methods to recover them from firms' balance sheets in the following sections.

5.1.2 R&D capital

Internally created R&D capital does not appear on firm's balance sheet, one can estimate it by accumulating past expenditures. R&D expenditure is from COMPUSTAT item *XRD*, "Research and Development Expense", it represents the amount of expenditures on research and development of a firm in a given fiscal year. Following Falato et al. (2013) and Peters and Taylor (2016), we recover R&D capital using perpetual inventory method[6]:

$$RD_{t+1} = (1 - \delta_{RD})RD_t + XRD_t$$

where δ_{RD} is the depreciation rate of R&D capital, consistent with Peters and Taylor (2016), the depreciation rates are following Li and Hall (2016), which is also published on BEA R&D satellite account. For unclassified industries, the depreciation rates are set to 15%. Our results are not sensitive to the choice depreciation rates.

However, this is not enough to identify the stock of capital, the initial value for R&D capital is still undefined. We use the first non-missing R&D expenditure, XRD, as the first R&D investment, then the initial stock of R&D capital is specified as,

$$RD_0 = \frac{XRD_1}{g_{RD} + \delta_{RD}} \tag{24}$$

where g_{RD} is the average annual growth rate of firm level R&D expenditure, which is 29.1% in my sample. The sample starts from 1975, since the accounting treatment of

[6] It is also used by BEA R&D satellite account

R&D expense reporting was standardized in 1975, the amount of XRD reported by firms may not be comparable to each other before this standard is adopted, therefore previous R&D expenditures are not taken into account.

5.1.3 Organizational Capital

Another internally created component is organizational capital, it is constructed by accumulating a fraction of past SGA expense, COMPUSTAT item *XSGA*, "Selling, General and Administrative Expense". It includes lots of items, e.g. marketing expense, employee benefit, etc. It indirectly reflects reputation or human capital of a firm. Additionally it includes R&D expenses unless it's included in cost of goods sold by the company, therefore we need to exclude the R&D part from XSGA.

Peters and Taylor (2016) document that XSGA (Selling, General and Administrative Expense) includes R&D expense unless the company record R&D expense as cost of goods sold (Compustat item *COGS*), and Compustat adds R&D to *XSGA* in 90 out of 100 cases. Additionally *XSGA* do not incorporate the in process R&D expense (Compustat item *RDIP*), *RDIP* is coded as negative numbers. To exclude R&D capital from organizational capital, following Peters and Taylor (2016), I define $SGA \equiv XSGA - XRD - RDIP$, where the absolute value of $RDIP$ is basically added to SGA. Additionally, following Peters and Taylor (2016), we add a filter: when XRD exceeds XSGA but is less than COGS, or when XSGA is missing, we keep XSGA with no further adjustment. we replace missing XSGA with zero. Following Hulten (2008), Eisfeldt and Papanikolaou (2014) and Peters and Taylor (2016), we count only 30% of SGA expense as investment in organizational capital, the rest 70% is treated as operating costs.

Using the same procedure, the organizational capital is constructed as,

$$
\begin{aligned}
SGA_t &= 0.3(XSGA_t - XRD_t - RDIP_t) \\
OG_{t+1} &= (1 - \delta_{OG})OG_t + SGA_t
\end{aligned}
$$

where δ_{SGA} is set at 20%, consistent with Falato, Kadyrzhanova, Sim, Falato, and Sim (2013) and Peters and Taylor (2016), g_{RD} is the average annual growth rate of firm level XSGA. I set initial level of organizational capital as

$$OG_0 = \frac{SGA_1}{g_{OG} + \delta_{OG}}$$

where $g_{OG} = 18.9\%$ in the sample.

Table 9: **Average Ratios Across Industries**

FF 12 Industry	Intangible Ratio	R&D Share	Book Leverage	Market Leverage
Hlth	1.02	0.39	0.16	0.12
BusEq	0.92	0.36	0.13	0.13
Shops	0.70	0.01	0.23	0.29
Chems	0.67	0.16	0.21	0.22
Durbl	0.65	0.10	0.23	0.27
NoDur	0.62	0.04	0.24	0.28
Other	0.54	0.09	0.23	0.26
Manuf	0.47	0.14	0.22	0.27
Telcm	0.47	0.04	0.34	0.35
Enrgy	0.18	0.04	0.25	0.26

This table provides average ratios for different industries according to Fama French 12 industry classification. Firstly the average firm level ratios are computed, then the industry level average is computed. Intangible ratio is intangible capital divide by total assets (AT), R&D share is R&D capital divide by intangible capital, book leverage is financial debt (DLTT+DLC) divide by total asset, market leverage is financial debt divide by market capitalization.

5.2 Additional Tables

Table 9 documents the average intangible ratio across Fama French 12 industry classification. On average, health industry has the highest intangible ratio, since they invest heavily in developing new drugs or devices, meanwhile they have to invest a lot on scientists, marketing. Business equipment industry is mainly of software companies, they are considered to be high tech companies, with high human capital and lots of R&D expenditures. This table also shows that telecommunication and energy companies do not have high shares of intangible capital. However, some of the firms in these industries do have lots of intangible capital, but they also hold a large amount of valuable tangible assets, like offshore oil platform, network infrastructure, etc, which decreases the share of intangible capital. One may argue that firms with more intangible ratio would be the startup companies, which have smaller size and more R&D expenditure or key talents. Due to the design of COMPUSTAT, the firms in the sample are public traded firms, which means they are more mature firms rather than startups.

Table 10: **Dissecting by Fama French 12 Industry**

This table shows the distribution of firms across five quintiles within each industry. For every fiscal year, a firm is allocated into five quintiles based on intangible ratio. This sample excludes financial service and utility firms.

	Quintile					
FF Industries	**1**	**2**	**3**	**4**	**5**	**Total**
	%	%	%	%	%	%
BusEq	4.2	14.1	21.1	29.4	31.2	100.0
Chems	15.4	31.9	20.6	16.8	15.2	100.0
Durbl	4.1	26.3	34.4	22.3	12.9	100.0
Enrgy	80.2	12.3	4.4	2.1	1.0	100.0
Hlth	8.3	11.7	18.2	28.2	33.7	100.0
Manuf	22.7	33.0	25.1	13.4	5.8	100.0
NoDur	9.0	21.4	28.0	26.2	15.5	100.0
Other	37.5	20.6	14.6	15.1	12.2	100.0
Shops	17.6	19.7	22.3	20.0	20.4	100.0
Telcm	33.4	19.1	26.1	17.8	3.6	100.0
Total	24.1	20.2	19.6	19.3	16.8	100.0