The Collateralizability Premium

Hengjie Ai, Jun E. Li, Kai Li and Christian Schlag*

Abstract

A common prediction of macroeconomic models of credit market frictions is that the tightness of financial constraints is countercyclical. As a result, theory implies a negative collateralizbility premium, that is, capital that can be used as collateral to relax financial constraints provides insurance against aggregate shocks and commands a lower risk compensation compared to non-collateralizable assets. We show that a long-short portfolio constructed using a novel measure of asset collateralizability generates an average excess return of around 8% per year. We develop a general equilibrium model with heterogeneous firms and financial constraints to quantitatively account for the colltateralizability premium.

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* Hengjie Ai (hengjie.ai@umn.edu) is at the Carlson School of Management of University of Minnesota; Jun E. Li (junli@saif.sjtu.edu.cn) is at Shanghai Advanced Institute of Finance, Shanghai Jiao Tong University; Kai Li (kaili@ust.hk) is at Hong Kong University of Science and Technology; and Christian Schlag (schlag@finance.uni-frankfurt.de) is at Goethe University Frankfurt and Research Center SAFE. This paper was previously circulated under the title "Asset Collateralizabiltiy and the Cross-Section of Expected Returns". The authors thank Frederico Belo, Adrian Buss (EFA discussant), Zhanhui Chen (ABFER and Finance Down Under discussant), Nicola Fuchs-Schündeln, Bob Goldstein, Jun Li, Xiaoji Lin (AFA discussant), Dimitris Pananikolaou, Julien Penasse, Vincenzo Quadrini, Adriano Rampini (NBER SI discussant), Amir Yaron, Harold Zhang, Lei Zhang (CICF discussant) as well as the participants at ABFER annual meeting, SED, NBER Summer Institute (Capital Market and the Economy), EFA, CQAsia Annual Conference in Hong Kong, Finance Down Under, University of Minnesota (Carlson), Goethe University Frankfurt, Hong Kong University of Science and Technology, UT Dallas, City University of Hong Kong for their helpful comments. Kai Li gratefully acknowledges the General Research Fund of the Research Grants Council of Hong Kong (Project Number: 16502617) for financial support. Jun E. Li and Christian Schlag gratefully acknowledge research and financial support from the Research Center SAFE, funded by the State of Hessen initiative for research LOEWE. The usual disclaimer applies.

1 Introduction

A large 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 relaxing financial constraints should provide insurance against aggregate shocks. We evaluate the implication of this mechanism for the cross-section of equity returns.

From an asset pricing perspective, when financial constraints are binding, the value of collateralizable capital includes not only the dividends it generates, but also the present value of the Lagrangian multipliers of the collateral constraints it relaxes. If financial constraints are tighter in recessions, then a firm holding more collateralizable capital should require a lower expected return in equilibrium, since the collateralizability of its assets provides a hedge against the risk of being financially constrained in recessions, making the firm less risky overall.

To examine the relationship between asset collateralizability and expected returns, we first construct a measure of firms' asset collateralizability. Guided by the corporate finance theory linking firms' capital structure decisions to collateral constraints (e.g., Rampini and Viswanathan (2013)), we measure asset collateralizability as the value-weighted average of the collateralizability of the different types of assets owned by the firm. Our measure can be interpreted as the fraction of firm value that can be attributed to the collateralizability of its assets.

We sort stocks into portfolios according to this collateralizability measure and document that the spread between the low and the high collateralizability portfolio is on average close to 8% per year within the subset of financially constrained firms. The difference in returns remains significant after controlling for conventional factors such as the market, size, value, momentum, and profitability.

To quantify the effect of asset collateralizability on the cross-section of expected returns,

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

we develop a general equilibrium model with heterogeneous firms and financial constraints. In our model, firms are operated by entrepreneurs who experience idiosyncratic productivity shocks. As in Kiyotaki and Moore (1997, 2012), lending contracts can not be fully enforced and therefore require collateral. Firms with high productivity and low net worth have higher financing needs and, so that they, in equilibrium, acquire more collateralizable assets in order to borrow. In the constrained efficient allocation in our model, heterogeneity in productivity and net worth translate into heterogeneity in the collateralizability of firm assets. In this setup, we show that, at the aggregate level, collateralizable capital requires lower expected returns in equilibrium, and, in the cross-section, firms with high asset collateralizability earn low risk premiums.

In our model, assets with different levels of collateralizability are traded, and firms with higher financing needs endogenously acquire more collateralizable assets. Because owners of collateralizable assets rationally expect that potential buyers will be able to use the assets as collateral to relax their borrowing constraint, the price of collateralizable assets must contain the present value of the appropriately normalized Lagrangian multipliers associated with financial constraints. The countercyclicality of these Lagrangian multipliers, therefore, in equilibrium, translates into the cross-sectional dispersion of expected returns across collateralibability sorted portfolios.

We show that our model, when calibrated to match the conventional macroeconomic quantity dynamics and asset pricing moments, is able to generate a significant collateralizability spread. As in the data, firms with more asset collateralizability have higher financial leverage. However, despite the higher leverage, a higher degree of asset collateralizability is associated with lower average returns. Quantitatively, our model matches the empirical relationship between asset collateralizability, leverage, and expected returns in the data quite well.

Related Literature This paper builds on the large macroeconomics literature studying the role of credit market frictions in generating fluctuations across the business cycle (see Quadrini (2011) and Brunnermeier et al. (2012) for recent reviews). The papers that are most related to ours are those emphasizing the importance of borrowing constraints and contract enforcements, such as Kiyotaki and Moore (1997, 2012), Gertler and Kiyotaki (2010), He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), and Elenev, Landvoigt, and Van Nieuwerburgh (2018). Gomes, Yamarthy, and Yaron (2015) study the asset pricing implications of credit market frictions in a production economy. A common prediction of the papers in this literature is that the tightness of borrowing constraints is counter-cyclical. We study the implications of this prediction for the cross-section of expected returns.

Our paper is also related to the corporate finance literature that emphasizes the importance of asset collateralizability for the capital structure decisions of firms. Albuquerque and Hopenhayn (2004) study dynamic financing with limited commitment, Rampini and Viswanathan (2010, 2013) develop a joint theory of capital structure and risk management based on asset collateralizability, and Schmid (2008) considers the quantitative implications of dynamic financing with collateral constraints. Falato, Kadyrzhanova, and Sim (2013) provide empirical evidence for the link between asset collateralizability and leverage in aggregate time series and in the cross section.

Our paper further belongs to the literature on production-based asset pricing, for which Kogan and Papanikolaou (2012) provide an excellent survey. From the methodological point of view, our general equilibrium model allows for a cross section of firms with heterogeneous productivity and is related to previous work including Gomes et al. (2003), Gârleanu, Kogan, and Panageas (2012), Ai and Kiku (2013), and Kogan, Papanikolaou, and Stoffman (2017). Compared to these papers, our model incorporates financial frictions. In addition, our aggregation result is novel in the sense that despite heterogeneity in productivity and the presence of aggregate shocks, the equilibrium in our model can be solved for without having to use any distribution as a state variable.

Finally, our paper is connected to the broader literature linking investment to the cross-section of expected returns. Berk, Green, and Naik (1999) discuss how optimal investment decisions affect the valuation of growth option and asset in place. Zhang (2005) provides an investment-based explanation for the value premium. Li (2011) and Lin (2012) focus on the relationship between R&D investment and expected stock returns. Eisfeldt and Papanikolaou (2013) develop a model of organizational capital and expected returns. Belo, Lin, and Yang

(2017) study implications of equity financing frictions on the cross-section of stock returns.

The rest of the paper is organized as follows. We summarize our empirical results on the relationship between asset collateralizability and the expected returns in Section 2. We describe a general equilibrium model with collateral constraints in Section 3 and analyze its asset pricing implications in Section 4. In Section 5, we provide a quantitative analysis of our model. Section 6 contains the results of our empirical investigation. Section 7 concludes.

2 Empirical Facts

2.1 Measuring collateralizability

To empirically examine the link between asset collateralizability and expected returns, we first construct a measure of asset collateralizability at the firm level. Models with financial frictions typically feature a collateral constraint that takes the following general form:

$$B_{i,t} \leq \sum_{j=1}^{J} \zeta_j q_{j,t} K_{i,j,t+1}, \tag{1}$$

where $B_{i,t}$ denotes the total amount of borrowing by firm i at time t, and where $q_{j,t}$ is the price of type-j capital at time t.[2] The amount of capital, $K_{i,j,t+1}$, used by firm i at time $t+1$, is determined at time t. This means we assume a one period time to build as in standard real business cycle models.

Different types of capital differ with respect to their respective collateralizability. The parameter $\zeta_j \in [0,1]$ in (1) measures the degree to which type-j capital is collateralizable. $\zeta_j = 1$ implies that type-j capital can be fully collateralized, while $\zeta_j = 0$ means that this type of capital cannot be collateralized at all. Equation (1) thus says that total borrowing by the firm is constrained by the total collateral it can provide.

Our collateralizability measure is a value-weighted average of collateralizabilities of dif-

[2] In the model, we assume firms can only issue one-period bonds. A firm has to repay all the debt in order to borrow new debt. Under this assumption, the current one-period bond indeed represents the total debt of a firm.

ferent types of firm assets. Specifically, the overall collateralizability of firm i's assets at time t, $\bar{\zeta}_{i,t}$, is defined as:

$$\bar{\zeta}_{i,t} \equiv \sum_{j=1}^{J} \zeta_j \frac{q_{j,t} K_{i,j,t+1}}{V_{i,t}}, \tag{2}$$

where $V_{i,t}$ denotes the total value of firm i's assets. In models with collateral constraints, the value of the collateralizable capital typically includes the present value of both the cash flows it generates and of the Lagrangian multipliers of the collateral constraint. These represent the marginal value of relaxing the constraint through the use of collateralizable capital. In Section 5.4 below we show that, in our model, the firm-level collateralizability measure $\bar{\zeta}_{i,t}$ can be intuitively interpreted as the relative weight of the present value of the Lagrangian multipliers in the total value of the firm's assets.[3] As a result, it summarizes the heterogeneity in firms' risk exposure due to the asset collateralizability.

To empirically construct the collateralizability measure $\bar{\zeta}_{i,t}$ for each firm, we follow a two-step procedure. First, we use a regression-based approach to estimate the callateralizability parameters ζ_j for each type of capital. Motivated by previous work (e.g., Rampini and Viswanathan (2013, 2017)), we broadly classify assets into three categories based on their collateralizability: structure, equipment, and intangible capital. Focusing on the subset of financially constrained firms for which the constraint (1) holds with equality, we divide both sides of the equation by the total value of firm assets at time t, $V_{i,t}$, and obtain

$$\frac{B_{i,t}}{V_{i,t}} = \sum_{j=1}^{J} \zeta_j \frac{q_{j,t} K_{i,j,t+1}}{V_{i,t}}.$$

The above equation links firm i's leverage ratio, $\frac{B_{i,t}}{V_{i,t}}$ to its value-weighted collateralizability measure. Empirically, we run a panel regression of firm leverage, $\frac{B_{i,t}}{V_{i,t}}$, on the value weights of the different types of capital, $\frac{q_{j,t} K_{i,j,t+1}}{V_{i,t}}$, to estimate the collateralizability parameters ζ_j for structure and equipment, respectively.[4] The results the estimates of the collateralizability parameters are shown in Table 2. We firstly run the leverage regression for firms classified as

[3]See equation (32) below.

[4]We impose the restriction that $\zeta = 0$ for intangible capital, both because previous work typically argues that intangible capital cannot be used as collateral, and because its empirical estimate is slightly negative in unrestricted regressions.

financially constrained and for the full sample. We then consider three alternative financial constraint measures: the WW index (Whited and Wu (2006)), the SA index (Hadlock and Pierce (2010)), and an indicator of whether the firm has paid dividends or not in a given year.

As we can see in all of the specifications, there is a significant difference between structure and equipment capital in terms of their regression coefficients, in the sense that structure capital contributes more to a firm's debt capacity than equipment capital. This result is in line with the findings in Campello and Giambona (2013).

Second, the firm specific "collateralizability score" at time t, denoted by $\bar{\zeta}_{i,t}$, is computed as a value-weighted average of the collateralizability coefficients across different types of assets, i.e.,

$$\bar{\zeta}_{i,t} = \sum_{j=1}^{J} \widehat{\zeta}_j \frac{q_{j,t} K_{i,j,t+1}}{V_{i,t}},$$

where $\widehat{\zeta}_j$ is the coefficient estimated from the panel regression described above. We provide further details regarding the construction of the collateralizability measure in Appendix D.2.

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2.2 Collateralizability and expected returns

Equipped with the time series of the collateralizability measure for each firm, we follow the standard procedure and construct collateralizability-sorted portfolios. Consistent with our theory, we focus on the subset of financially constrained firms, whose asset valuations contain a non-zero Lagrangian multiplier component.

Table 1 reports average annualized excess returns, t-statistics, volatilities, Sharpe ratios and market betas of the five collateralizability-sorted portfolios. We consider the three alternative measures introduced above for the degree to which a firm is financially constrained: the WW index (Whited and Wu (2006), Hennessy and Whited (2007)), the SA index (Hadlock and Pierce (2010)), and an indicator of whether the firm has paid dividends over the past year.

The top panel shows that, based on the WW index, the average equity return for firms with low collateralizability (Quintile 1) is 7.86% higher on an annualized basis than that of a typical high collateralizability firm (Quintile 5). We call this return spread the (negative) collateralizability premium. The return difference is statistically significant with a t-value of 2.53, and its Sharpe ratio is 0.44. The premium is robust with respect to the way we measure if a firm is financially constrained, as can be seen from the middle and bottom panels of Table 1.[5]

In sum, the evidence on the collateralizability spread among financially constrained firms strongly supports our theoretical prediction that the collateralizable assets are less risky and therefore are expected to earn a lower return. In the next section, we develop a general equilibrium model with heterogenous firms and financial constraints to formalize the above intuition and to quantitatively account for the negative collateralizability premium.

3 A General Equilibrium Model

In this section, we describe the ingredients of our quantitative model of the collateralizability spread. The aggregate aspect of the model is intended to follow standard macro models with collateral constraints such as Kiyotaki and Moore (1997) and Gertler and Kiyotaki (2010). We allow for heterogeneity in the collateralizability of assets as in Rampini and Viswanathan (2013). The key additional elements in our theory are idiosyncratic productivity shocks and firm entry and exit. These features allow us to generate quantitatively plausible firm dynamics in order to study the implications of financial constraints for the cross-section of equity returns.

[5]The negative collateralizability premium is present also for financially unconstrained firms, but not as significantly as for constrained firms. It amounts to about 1% per year in our sample period. This is consistent with our theory. As we show in our model, the collateralizability premium applies to unconstrained firms because the value of their assets includes the present value of the Lagrangian multipliers of all constraints which potentially become binding in the future. The collateralizability premium for these firms should be lower, because for currently unconstrained firms, the Lagrangian multiplier represents only a small fraction of firm value.

3.1 Households

Time is infinite and discrete. The representative household consists of a continuum of workers and a continuum of entrepreneurs. Workers (entrepreneurs) receive their labor (capital) income every period and submit it to the planner of the household, who makes the consumption decision for all members of the household. Entrepreneurs and workers make their financial decisions separately.[6]

The household ranks the utility of consumption plans according to the following recursive preferences as in Epstein and Zin (1989):

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

where β is the time discount rate, ψ is the intertemporal elasticity of substitution, and γ is the relative risk aversion. As we will show later in the paper, together with the endogenous equilibrium long run risk, the recursive preferences in our model generate a volatile pricing kernel and a significant equity premium as in Bansal and Yaron (2004).

In every period t, the household purchases the amount $B_{i,t}$ of risk-free bonds from entrepreneur i, from whom it will receive $B_{i,t}R^f_{t+1}$ next period, where R^f_{t+1} denotes the gross risk-free interest rate from period t to $t+1$. In addition, it receives capital income $\Pi_{i,t}$ from entrepreneur i and labor income W_tL_t from all members who are workers. Without loss of generality, we assume that all workers are endowed with the same number L_t of hours per period. The household budget constraint at time t can therefore be written as

$$C_t + \int B_{i,t}di = W_tL_t + R^f_t \int B_{i,t-1}di + \int \Pi_{i,t}di.$$

Let M_{t+1} denote the the stochastic discount factor implied by household optimization. Under recursive utility, $M_{t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\psi}}\left(\frac{U_{t+1}}{E_t[U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma}$, and the optimality of the

[6] As in Gertler and Kiyotaki (2010), we make the assumption that household members make joint decisions on their consumption to avoid the need to keep the distribution of entrepreneur income as the state variable. The entrepreneurs are borrowing from other households which she does not live in.

intertemporal saving decisions implies that the risk-free interest rate must satisfy

$$E_t[M_{t+1}]R^f_{t+1} = 1. \tag{3}$$

3.2 Entrepreneurs

There a continuum of entrepreneurs in our economy indexed by $i \in [0,1]$. Entrepreneurs are agents operating productive ideas. An entrepreneur who starts at time 0 draws an idea with initial productivity $\bar{z}$ and begins the operation with initial net worth N_0. Under our convention, N_0 is also the total net worth of all entrepreneurs at time 0 because the total measure of all entrepreneurs is normalized to one.

Let $N_{i,t}$ denote entrepreneur i's net worth at time t, and let $B_{i,t}$ denote the total amount of risk-free bonds the entrepreneur issues to households at time t. Then the time-t budget constraint for the entrepreneur is given as

$$q_{K,t}K_{i,t+1} + q_{H,t}H_{i,t+1} = N_{i,t} + B_{i,t}. \tag{4}$$

In (4), we assume that there are two types of capital, K and H, that differ in their collateralizability, and we use $q_{K,t}$ and $q_{H,t}$ to denote their prices at time t. $K_{i,t+1}$ and $H_{i,t+1}$ are the amount of capital that entrepreneur i purchases at time t, which can be used for production over the period from t to $t+1$. We assume that the entrepreneur has access to only risk-free borrowing contracts, i.e., we do not allow for state-contingent debt. At time t, the entrepreneur is assumed to have an opportunity to default on his contract and abscond with all of the type-H capital and a fraction of $1-\zeta$ of the type-K capital. Because lenders can retrieve a ζ fraction of the type-K capital upon default, borrowing is limited by

$$B_{i,t} \leq \zeta q_{K,t}K_{i,t+1}. \tag{5}$$

Type-K capital can therefore be interpreted as collateralizable, while type-H capital cannot be used as collateral.

From time t to $t+1$, the productivity of entrepreneur i evolves according to the law of motion

$$z_{i,t+1} = z_{i,t} e^{\varepsilon_{i,t+1}}, \tag{6}$$

where $\varepsilon_{i,t+1}$ is a Gaussian shock with mean μ_ε and variance σ_ε^2, assumed to be i.i.d. across agents i and over time. We use $\pi\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right)$ to denote entrepreneur i's equilibrium profit at time $t+1$, where $\bar{A}_{t+1}$ is aggregate productivity in period $t+1$, and $z_{i,t+1}$ denotes entrepreneur i's idiosyncratic productivity. The specification of the aggregate productivity processes will be provided below in Section 5.1.

In each period, after production, the entrepreneur experiences a liquidation shock with probability λ, upon which he loses his idea and needs to liquidate his net worth to return it back to the household.[7] If the liquidation shock happens, the entrepreneur restarts with a draw of a new idea with initial productivity $\bar{z}$ and an initial net worth of χN_t in period $t+1$, where N_t is the total (average) net worth of the economy in period t, and $\chi \in (0,1)$ is a parameter that determines the ratio of the initial net worth of entrepreneurs relative to that of the economy-wide average. Conditional on no liquidation shock, the net worth $N_{i,t+1}$ of entrepreneur i at time $t+1$ is determined as

$$\begin{aligned} N_{i,t+1} &= \pi\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right) + (1-\delta)\, q_{K,t+1} K_{i,t+1} \\ &\quad + (1-\delta)\, q_{H,t+1} H_{i,t+1} - R_{f,t+1} B_{i,t}. \end{aligned} \tag{7}$$

The interpretation is that the entrepreneur receives the profit $\pi\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right)$ from production. His capital holdings depreciate at rate δ, and he needs to pay back the debt borrowed from last period plus interest, amounting to $R_{f,t+1} B_{i,t}$.

Because of the fact that whenever a liquidity shock occurs, entrepreneurs submit their net worth to the household who chooses consumption collectively for all members, entrepreneurs value their net worth using the same pricing kernel as the household. Let $V_t^i\left(N_{i,t}\right)$ denote

[7] This assumption effectively makes entrepreneurs less patient than the household and prevents them from saving their way out of the financial constraint.

the value function of entrepreneur i. It must satisfy the following Bellman equation:

$$V_t^i(N_{i,t}) = \max_{\{K_{i,t+1},H_{i,t+1},N_{i,t+1},B_{i,t}\}} E_t\left[M_{t+1}\{\lambda N_{i,t+1} + (1-\lambda) V_{t+1}^i(N_{i,t+1})\}\right], \tag{8}$$

subject to the budget constraint (4), the collateral constraint (5), and the law of motion of N_i given by (7).

We use variables without a subscript i to denote economy-wide aggregate quantities. The aggregate net worth in the entrepreneurial sector satisfies

$$N_{t+1} = (1-\lambda)\left[\begin{array}{c} \pi\left(\bar{A}_{t+1}, K_{t+1}, H_{t+1}\right) + (1-\delta)\, q_{K,t+1} K_{t+1} \\ +(1-\delta)\, q_{H,t+1} H_{t+1} - R_{f,t+1} B_t \end{array}\right] + \lambda\chi N_t, \tag{9}$$

where $\pi\left(\bar{A}_{t+1}, K_{t+1}, H_{t+1}\right)$ denotes the aggregate profit of all entrepreneurs.

3.3 Production

Final output With $z_{i,t}$ denoting the idiosyncratic productivity for firm i at time t, output $y_{i,t}$ of firm i at time t is assumed to be generated through the following production technology:

$$y_{i,t} = \bar{A}_t\left[z_{i,t}^{1-\nu}(K_{i,t} + H_{i,t})^{\nu}\right]^{\alpha} L_{i,t}^{1-\alpha} \tag{10}$$

Here, α denotes the capital share, and ν is the span of control parameter as in Atkeson and Kehoe (2005). Note that collateralizable and non-collateralizable capital are perfect substitutes in production. This assumption is made for tractability.

Firm i's profit at time t, $\pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right)$ is given as

$$\begin{aligned} \pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right) &= \max_{L_{i,t}} y_{i,t} - W_t L_{i,t} \\ &= \max_{L_{i,t}} \bar{A}_t\left[z_{i,t}^{1-\nu}(K_{i,t} + H_{i,t})^{\nu}\right]^{\alpha} L_{i,t}^{1-\alpha} - W_t L_{i,t}, \end{aligned} \tag{11}$$

where W_t is the equilibrium wage rate, and $L_{i,t}$ is the amount of labor hired by entrepreneur i at time t.

It is convenient to write the profit function explicitly by maximizing out labor in equation (11) and using the labor market clearing condition $\int L_{i,t}di = 1$ to get

$$L_{i,t} = \frac{z_{i,t}^{1-\nu}\left(K_{i,t}+H_{i,t}\right)^{\nu}}{\int z_{i,t}^{1-\nu}\left(K_{i,t}+H_{i,t}\right)^{\nu}di}, \tag{12}$$

so that entrepreneur i's profit function becomes

$$\pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right) = \alpha\bar{A}_t z_{i,t}^{1-\nu}\left(K_{i,t}+H_{i,t}\right)^{\nu}\left[\int z_{i,t}^{1-\nu}\left(K_{i,t}+H_{i,t}\right)^{\nu}di\right]^{\alpha-1}. \tag{13}$$

Given the output $y_{i,t}$ of entrepreneur i at time t from equation (10), the total output of the economy is given as

$$\begin{aligned} Y_t &= \int y_{i,t}di, \\ &= \bar{A}_t\left[\int z_{i,t}^{1-\nu}\left(K_{i,t}+H_{i,t}\right)^{\nu}di\right]^{\alpha}. \end{aligned} \tag{14}$$

Capital goods We assume that capital goods are produced from a constant-return-to-scale and convex adjustment cost function $G(I, K+H)$, that is, one unit of the investment good costs $G(I, K+H)$ units of consumption goods. Therefore, the aggregate resource constraint is

$$C_t + I_t + G\left(I_t, K_t+H_t\right) = Y_t. \tag{15}$$

Without loss of generality, we assume that $G\left(I_t, K_t+H_t\right) = g\left(\frac{I_t}{K_t+H_t}\right)\left(K_t+H_t\right)$ for some convex function g.

We further assume that the fractions ϕ and $1-\phi$ of the new investment goods can be used for type-K and type-H capital, respectively. This is another simplifying assumption. It implies that, at the aggregate level, the ratio of type-K to type-H capital is always equal to $\phi/(1-\phi)$, and thus the total capital stock of the economy can be summarized by a single state variable. The aggregate stocks of type-H and type-K capital follow the law of motion[8]

$$\begin{aligned} H_{t+1} &= (1-\delta) H_t + (1-\phi) I_t \\ K_{t+1} &= (1-\delta) K_t + \phi I_t. \end{aligned} \tag{16}$$

In summary, to study how asset collateralizability affects expected returns, we have presented a model in which the heterogeneity in firm-level productivity drives their financing needs and therefore their equilibrium choice of asset collateralizability. To maintain tractability, we will borrow elements from the financial intermediation literature, for example, Gertler and Kiyotaki (2010) and Elenev, Landvoigt, and Van Nieuwerburgh (2018) to keep the representative agent setup on the consumer side. In our model, equities are held by entrepreneurs who are often financially constrained. As a result, the optimality condition for entrepreneurs' problem (8) typically involves the Lagrangian multipliers on financing constraints. The key insight of our analysis will be that assets of different collateralizability have different loadings on the Lagrangian multipliers and therefore different expected returns. We now turn to the asset pricing implications of the model.

4 Equilibrium Asset Pricing

4.1 Aggregation

Our economy is one with both aggregate and idiosyncratic productivity shocks. In general, we would have to use the joint distribution of capital and net worth as an infinite-dimensional state variable in order to characterize the equilibrium recursively. In this section, we present a novel aggregation result and show that the aggregate quantities and prices of our model can be characterized without any reference to distributions. Given aggregate quantities and prices, quantities and shadow prices at the individual firm level can be computed using

[8]For tractability, we have assumed that type K and type H capital are perfect substitutes in production. Under this assumption, if investors can determine which capital to produce, they will always choose not to produce type H capital, as it can be perfectly substituted by type K capital in production and is strictly dominated by type K capital when used as collateral. Our assumption that capital production is Leontief in type K and type H ensures that both types of capital are produced in equilibrium.

equilibrium conditions.

Distribution of idiosyncratic productivity In our model, the law of motion of idiosyncratic productivity shocks in (6) is time invariant, implying that the cross-sectional distribution of the $z_{i,t}$ will eventually converge to a stationary distribution.[9] At the macro level, the heterogeneity of idiosyncratic productivity can be conveniently summarized by the simple statistic $Z_t \equiv \int z_{i,t}\, di$. It is useful to compute this integral explicitly.

Given the law of motion of z_i from equation (6) and the fact that entrepreneurs receive a liquidation shock with probability λ, we have:

$$Z_{t+1} = (1-\lambda) \int z_{i,t} e^{\varepsilon_{i,t+1}} di + \lambda \bar{z}.$$

The interpretation is that only a fraction $(1-\lambda)$ of entrepreneurs will survive until the next period, while the rest will restart with a productivity of $\bar{z}$. Note that based on the assumption that $\varepsilon_{i,t+1}$ is independent of $z_{i,t}$, we can integrate out $\varepsilon_{i,t+1}$ and rewrite the above equation as [10]

$$\begin{aligned} Z_{t+1} &= (1-\lambda) \int z_{i,t} E\left[e^{\varepsilon_{i,t+1}}\right] di \; + \lambda \bar{z}, \\ &= (1-\lambda)\, Z_t e^{\mu_\varepsilon + \frac{1}{2}\sigma_\varepsilon^2} + \lambda \bar{z}, \end{aligned} \tag{17}$$

where the last equality follows from the fact that $\varepsilon_{i,t+1}$ is normally distributed. It is straightforward to see that if we choose the normalization $\bar{z} = \frac{1}{\lambda}\left[1 - (1-\lambda)\, e^{\mu_\varepsilon + \frac{1}{2}\sigma_\varepsilon^2}\right]$ and initialize the economy by setting $Z_0 = 1$, then $Z_t = 1$ for all t. This will be the assumption we maintain for the rest of the paper.

[9] In fact, the stationary distribution of $z_{i,t}$ is a double-sided Pareto distribution. Our model is therefore consistent with the empirical evidence regarding the power law distribution of firm size.

[10] The first line requires us to define the set of firms and the notion of integration in a mathematically careful way. Rather than going to the technical details, we refer the readers to Feldman and Gilles (1985) and Judd (1985). Constantinides and Duffie (1996) use a similar construction in the context of heterogenous consumers. See footnote 5 in Constantinides and Duffie (1996) for a more careful discussion on possible constructions of an appropriate measurable space under which the integration is valid.

Firm profits We assume that $\varepsilon_{i,t+1}$ is observed at the end of period t when the entrepreneurs plan next period's capital. As we show in A, this implies that entrepreneur i will choose $K_{i,t+t} + H_{i,t+1}$ to be proportional to $z_{i,t+1}$ in equilibrium. Additionally, since $\int z_{i,t+1}\, di = 1$, we must have

$$K_{i,t+1} + H_{i,t+1} = z_{i,t+1} \left(K_{t+1} + H_{t+1}\right), \tag{18}$$

where K_{t+1} and H_{t+1} are the aggregate quantities of type-K and type-H capital, respectively.

The assumption that capital is chosen after $z_{i,t+1}$ is observed rules out capital misallocation and implies that total output does not depend on the joint distribution of idiosyncratic productivity and capital. This is because, given idiosyncratic shocks, all entrepreneurs choose the optimal level of capital such that the marginal productivity of capital is the same across all entrepreneurs. This fact allows us to write $Y_t = \bar{A}_t \left(K_{t+1} + H_{t+1}\right)^{\alpha\nu} \int z_{i,t} di = \bar{A}_t \left(K_{t+1} + H_{t+1}\right)^{\alpha\nu}$. It also implies that the profit at the firm level is proportional to aggregate productivity, i.e.,

$$\pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right) = \alpha \bar{A}_t z_{i,t} \left(K_t + H_t\right)^{\alpha\nu},$$

and the marginal products of capital are equalized across firms for the two types of capital:

$$\frac{\partial}{\partial K_{i,t}} \pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right) = \frac{\partial}{\partial H_{i,t}} \pi\left(\bar{A}_t, z_{i,t}, K_{i,t}, H_{i,t}\right) = \alpha\nu \bar{A}_t \left(K_t + H_t\right)^{\alpha\nu - 1}. \tag{19}$$

To prove (19), we take derivatives of firm i's output function (10) with respect to $K_{i,t}$ and $H_{i,t}$, and then impose the optimality conditions (12) and (18).

Intertemporal optimality Having simplified the profit functions, we can derive the optimality conditions for the entrepreneur's maximization problem (8). Note that given equilibrium prices, the objective function and the constraints are linear in net worth. Therefore, the value function V_t^i must be linear as well. We write $V_t^i\left(N_{i,t}\right) = \mu_t^i N_{i,t}$, where μ_t^i can be interpreted as the marginal value of net worth for entrepreneur i. Furthermore, let η_t^i be the Lagrangian multiplier associated with the collateral constraint (5). The first order condition with respect to $B_{i,t}$ implies

$$\mu_t^i = E_t\left[\widetilde{M}_{t+1}^i\right] R_{t+1}^f + \eta_t^i, \tag{20}$$

where we use the definition

$$\widetilde{M}_{t+1}^i \equiv M_{t+1}[(1-\lambda)\,\mu_{t+1}^i + \lambda]. \tag{21}$$

The interpretation is that one unit of net worth allows the entrepreneur to reduce one unit of borrowing, the present value of which is $E_t\left[\widetilde{M}_{t+1}^i\right] R_{t+1}^f$, and relaxes the collateral constraint, the benefit of which is measured by η_t^i.

Similarly, the first order condition for $K_{i,t+1}$ is

$$\mu_t^i = E_t\left[\widetilde{M}_{t+1}^i \frac{\frac{\partial}{\partial K_{i,t+1}}\pi\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right) + (1-\delta)\,q_{K,t+1}}{q_{K,t}}\right] + \zeta\eta_t^i. \tag{22}$$

An additional unit of type-K capital allows the entrepreneur to purchase $\frac{1}{q_{K,t}}$ units of capital, which pays a profit of $\frac{\partial\pi}{\partial K}\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right)$ over the next period before it depreciates at rate δ. In addition, a fraction ζ of type-K capital can be used as collateral to relax the borrowing constraint.

Finally, optimality with respect to the choice of type-H capital implies

$$\mu_t^i = E_t\left[\widetilde{M}_{t+1}^i \frac{\frac{\partial}{\partial H_{i,t+1}}\pi\left(\bar{A}_{t+1}, z_{i,t+1}, K_{i,t+1}, H_{i,t+1}\right) + (1-\delta)\,q_{H,t+1}}{q_{H,t}}\right]. \tag{23}$$

Recursive construction of the equilibrium Note that, in our model, firms differ in their net worth. First, net worth depends on the entire history of idiosyncratic productivity shocks, as can be seen from equation (7), since, due to (6), $z_{i,t+1}$ depends on $z_{i,t}$, which in turn depends on $z_{i,t-1}$ etc. Furthermore, net worth also depends on the need for capital, which depends on the realization of next period's productivity shock. Therefore, in general, the marginal benefit of net worth, μ_t^i, and the tightness of the collateral constraint, η_t^i, depend on the individual firm's entire history. Below we show that despite the heterogeneity in net worth and capital holdings across firms, our model allows an equilibrium in which μ_t^i and η_t^i

are equalized across firms, and aggregate quantities can be determined independently of the distribution of net worth and capital.[11]

The assumptions that type-K and type-H capital are perfect substitutes in production and that the idiosyncratic shock $z_{i,t+1}$ is observed before the decisions on $K_{i,t+1}$ and $H_{i,t+1}$ are made imply that the marginal products of the two types of capital are equalized within and across firms, as shown in equation (19). As a result, equations (20) to (23) permit solutions, where μ_t^i and η_t^i are not firm-specific. Intuitively, because the marginal product of capital depends only on the sum of $K_{i,t+1}$ and $H_{i,t+1}$, but not on the individual summands, entrepreneurs will choose the total amount of capital to equalize its marginal product across firms. This is also because $z_{i,t+1}$ is observed at the end of period t. Depending on his borrowing need, an entrepreneur can then determine $K_{i,t+1}$ to satisfy the collateral constraint. Because capital can be purchased on a competitive market, entrepreneurs will choose $K_{i,t+1}$ to equalize its price to its marginal benefit, which includes the marginal product of capital and the Lagrangian multiplier η_t^i. Because both the prices and the marginal product of capital are equalized across firms, so is the tightness of the collateral constraint.

We formalize the above observation by constructing a recursive equilibrium in two steps. First, we show that the aggregate quantities and prices can be characterized by a set of equilibrium functionals. Then we construct individual firm quantities from aggregate quantities and prices. We make one final assumption, namely that the aggregate productivity is given by $\bar{A}_t = A_t \left(K_t + H_t\right)^{1-\alpha\nu}$, where $\{A_t\}_{t=0}^{\infty}$ is an exogenous Markov productivity process. On the one hand, this assumption follows Frankel (1962) and Romer (1986) and is a parsimonious way to generate endogenous growth. On the other hand, combined with recursive preferences, this assumption increases the volatility of the pricing kernel, as in the stream of long-run risk model (see, e.g., Bansal and Yaron (2004) and Kung and Schmid (2015)). From a technical point of view, thanks to this assumption, equilibrium quantities are homogenous of degree one in the total capital stock, $K_t + H_t$, and equilibrium prices do not depend on $K_t + H_t$. It is therefore convenient to work with normalized quantities, i.e., all the quantities in the economy will be scaled by the sum $K_t + H_t$.

[11] We believe that under our assumptions, this is the only type of equilibrium. However, a rigorous proof is non-trivial and beyond the scope of this paper.

Let lower case variables denote aggregate quantities normalized by the current capital stock, so that, for instance, n_t denotes aggregate net worth N_t normalized by the total capital stock $K_t + H_t$. The equilibrium objects are consumption, $c(A, n)$, investment, $i(A, n)$, the marginal value of net worth, $\mu(A, n)$, the Lagrangian multiplier on the collateral constraint, $\eta(A, n)$, the price of type-K capital, $q_K(A, n)$, the price of type-H capital, $q_H(A, n)$, and the risk-free interest rate, $R_f(A, n)$ as functions of the state variables A and n.

To introduce the recursive formulation, we denote a generic variable in period t as X and in period $t+1$ as X'. Given the above equilibrium functionals, we can define

$$\Gamma(A, n) \equiv \frac{K' + H'}{K + H} = (1 - \delta) + i(A, n)$$

as the growth rate of the capital stock and construct the law of motion of the endogenous state variable n from equation (9):[12]

$$\begin{aligned} n' &= (1-\lambda)\left[\alpha \nu A' + \phi(1-\delta) q_K(A', n') + (1-\phi)(1-\delta) q_H(A', n') - \zeta \phi q_K(A, n) R_f(A, n)\right] \\ &\quad + \lambda \chi \frac{n}{\Gamma(A, n)}. \end{aligned} \tag{24}$$

With the law of motion of the state variables, we can construct the normalized utility of the household as the fixed point of

$$u(A, n) = \left\{ (1-\beta) c(A, n)^{1-\frac{1}{\psi}} + \beta \Gamma(A, n)^{1-\frac{1}{\psi}} \left(E[u(A', n')^{1-\gamma}] \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}}.$$

The stochastic discount factors can then be written as

$$M' = \beta \left[\frac{c(A', n') \Gamma(A, n)}{c(A, n)} \right]^{-\frac{1}{\psi}} \left[\frac{u(A', n')}{E\left[u(A', n')^{1-\gamma}\right]^{\frac{1}{1-\gamma}}} \right]^{\frac{1}{\psi} - \gamma} \tag{25}$$

$$\widetilde{M}' = M'[(1-\lambda)\mu(A', n') + \lambda]. \tag{26}$$

Formally, an equilibrium in our model consists of a set of aggregate quantities,

[12] We make use of the property that the ratio of K over H is always equal to $\phi/(1-\phi)$, as implied by the law of motion of the capital stock in (16).

$\{C_t, B_t, \Pi_t, K_t, H_t, I_t, N_t\}$, individual entrepreneur choices, $\{K_{i,t}, H_{i,t}, L_{i,t}, B_{i,t}, N_{i,t}\}$, and prices $\left\{M_t, \widetilde{M}_t, W_t, q_{K,t}, q_{H,t}, \mu_t, \eta_t, R_{f,t}\right\}$ such that, given prices, quantities satisfy the household's and the entrepreneurs' optimality conditions, the market clearing conditions, and the relevant resource constraints. Below, we present a procedure to construct a Markov equilibrium, where all prices and quantities are functions of the state variables (A, n). For simplicity, we assume that the initial idiosyncratic productivity across all firms satisfies $\int z_{i,1} di = 1$, the initial aggregate net worth is N_0, aggregate capital holdings start with $\frac{K_1}{H_1} = \frac{\phi}{1-\phi}$, and firm's initial net worth satisfies $n_{i,0} = z_{i,1} N_0$ for all i.

Proposition 1. *(Markov equilibrium)*

Suppose there exists a set of equilibrium functionals $\{c(A,n), i(A,n), \mu(A,n), \eta(A,n), q_K(A,n), q_H(A,n), R_f(A,n)\}$ *satisfying the following set of functional equations:*

$$E\left[M' \middle| A\right] R_f(A,n) = 1,$$

$$\mu(A,n) = E\left[\widetilde{M}' \middle| A\right] R_f(A,n) + \eta(A,n),$$

$$\mu(A,n) = E\left[\widetilde{M}' \frac{\alpha\nu A' + (1-\delta) q_K(A',n')}{q_K(A,n)} \middle| A\right] + \zeta\eta(A,n),$$

$$\mu(A,n) = E\left[\widetilde{M}' \frac{\alpha\nu A' + (1-\delta) q_H(A',n')}{q_H(A,n)} \middle| A\right],$$

$$\frac{n}{\Gamma(A,n)} = (1-\zeta)\phi q_K(A,n) + (1-\phi) q_H(A,n),$$

$$G'(i(A,n)) = \phi q_K(A,n) + (1-\phi) q_H(A,n),$$

$$c(A,n) + i(A,n) + g(i(A,n)) = A,$$

where the law of motion of n is given by (24), and the stochastic discount factors M' and $\widetilde{M}'$ are defined in (25) and (26). Then the equilibrium prices and quantities can be constructed as follows, and they constitute a Markov equilibrium:

1. *Given the sequence of exogenous shocks $\{A_t\}$, the sequence of n_t can be constructed*

using the law of motion in (24), and the normalized policy functions are computed as:

$$x_t = x(A_t, n_t), \ \ for \ x = c, i, \mu, \eta, q_K, q_H, R_f.$$

2. *Given the sequence of normalized quantities, aggregate quantities are constructed as:*

$$\begin{aligned} H_{t+1} &= H_t [1 - \delta + i_t], \quad K_{t+1} = K_t [1 - \delta + i_t] \\ X_t &= x_t [H_t + K_t] \end{aligned}$$

   for $x = c, i, b, n$, $X = C, I, B, N$, *and all* t.

3. *Given the aggregate quantities, the individual entrepreneurs' net worth follows from (7). Given the sequences* $\{N_{i,t}\}$, *the quantities* $B_{i,t}, K_{i,t}$ *and* $H_{i,t}$ *are jointly determined by equations (4), (5), and (18). Finally,* $L_{i,t} = z_{i,t}$ *for all* i, t.

Proof. See Appendix A. □

The above proposition implies that we can solve for aggregate quantities first, and then use the firm-level budget constraint and the law of motion of idiosyncratic productivity to construct the cross-section of net worth and capital holdings. Note that our construction of the equilibrium allows $\eta(A, n) = 0$ for some values of (A, n). That is, our general setup allows occasionally binding constraints. Numerically, we use a local approximation method to solve the model by assuming the constraint is always binding.

In our model, because type H capital can perfectly substitute type K capital in production and because both types of capital are freely traded on the market, the marginal product of type K capital must be equalized across firms. Trading of type K capital therefore equalizes the Lagrangian multiplier of the financial constraints across firms. This is the key feature of our model that allows us to construct the Markov equilibrium without having to include the distribution of capital to be a state variable.[13]

[13] Due to these simplifying assumptions, our model is silent on why some firms are constrained and others are not.

4.2 The collateralizability spread

Our model allows for two types of capital, where type-K capital is collateralizable, while type-H capital is not. Note that one unit of type j capital costs $q_{j,t}$ in period t and it pays off $\Pi_{j,t+1} + (1-\delta)\, q_{j,t+1}$ in the next period, for $j \in \{K, H\}$. Therefore, the unlevered returns on the claims to the two types of capital are given by

$$R_{j,t+1} = \frac{\alpha\nu A_{t+1} + (1-\delta)\, q_{j,t+1}}{q_{j,t}} \tag{27}$$

for $j \in \{K, H\}$.

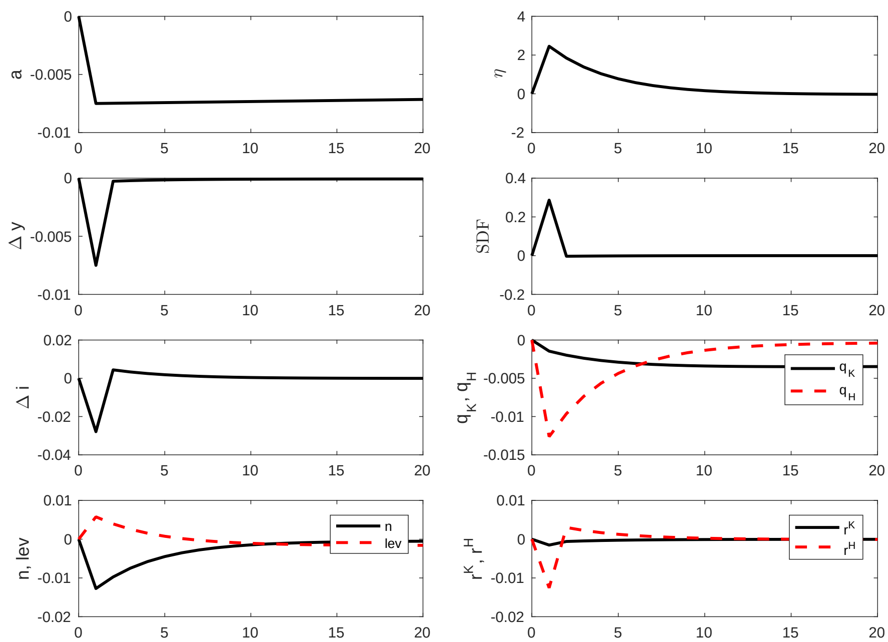
Risk premiums are determined by the covariances of the payoffs with the stochastic discount factor. Given that the components representing the marginal products are identical for the two types of capital, the key to understanding the collateralizability premium is an analysis of the cyclicality properties of the prices of the two types of capital, $q_{j,t+1}$.

We can iterate equations (22) and (23) forward to obtain an expression for $q_{K,t}$ and $q_{H,t}$ as the present value of all future cash flows. Clearly, $q_{K,t}$ contains the Lagrangian multipliers $\left\{\eta^i_{t+s}\right\}_{s=0}^{\infty}$, while $q_{H,t}$ does not. Because the Lagrangian multipliers are counter-cyclical and act as a hedge, $q_{K,t}$ will be less sensitive to aggregate shocks and less cyclical. These asset pricing implications of our model are best illustrated with impulse-response functions.

Based on the graphs in Figure 1 we make two observations. First, a negative productivity shock lowers output and investment (second and third graph in the left column) as in standard macro models. In addition, as shown in the bottom graph on the left, entrepreneur net worth drops sharply (third graph in the right column), and leverage goes up immediately. Second, upon a negative productivity shock, because entrepreneur net worth drops sharply, the price of type-H capital also goes down substantially. The decrease in the price of collateralizable type-K capital, on the other hand, is much smaller. This is because the Lagrangian multiplier η on the collateral constraint (first graph in the right column) increases upon impact and offsets the effect of a negative productivity shock on the price of type-K capital. As a result, the return of type-K capital responds much less to negative productivity shocks than that

Figure 1: Impulse-response functions for a negative aggregate productivity shock

The graphs in this figure represent log-deviations from the steady state for quantities (left column) and prices (right column) induced by a one-standard deviation negative shock to aggregate productivity. The parameters are shown in Table 3. The horizontal axis represents time in months.



of type-H capital (bottom graph in the right column), as can be seen from a comparison of the solid black and the red dashed line. This implies that collateralizable capital is indeed less risky than non-collateralizable capital in our model.

5 Quantitative model predictions

In this section, we calibrate our model and evaluate its ability to replicate key moments of both macroeconomic quantities and asset prices at the aggregate level. More importantly, we investigate its performance in terms of quantitatively accounting for key features of firm characteristics and producing a collateralizability premium in the cross-section. For macroeconomic quantities, we focus on a long sample of U.S. annual data from 1930 to 2016. All macroeconomic variables are real and per capita. Consumption, output and physical investment data are from the Bureau of Economic Analysis (BEA).

In order to obtain the time series of total amount of tangible and intangible asset, we first aggregate the respective total amount of intangible and tangible capital across all U.S. Compustat firms in a given year. The time series of the aggregate intangible-to-tangible asset ratio is then obtained by dividing the first by the second series elementwise.

For the purpose of cross-sectional analyses we make use of several data sources at the micro-level, including (1) firm level balance sheet data from the CRSP/Compustat Merged Fundamentals Annual Files, (2) monthly stock returns from CRSP, and (3) industry level non-residential capital stock data from the BEA table "Fixed Assets by Industry". Appendix D provides more details concerning our data sources at the firm and industry level.

5.1 Specification of aggregate shocks

We first formalize the specification of the exogenous aggregate shocks in this economy. First, log aggregate productivity $a \equiv \log(A)$ follows

$$a_{t+1} = a_{ss}\left(1 - \rho_A\right) + \rho_A a_t + \sigma_A \varepsilon_{A,t+1}, \tag{28}$$

where a_{ss} denotes the steady-state value of a. Second, we also introduce the shocks to entrepreneurs' liquidation probability λ. As is well known in the literature of macroeconomic models with financial frictions, the aggregate productivity shock alone does not create quantitatively enough volatility in capital prices and entrepreneurs' net worth. An additional source of shocks like, e.g., a capital quality shock as in Gertler and Kiyotaki (2010) and Elenev, Landvoigt, and Van Nieuwerburgh (2018), is needed to generate a higher volatility in net worth. In our model, because a shock to λ affects the entrepreneurs' discount rate and therefore their net worth, without directly affecting the real production, we interpret it as a financial shock, in a spirit similar to Jermann and Quadrini (2012). Importantly, our general model intuition that collateralizable assets provide a hedge against aggregate shocks holds for both productivity and financial shocks.

To technically maintain $\lambda \in (0,1)$ in a parsimonious way, we set

$$\lambda_t = \frac{\exp(x_t)}{\exp(x_t) + \exp(-x_t)},$$

where x_t follows the process,

$$x_{t+1} = x_{ss}(1-\rho_x) + \rho_x x_t + \sigma_x \varepsilon_{x,t+1},$$

with x_{ss} again denoting the steady-state value. We assume the innovations to a and x have the following structure:

$$\begin{bmatrix} \varepsilon_{A,t+1} \\ \varepsilon_{x,t+1} \end{bmatrix} \sim Normal\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{A,x} \\ \rho_{A,x} & 1 \end{bmatrix} \right),$$

in which the parameter $\rho_{A,x}$ captures the correlation between the two shocks. In the benchmark calibration, we assume $\rho_{A,x} = -1$. First, a negative correlation indicates that a negative productivity shock is associated with a positive discount rate shock. This assumption is necessary to quantitatively generate a positive correlation between consumption and investment growth consistent with the data. When only the financial shock ε_x is present, contemporaneous consumption and investment will be affected, but not output. In this case the resource constraint (15) implies a counterfactually negative correlation between consumption and investment growth. Second, the assumption of a perfectly negative correlation is for parsimony, and it effectively implies there is only one aggregate shock in this economy. We relax this assumption and provide sensitivity analyses by varying the shock correlation parameter $\rho_{A,x}$ to be different from -1 in Appendix B.

5.2 Calibration

We calibrate our model at the monthly frequency and present the parameters in Table 3. The first group of parameters are those which can be determined based on the literature. In particular, we set the relative risk aversion γ to 10 and the intertemporal elasticity of substitution ψ to 1.3. These parameter values are in line with papers in the long-run risks literature, most notably Bansal and Yaron (2004). The capital share parameter α is set to 0.33, as in the standard real business cycles literature (Kydland and Prescott (1982)). The span of control parameter ν is set to 0.77, broadly consistent with Atkeson and Kehoe (2005).

The parameters in the second group are determined by matching a set of first moments of quantities and prices. We set the long-term average economy-wide productivity growth rate a_{ss} to match a value for the U.S. economy of 2% per year. The time discount factor β is set to match the average real risk free rate of 1.5% per year. The share of type-K capital investment ϕ is set to 0.54 to match an intangible-to-tangible-asset ratio of 53% for the average U.S. Compustat firm.[14] The capital depreciation rate is set to be 9% per year, consistent with the RBC literature (Kydland and Prescott (1982)). For parsimony, we assume the same depreciation rate for both types of capital. The parameter x_{ss} is set to match an average exit probability $\overline{\lambda}$ of 0.01, targeting an average corporate duration of 10 years of US Compustat firms. We calibrate the remaining two parameters related to financial frictions, the collateralizability parameter ζ and the transfer to entering entrepreneurs χ, to generate an average non-financial corporate sector leverage ratio equal to 0.32 and an average investment-to-output ratio of 20%. These values are broadly in line with the data, where leverage is measured by the median lease capital adjusted leverage ratio of U.S. non-financial firms in Compustat.

The parameters in the third group are determined by second moments in the data. The persistence parameter of the TFP shocks ρ_A is set to 0.998 to roughly match the autocorrelation of output growth. We set the persistence parameter of the financial shock ρ_x equal to 0.961 to reproduce the persistence of the corporate leverage ratio that we find in the data. As discussed above, we impose a perfectly negative correlation between productivity and financial shocks, i.e., we set $\rho_{x,A} = -1$. The standard deviations of the shock to the exit probability λ, σ_x, and to productivity, σ_A, are jointly calibrated to match the volatilities of consumption growth and the correlation between consumption and investment growth. For

[14] The construction of intangible capital is explained in detail in Appendix D.3.

the capital adjustment cost function we choose a standard quadratic form, i.e.,

$$g\left(\frac{I_t}{K_t + H_t}\right) = \frac{I_t}{K_t + H_t} + \frac{\tau}{2}\left(\frac{I_t}{K_t + H_t} - \frac{I_{ss}}{K_{ss} + H_{ss}}\right)^2,$$

where X_{ss} denotes the steady state values for $X \in \{I, K, H\}$. The elasticity parameter of the adjustment cost function, τ, is set to allow our model to achieve a sufficiently high volatility of investment, broadly in line with the data.

The last group contains the parameters related to the idiosyncratic productivity shocks, μ_ε and σ_ε. We calibrate them to match the mean (2.5%) and the volatility (10%) of the idiosyncratic productivity growth of the cross-section of U.S. non-financial firms in Compustat.

5.3 Aggregate moments

We now turn to the quantitative performance of the model at the aggregate level. We solve and simulate our model at the monthly frequency and aggregate the model-generated data to compute annual moments.[15] We show that our model is broadly consistent with the key empirical features of macroeconomic quantities and asset prices. More importantly, it produces a sizable negative collateralizability spread at the aggregate level, i.e., the expected return on collateralizable capital is substantially lower than that on non-collateralizable capital.

Table 4 reports the model simulated moments of macroeconomic quantities (top panel) and those of asset returns (bottom panel) respectively, and compares them to their counterparts in the data where available.

In terms of aggregate moments for macro quantities (top panel), our calibration features a low volatility of consumption growth (2.45%) and a relatively high volatility of investment (6.86%). Thanks to the negative correlation between the productivity and financial shocks, our model can reproduce a positive consumption-investment correlation (44%), consistent with the data. The model also generates a persistence of output growth in line with aggregate

[15] Because the limited commitment constraint is binding in the steady-state, we solve the model using a second-order local approximation around the steady state using the `Dynare` package. We have also solved versions of our model using the global method developed in Ai et al. (2016) and verified the accuracy of the local approximation.

data and an average intangible-to-tangible-capital ratio of 54%, a value broadly consistent with the average ratio across U.S. Compustat firms. The capital-to-output ratio is 1.44, which is close to the value of 1.13 in the data. In summary, our model inherits the success of real business cycles models with respect to the quantity side of the economy.

Turning the attention to the asset pricing moments (bottom panel), our model produces a low average risk free rate (1.46%) and a high equity premium (7.00%), comparable to key empirical moments for aggregate asset markets. Moreover, in our model difference in average returns between type-K and type-H capital, or, equivalently, the difference between their risk premia is negative and large (-6.91% annually).

Note that the difference between the levered return on type K-capital and the unlevered return on type H-capital in Table 4 is still negative and large, but now the difference is smaller in absolute value than before for unlevered type K capital. This comparison reflects that there is an offsetting effect on the negative colllateralizability premium from financial leverage. Type-K capital is collateralizable, and allows the firm to borrow more, so that leverage increases, which in turn increases the expected return on equity. If we assume a binding borrowing constraint and replace $B_{i,t}$ by $\zeta q_{j,t} K_{j,t+1}$, one can see that buying type-K capital effectively delivers a levered return, since

$$\begin{aligned} R^{Lev}_{K,t+1} &= \frac{\alpha \nu A_{t+1} + (1-\delta)\, q_{K,t+1} - R_{f,t+1} \zeta q_{K,t}}{q_{K,t}\,(1-\zeta)}, \\ &= \frac{1}{1-\zeta}(R_{K,t+1} - R_{f,t+1}) + R_{f,t+1}. \end{aligned} \tag{29}$$

In the first line, the denominator $q_{K,t}\,(1-\zeta)$ represents the amount of internal net worth required to buy one unit of type-K capital, and it can be interpreted as the minimum down payment per unit of capital. The numerator $\alpha \nu A_{t+1} + (1-\delta)\, q_{K,t+1} - R_{f,t+1} \zeta q_{K,t}$ is tomorrow's payoff per unit of capital, after subtracting the debt repayment. Because type-H capital is non-collateralizable and has to be purchased 100% with equity, it cannot be levered up. In sum, the (negative) collateralizability premium at the aggregate level can be interpreted as the difference between the average return of a levered claim on the type-K capital and an un-levered claim on type-H capital.

Combining the two Euler equations (20) and (22), and eliminating η_t, we obtain

$$E_t\left[\widetilde{M}_{t+1}R^{Lev}_{K,t+1}\right] = \mu_t,$$

and a rearrangement of equation (23) gives

$$E_t\left[\widetilde{M}_{t+1}R_{H,t+1}\right] = \mu_t.$$

Therefore, the expected return spread is equal to

$$\begin{aligned} E_t\left(R^{Lev}_{K,t+1} - R_{H,t+1}\right) &= -\frac{1}{E_t\left(\widetilde{M}_{t+1}\right)}\left(Cov_t\left[\widetilde{M}_{t+1}, R^{Lev}_{K,t+1}\right] - Cov_t\left[\widetilde{M}_{t+1}, R_{H,t+1}\right]\right), \\ &= -\frac{1}{E_t\left(\widetilde{M}_{t+1}\right)}\left(\frac{1}{1-\zeta}Cov_t\left[\widetilde{M}_{t+1}, R_{K,t+1}\right] - Cov_t\left[\widetilde{M}_{t+1}, R_{H,t+1}\right]\right). \end{aligned} \tag{30}$$

On the right-hand side of equation (30), we can see the two offsetting effects at work. On the one hand, the counter-cyclical tightness of the collateral constraint makes $R_{K,t+1}$ covary less with the stochastic discount factor $\widetilde{M}_{t+1}$. However, the leverage multiplier $\frac{1}{1-\zeta}$ may offset this effect by amplifying the cyclical fluctuations of a levered claim on type-K capital. The relative riskiness of the type-K versus type-H capital thus depends on the relative contributions of the Lagrangian multiplier effect and the offsetting leverage effect. As stated above.our model produces a sizable negative average return spread of -4.8% between levered collateralizable capital and unlevered non-collateralizable capital, so that with the given calibration, the first effect clearly dominates, and the collateralizability premium is negative.

In order to further understand the performance of the model under different calibration schemes, we present sensitivity analysis in Appendix B.

5.4 The cross section of collateralizability and equity returns

In this section, we study the collateralizability spread at the cross-sectional level. In particular, we simulate firms from the model, measure the collateralizability of firm assets, and conduct the same collateralizability-based portfolio sorting procedure as in the data.

Equity claims to firms in our model can be freely traded among entrepreneurs. The return on an entrepreneur's net worth is $\frac{N_{i,t+1}}{N_{i,t}}$. Using equations (4) and (7), we obtain

$$\begin{aligned}\frac{N_{i,t+1}}{N_{i,t}} &= \frac{\alpha\nu A_{t+1}\left(K_{i,t+1}+H_{i,t+1}\right)+(1-\delta)\,q_{K,t+1}K_{i,t+1}+(1-\delta)\,q_{H,t+1}H_{i,t+1}-R_{f,t+1}B_{i,t}}{q_{K,t}K_{i,t+1}+q_{H,t}H_{i,t+1}-B_{i,t}},\\ &= \frac{(1-\zeta)q_{K,t}K_{i,t+1}}{N_{i,t}}R^{Lev}_{K,t+1}+\frac{q_{H,t}H_{i,t+1}}{N_{i,t}}R_{H,t+1},\end{aligned}$$

where $R^{Lev}_{K,t+1}$ is the levered return on the type-K capital, as defined in equation (29). The above expression has an intuitive interpretation. The return on equity is the weighted average of the levered return on type-K capital and the unlevered return on type-H capital. The weights $\frac{(1-\zeta)q_{K,t}K_{i,t+1}}{N_{i,t}}$ and $\frac{q_{H,t}H_{i,t+1}}{N_{i,t}}$ are the relative shares of the entrepreneur's net worth represented by type-K and type-H capital, respectively. In the case of a binding collateral constraint, these weights sum up to one. Since, in our model, $R^{Lev}_{K,t+1}$ and $R_{H,t+1}$ are the same across all firms, firm level expected returns differ only because of the way total capital is composed of type H and type K. This composition can be equivalently summarized by the collateralizability measure for the firm's assets.

To see this, note that μ^i_t and η^i_t are identical across firms, so that we can drop the subscript i in equation (22) and (23) and rewrite them in a general form,

$$\mu_t q_{j,t}K_{j,t+1} = E_t\left[\widetilde{M}_{t+1}\left\{\Pi_{j,t+1}+(1-\delta)\,q_{j,t+1}\right\}K_{j,t+1}\right]+\zeta_j\eta_t q_{j,t}K_{j,t+1}, \tag{31}$$

where $j \in \{K, H\}$ is the index denoting type-K and type-H capital. Note $\zeta_H = 0$.

Dividing the above equation by the total value of the firm's assets V_t, defined as $\sum_{j=1}^{J} q_{j,t}K_{j,t+1}$ and summing across all j, we obtain

$$\mu_t = \frac{\sum_{j=1}^{J} E_t\left[\widetilde{M}_{t+1}\left\{\Pi_{j,t+1}+(1-\delta)\,q_{j,t+1}\right\}K_{j,t+1}\right]}{V_t}+\eta_t\sum_{j=1}^{J}\zeta_j\frac{q_{j,t}K_{j,t+1}}{V_t}. \tag{32}$$

μ_t is the shadow value of entrepreneur's net worth. Equation (32) decomposes μ_t into two parts. Since the term $E_t\left[\widetilde{M}^i_{t+1}\left\{\Pi_{j,t+1}+(1-\delta)\,q_{j,t+1}\right\}K_{j,t+1}\right]$ can be interpreted as the present value of the cash flows generated by type-j capital, the first component is the fraction of firm value that comes from cash flows. The second component is the relative contribution of the Lagrangian multiplier for the collateral constraint, multiplied by our measure of asset collateralizability.

In our model, μ_t and η_t are common across all firms, and all types of capital generate the same marginal product in all periods. As a result, expected returns differ only because of the effect coming from the component in (32) associated with the Lagrangian multiplier. Different compositions of asset collateralizability lead to different sensitivity to the valuation of Lagrangian multiplier. This is completely summarized by the asset collateralizability measure, i.e., by the term $\sum_{j=1}^{J} \zeta_j \frac{q_{j,t} K_{j,t+1}}{V_t}$. As we show next in this section, this parallel between our model and our empirical procedure allows our model to match the quantitative features of the collateralizability spread in the data very well.

In Table 5, we report our model's implications for the cross-section of asset collateralizability, leverage ratio, and expected returns and compare them to the data. In the data, we focus on financially constrained firms, which are defined according to the WW index, and report our results in the upper panel in Table 5. As we had shown in Section 2, other measures of financial constraints yield quantitatively similar results regarding the collateralizability premium. We follow the same procedure with the simulated data in our model and sort stocks into five portfolios based on the collateralizability measure. The corresponding moments are reported in the bottom panel of Table 5.

We make three observations. First, the collateralibility scores in our model are similar to those in the data across the quintile portfolios. Despite its simplicity, our model endogenously generates a plausible distribution of asset collateralizability in the cross-section.

Second, as in the data, leverage is by and large increasing in asset collateralizability. This implication of our model is consistent with the corporate finance literature emphasizing the importance of collateral in firms' capital structure decisions (e.g., Rampini and Viswanathan (2013)). The dispersion in leverage in our model is somewhat higher than that in the data. This is not surprising, as in our model, asset collateralizability is the only factor determining leverage, while in the data there are many other determinants of the capital structure.

Finally, and most importantly, firms with high asset collateralizability, despite their high leverage, have a significantly lower expected return than those with low asset collateralizability. Quantitatively, our model produces a sizable collateralizability spread of around 4%, representing is more than 50% of the value in the data.

As discussed above, an increase in the holdings of type-K capital raises the firm's asset collateralizability and has two effects on the expected return of its equity. On one hand, higher asset collateralizability allows the firm to borrow more,which increases leverage, makes the firm more exposed to aggregate risks, and thus leads to higher expected equity returns in equilibrium. On the other hand, since collateralizable capital has a lower expected return than non-collateralizable capital, higher asset collateralizability tends to lower the expected return on equity. Our quantitative analysis shows that the second effect dominates the first, leading to a negative collateralizablity premium. This helps to reconcile the mixed evidence on the relationship between leverage and expected stock returns, as discussed in Gomes and Schmid (2008).

Our model can also match the empirical fact documented in the literature, for example, Cooper et al. (2008), that firms with high asset growth have lower average returns. The intuition is that firms with a history of positive idiosyncratic productivity shocks, due to higher financing needs, invest more in type-K capital, which can be used as collateral. Since the expected return on type-K capital is lower due to the collateral effect, these firms are expected to earn lower average returns in the future.

6 Empirical Analysis

In this section, we provide empirical evidence on the relation between collateralizability and the cross-section of stock returns. We first perform several standard multi-factor asset pricing tests. We also investigate the joint link between collateralizability and other firm characteristics on one hand and future stock returns on the other using multivariate regressions. Then, we construct the dividend series of collateralizability-sorted portfolios, and document that there are no systematic differences between the portfolios with respect to cash flow beta, consistent with our model mechanism. Finally, we consider the percentage change of the wealth share of top 1% households (Gomez (2017)) as a proxy for financial shocks, which we show has a positive price of risk. High collateralizability firms are more negatively exposed to this shock, which corroborates the model mechanism that collateralizable assets provide an insurance against aggregate shocks.

6.1 Asset pricing tests

We now perform a number of standard asset pricing tests to show that the collateralizability premium cannot be explained by standard risk factors, as represented by the Carhart (1997) four factor model, the Fama and French (2015) five factor model, or the organizational capital factor proposed by Eisfeldt and Papanikolaou (2013). We also investigate the incremental predictive power of current asset collateralizability for future stock returns at the firm-level.

First, we investigate to what extent the variation in the returns of the collateralizability sorted portfolios can be explained by standard risk factors suggested by Carhart (1997) and Fama and French (2015). In particular, we run monthly time-series regressions of the (annualized) excess returns of each portfolio on a constant and the risk factors included in the above models. Table 6 reports the intercepts (i.e., alphas) and exposures (i.e., betas). The intercepts can be interpreted as pricing errors (abnormal returns), which remain unexplained by the given set of factors.

We make two key observations. First, the pricing errors of the collateralizablity-sorted portfolios with respect to the given sets of factors are large and statistically significant. The estimated alphas of the low-minus-high portfolio are 9.34% for the Carhart (1997) model and 5.80% for the Fama and French (2015) five-factor model, respectively, with associated t-statistics of around 3.5 and 2.1.

Second, in order to distinguish our collateralizability measure from organizational capital, we also control for this factor constructed by Eisfeldt and Papanikolaou (2013),[16] together with the three Fama-French factors.

The results are shown in Panel C of Table 6. The pricing error of the low-minus-high

[16]We would like to thank Dimitris Papanikolaou for sharing this time series of the organizational factor.

portfolio is still significant in the presence of the organizational capital factor (OMK) and amounts almost 9% per year with a t-statistic of greater than 2.6. In particular, the five portfolios sorted on collateralizability are not strongly exposed to this factor, indicated by economically small and statistically insignificant coefficients, except for Quintile 5.

Taken together, the cross-sectional return spread across collateralizability sorted portfolios cannot be explained by either the Carhart (1997) four-factor model, the Fama and French (2015) five-factor model, or the organizational capital factor proposed by Eisfeldt and Papanikolaou (2013).

Second, we extend the previous analysis to the investigation of the link between collateralizability and future stock returns using firm-level multivariate regressions that include firm's collateralizability and other controls as return predictors. In particular, we perform standard firm-level cross-sectional regressions (Fama and MacBeth (1973)) to predict future stock returns:

$$R_{i,t+1} = \alpha_i + \beta \cdot Collateralizability_{i,t} + \gamma \cdot Controls_{i,t} + \varepsilon_{i,t+1},$$

where $R_{i,t+1}$ is stock i's cumulative (raw) return over the respective next year, i.e., from July of year t to June of each year $t+1$. The control variables include current collateralizability, size, book-to-market (BM), profitability (ROA), and book leverage. To avoid using future information, all the balance sheet variables are based on the values available before the end of year t. Table 7 reports the results. The regressions exhibit a significantly negative slope coefficient for collateralizability across all specifications, which supports our theory, since a higher current degree of collateralizability implies lower overall risk exposure, so that expected future returns should indeed be smaller with higher collateralizability.

In our empirical measure, only structure and equipment capital contribute to firms' collateralizability, but not intangible capital. Therefore, by construction, our collateralizability measure weakly negatively correlates with measures of intangible capital. In order to empirically distinguish our theoretical channel from the ones focusing on organizational capital (Eisfeldt and Papanikolaou (2013)) and R&D capital (Chan et al. (2001), Croce et al. (2017)), we also control for OG/AT, the ratio of organizational capital to total assets, and XRD/AT, the ratio of R&D expenses to total assets, as suggested in the literature. The results in Table 7 show that the negative slope coefficients for collateralizability remain significant, although they become smaller in magnitude, after controlling for these two firm characteristics. Instead of using the ratio of R&D expenditure to total assets, we also used the ratio of R&D capital to total assets as a control. The results remain very similar.

6.2 Cash flow risks of collateralizability-sorted portfolios

Our theory suggests that the collateralizability premium comes from the countercyclicality of the marginal value of collateralizable capital. This countercycalical nature of collateralizable capital provides a hedge against bad states of the world and relaxes the financial constraint. In order to highlight this channel, we now provide evidence that cash flow beta cannot explain the cross section of collateralizability sorted portfolios.

Portfolio cash flows are constructed by first aggregating the dividend of all the firms within a given portfolio, then taking log differences to obtain growth rates. We aggregate the dividend series to the annual level and compute the sensitivity (β) of the cash flows with respect to several macroeconomic factors and the standard Fama-French five factors.

For the purpose of this analysis, we first extract dividend payments associated with collateralizability-sorted portfolios. Our construction of the dividend series is the same as that in Bansal et al. (2005). We first use the observations of returns with and without dividends to construct the level of dividends for all the portfolios on a monthly basis, and then construct annual levels of dividends by summing up the level of dividends within a year. Afterwards we compute the sensitivity, i.e., the beta, of the portfolio dividend growth with respect to several macroeconomic risk factors and the five Fama-French factors. The results are reported in Table 8. The macroeconomic shocks include a long-run risk shock (LRR), which is computed as the moving average of the past 4 years' consumption growth, as in Bansal et al. (2005). Furthermore, there is a TFP shock from Feenstra et al. (2015), the equity issuance cost shock (ICS) from Belo et al. (2017), the external financing cost shock (ExF) from Eisfeldt and Muir (2016), and the the financial shock (JQ) from Jermann and Quadrini (2012). Consistent with our model, there are no systematic differences in cash flow betas across the sorted portfolios.

In fact, we view this as an advantage of our model. In the data, previous research typically finds that the link between cash flow beta and expected returns is even weaker than the link between return beta and expected returns. This weak link between cash flow betas and expected returns is also a unique implication of our model.

In frictionless models in which there is a unique stochastic discount factor, the market price of any asset equals the present value of its cash flow. In our model, however, the market price also includes the present value of Lagrangian multipliers, which characterize the tightness of the collateral constraint. Therefore, our model allows the possibility that firms have identical cash flow properties but still have different expected returns.

6.3 Collateralizability spreads and macro shocks

In the previous sections, we showed that the collateralizability spread is not captured by the standard factors. In this section, we provide empirical evidence for the link between the collateralizability spread and a proxy for financial shocks consistent with our model interpretation.

In our model, a financial shock, that is, a shock to entrepreneurs' liquidation probability, affects the relative wealth of both entrepreneurs, who directly invest in equity, and households who do not. In the data, this shock can be proxied by the the percentage change of the wealth share of the wealthiest 1% of households (Gomez (2017))[17]. We show this proxy is a a positively priced source of aggregate risk that high collateralizability firms are more negatively exposed to. This provides additional evidence in favor of the key mechanism in our model, namely that collateralizable assets provide insurance against aggregate shocks.

Empirically, we consider a two-factor asset pricing model with the market (Mkt) and the financial shock proxy ($\Delta WS\%$) as factors. Following the standard approach developed by Fama and MacBeth (1973), we first estimate the exposures (betas) of the five collateralizability-sorted portfolios with respect to the market and the financial shock factor

[17]We would like to thank Matthieu Gomez for generously sharing his data on wealth share.

using the whole sample.

Next, we run period-by-period cross-sectional regressions of realized portfolio returns on betas to estimate the market prices of risks, given by the average slope from the period-by-period cross-sectional regressions. The results are presented in Panel B of Table 9.

The results for these two exercises are shown in Table 9, where Panel A presents the exposures of the five portfolios to the two factors, while the estimated market prices of risk are shown in Panel B.

We make several observations. First and importantly, one can see from Panel A , that the betas with respect to the financial shock proxy ($\Delta WS\%$) display a monotonically decreasing pattern from low to high collateralizability portfolios. In particular, the high collateralizability quintiles 4 and 5 even exhibit significantly negative betas, so that their exposure to the financial shock factor is negative. This once again highlights the main economic feature in our model, namely that collateralizable assets provide an insurance against financial shocks through a relaxation of financial constraints.

Furthermore, in the second stage cross-sectional regressions, in which we use five collateralizability-sorted portfolios as the test assets, we compare the two-factor model ($Mkt + \Delta WS\%$) with the standard CAPM with only the market factor. Probably not surprisingly, we observe that the CAPM fails. On one hand, the average pricing error, represented by the intercept, is statistically significantly different from zero. On the other hand, the estimated market price of risk for market factor (λ_{Mkt}) is counterfactually high, amounting to 37.2% annually. Taken together, these results indicate that the spread of CAPM betas across the test portfolios is too small to provide an explanation of the collateralizability premium. When we add he financial shock factor in the second regression, the estimated market price of risk for this new factor is positive and significant. The average pricing error (i.e., intercept) becomes economically smaller and statistically insignificant.

7 Conclusion

In this paper, we present a general equilibrium asset pricing model with heterogenous firms and collateral constraints. Our model predicts that collateralizable assets provide insurance against aggregate shocks and should therefore earn a lower expected return. They relax the collateral constraint, which is more binding in recessions.

We develop an empirical collateralizability measure for a firm's assets, and provide empirical evidence consistent with the predictions of our model. In particular, we find in the data that the difference in average equity returns between firms with a low and a high degree of asset collateralizability amounts to almost 8% per year. When we calibrate our model to the dynamics of macroeconomic quantities, we show that this credit market friction is a quantitatively important determinant for the cross-section of asset returns.

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Table 1: Portfolios Sorted on Collateralizability

This table reports average value-weighted excess returns for portfolios sorted on collateralizability. The sample period is from July 1979 to December 2016. At the end of June of each year t, we sort the constrained firms into quintiles based on their collateralizability measures available at the end of year $t-1$, where quintile 1 (quintile 5) contains the firms with the lowest (highest) share of collateralizable assets. We hold the portfolios for one year, from July of year t until the June of year $t+1$. A firm is classified as financially constrained in year t, if its WW (Whited and Wu (2006)) index is greater than the corresponding cross-sectional median in year end $t-1$. The same for the SA index (Hadlock and Pierce (2010)). "Non-Dividend" means that a firm has not paid any dividends in year $t-1$. The t-statistics are computed based on Newey-West adjusted standard errors. For each portfolio, as well as for the long-short portfolio denoted by "1-5", the table reports its average excess return $E[R] - R_f$ (in annualized percentage term), the associated t-statistic, its return volatility σ (in annualized percentage term), Sharpe ratio (SR), market beta β_{Mkt} and the associated t-statistic. We annualize returns by multiplying with 12.

	1	2	3	4	5	1-5
	Financially constrained firms - WW index					
$E[R] - R_f$	13.27	10.76	10.90	7.74	5.41	7.86
$t_{E[R]-R_f}$	2.75	2.36	2.54	1.94	1.29	2.53
σ	29.26	26.26	24.31	23.72	22.87	18.05
SR	0.45	0.41	0.45	0.33	0.24	0.44
β_{Mkt}	1.27	1.24	1.19	1.22	1.18	0.09
t_β	16.68	19.50	20.80	23.47	21.45	1.25
	Financially constrained firms - SA index					
$E[R] - R_f(\%)$	12.03	11.97	11.39	6.57	4.52	7.51
$t_{E[R]-R_f}$	2.38	2.48	2.70	1.53	1.02	2.48
$\sigma(\%)$	30.23	27.22	24.42	24.81	23.99	17.67
SR	0.40	0.44	0.47	0.26	0.19	0.42
β_{Mkt}	1.34	1.25	1.16	1.28	1.25	0.08
t_β	16.47	17.07	19.39	23.39	23.92	1.16
	Financially constrained firms - Non-Dividend					
$E[R] - R_f(\%)$	16.12	10.12	7.50	8.45	8.14	7.98
$t_{E[R]-R_f}$	3.72	2.20	1.72	1.88	2.01	2.85
$\sigma(\%)$	27.13	26.05	25.56	25.67	24.17	16.73
SR	0.59	0.39	0.29	0.33	0.34	0.48
β_{Mkt}	1.34	1.35	1.37	1.41	1.32	0.02
t_β	20.67	21.41	26.96	27.65	25.65	0.22

Table 2: Capital Structure Regressions

This table reports the results for the regression

$$\frac{B_{i,t}}{AT_{i,t}} = \zeta_S StructShare_{l(i),t} + \zeta_E EquipShare_{l(i),t} + \gamma X_{i,t} + \varepsilon_{i,t}.$$

where, for a given firm i, $l(i)$ denotes the industry l which the firm i belongs to in year t. The sample starts in 1978 and ends at 2016, at annual frequency. *StructShare* and *EquipShare* are the respective shares of structure and equipment capital in a given industry, computed according to Table D.7 in the appendix. We assume all firms within the same industry have the same structure and equipment shares. $X_{i,t}$ represents a vector of controls typically used in capital structure regressions, including size, book-to-market ratio, profitability, marginal tax rate, earnings volatility, and bond ratings.. $B_{i,t}$ is total debt, defined as the sum of long term and short term financial debt ($DLTT + DLC$). Additionally, in order to capture non-financial debt, we adjust debt by adding capitalized value of operating leases to the financial debt, following Li, Whited, and Wu (2016). The column labeled "Full" corresponds to the regression performed on all firms. The columns labeled "Non-Dividend", "SA cons.", and "WW cons." show the results for the samples of firms classified as constrained based on them not having paid dividends, their SA index (Hadlock and Pierce (2010)) being above the median, or their WW index (Whited and Wu (2006)) being above the median in year $t-1$, respectively. The column "All Cons." refers to the regression for the sample of firms which are classified as constrained with respect to all three measures. All right-hand side variables, except *Struct Share* and *Equip Share*, are demeaned. Standard errors are clustered at the firm-year level.

	(1) Full	(2) Non-Dividend	(3) SA cons.	(4) WW cons.	(5) All cons.
Struct Share	0.624***	0.714***	0.648***	0.677***	0.686***
	(33.96)	(23.62)	(12.41)	(18.79)	(10.65)
Equip Share	0.412***	0.501***	0.406***	0.455***	0.436***
	(27.56)	(19.85)	(13.01)	(18.58)	(11.96)
Observations	63,691	31,461	21,808	27,122	15,944
R^2	0.644	0.620	0.553	0.599	0.572

t-statistics in parentheses
***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table 3: **Calibrated Parameter Values**

This table reports the parameter values used for our monthly calibrations.

Parameter	Symbol	Value
Relative risk aversion	γ	10
IES	ψ	1.3
Capital share in production	α	0.33
Span of contral parameter	ν	0.77
Mean productivity growth rate	$e^{a_{ss}}$	0.048
Time discount rate	β	0.999
Share of type-K investment	ϕ	0.543
Capital depreciation rate	δ	0.09/12
Average death rate of entrepreneurs	$\bar{\lambda}$	0.012
Collateralizability parameter	ζ	0.550
Transfer to entering entrepreneurs	χ	0.938
Persistence of TFP shocks	ρ_A	0.998
Persistence of financial shocks	ρ_x	0.961
Vol. of TFP shock	σ_A	0.007
Vol. of financial shock	σ_x	0.062
Corr. between TFP and financial shocks	$\rho_{A,x}$	-1
Invest. adj. cost paramter	τ	28
Mean idio. Productivity growth	μ_Z	0.0037
Vol. of idio. Productivity growth	σ_Z	0.035

Table 4: Aggregate Moments: Model and Data

This table presents annualized moments from the model simulations and the data. The moments for the model are obtained from repetitions of small samples. We simulate the model at the monthly frequency based on the calibration in Table 3, and then time aggregate the monthly observations to annual frequency. Data refer to the US and span the period 1930-2016, unless otherwise stated. Numbers in parentheses are Newey-West adjusted standard errors, following Newey and West (1987). Inside our model, $\frac{B}{K+H}$ captures the book leverage ratio. The market return R_M corresponds to the aggregate return on entrepreneurs' net worth at the aggregate level and embodies the endogenous financial leverage. R_j denotes the unlevered return on type-j, where $j \in \{K, H\}$. R_K^{Lev} is the levered return on type-K capital.volatility, correlation and first-order autocorrelation are denoted as $\sigma(\cdot)$, $corr(\cdot,\cdot)$ and $AC1(\cdot)$, respectively. As the empirical counterparts, we report the lease adjusted leverage ratio. We use physical asset (PPEGT), which consists of both structure and equipment capitals, and the intangible capital to proxy for type-K and type-H, respectively. The construction of firm-level intangible capital is detailed in Appendix D.3. .

Moments	Data		Benchmark
$\sigma(\Delta y)$	3.05	(0.60)	2.84
$\sigma(\Delta c)$	2.53	(0.56)	2.45
$\sigma(\Delta i)$	10.30	(2.36)	6.86
$corr(\Delta c, \Delta i)$	0.40	(0.28)	0.44
$corr(\Delta c, \Delta y)$	0.82	(0.07)	0.91
$AC1(\Delta y)$	0.49	(0.15)	0.53
$AC1(\frac{B}{K+H})$	0.86	(0.33)	0.89
$E[\frac{B}{K+H}]$	0.32	(0.01)	0.33
$E[K/(H+K)]$	0.53	(0.01)	0.54
$E[K/Y]$	1.13	(0.01)	1.44
$E[R_M - R^f]$	5.71	(2.25)	7.00
$\sigma(R_M - R^f)$	20.89	(2.21)	3.76
$E[R^f]$	1.10	(0.16)	1.46
$\sigma(R^f)$	0.97	(0.31)	2.75
$E[R_K - R_H]$			-6.91
$E[R_K^{Lev} - R_H]$			-4.78

Table 5: Firm Characteristics and Expected Returns: Data and Model

This table compares the moments in the empirical data (Panel A) and the model simulated data (Panel B) at the portfolio level. Panel A reports the statistics computed from the sample of financially constrained firms in the empirical data, from July 1979 to December 2016. In each year t, a firm is classified as financially constrained if its WW index is higher than the cross-sectional median in year $t-1$. We sort the constrained firms into quintiles at the end of June of each year t, based on collateralizability measure at the end of year $t-1$. The portfolios are held a year and then rebalanced every year in July. We perform model simulation at the monthly frequency, and then perform the same portfolio sorts as in the data. The table shows the median of firm characteristics using the value from the year end, such as the collateralizability measure, book leverage (lease adjusted), growth rate of physical capital. We also report the value-weighted excess returns, $E[R^e](\%)$ (annualized by multiplying with 12, in percentage term), for quintile portfolios sorted on collateralizability. In Panel A, collateralizability is constructed as in Appendix D.2. Type-K asset growth is defined as the growth rate of physical capital (PPEGT). Book leverage is adjusted for leased capital following Li, Whited, and Wu (2016). For the model moments in Panel B, collateralizability is computed as $\frac{\zeta K}{K+H}$, book leverage is $\frac{B}{K+H}$, and type-K asset growth is $\frac{\Delta K}{K}$.

Panel A: Data

	1	2	3	4	5	1-5
Collateralizability	0.08	0.17	0.26	0.38	0.62	
Book leverage	0.10	0.16	0.23	0.34	0.46	
Type-K asset growth	0.08	0.09	0.10	0.11	0.13	
$E[R^e]$ (%)	13.27	10.76	10.90	7.74	5.41	7.86

Panel B: Model

	1	2	3	4	5	1-5
Collateralizability	0.27	0.34	0.37	0.40	0.51	
Book leverage	0.31	0.40	0.43	0.47	0.60	
Type-K asset growth	-0.03	0.04	0.07	0.10	0.12	
$E[R^e]$ (%)	7.59	6.99	6.56	5.65	3.38	4.21

Table 6: Asset Pricing Tests of Collateralizability-sorted Portfolios

This table shows the coefficients of regressions of the annualized returns for quintile portfolios sorted by collateralizability on the factors from the Carhart (1997) four-factor model (Panel A), the Fama and French (2015) five-factor model (Panel B), and a model featuring the Fama-French three-factor model augmented by the organizational capital factor suggested by Eisfeldt and Papanikolaou (2013) (Panel C). The t-statistics are computed based on Newey-West adjusted standard errors, following Newey and West (1987). The analysis is performed for financially constrained firms. A firm is classified as constrained in year t, if its WW index according to Whited and Wu (2006) is greater than the sample median in year $t-1$. The sample period is from July 1979 to December 2016, with the exception of Panel C, where the sample ends in December 2008 due to the length of the organizational capital factor. We annualize returns by multiplying with 12.

Panel A: Carhart Four-Factor Model

	1	2	3	4	5	1-5
α	5.43	2.94	2.04	-1.87	-3.91	9.34
(t)	2.80	1.76	1.35	-1.45	-2.44	3.47
β_{MKT}	1.07	1.07	1.07	1.12	1.10	-0.03
(t)	25.25	27.91	32.58	35.68	26.93	-0.48
β_{HML}	-0.62	-0.49	-0.21	-0.12	0.01	-0.63
(t)	-9.72	-8.60	-3.87	-2.31	0.16	-6.03
β_{SMB}	1.34	1.11	1.06	0.97	0.84	0.50
(t)	15.66	15.77	22.71	15.28	8.72	3.27
β_{MOM}	-0.04	-0.06	-0.05	-0.02	-0.07	0.03
(t)	-0.73	-1.74	-1.27	-0.56	-1.31	0.33
R^2	0.85	0.87	0.88	0.90	0.84	0.27

Panel B: Fama-French Five-Factor Model

	1	2	3	4	5	1-5
α	13.02	12.45	12.87	9.22	7.22	5.80
(t)	2.84	2.75	3.07	2.16	1.67	2.06
β_{MKT}	0.49	0.07	0.08	0.20	0.07	0.42
(t)	0.75	0.13	0.15	0.37	0.12	1.01
β_{SMB}	2.03	1.24	1.17	1.28	1.38	0.65
(t)	2.00	1.55	1.43	1.62	1.79	1.08
β_{HML}	-3.84	-4.34	-3.67	-3.15	-2.49	-1.35
(t)	-2.55	-3.21	-2.99	-2.65	-1.92	-1.12
β_{RMW}	-2.77	-3.12	-2.32	-1.90	-1.34	-1.43
(t)	-1.47	-2.11	-1.48	-1.33	-0.97	-1.11
β_{CMA}	2.10	1.00	1.74	0.92	0.94	1.17
(t)	0.83	0.46	1.02	0.53	0.62	0.58
R^2	0.09	0.10	0.08	0.07	0.06	0.04

Panel C: Control for Organizational Capital Factor

	1	2	3	4	5	1-5
α	5.06	3.42	1.56	-0.95	-3.90	8.96
(t)	2.30	1.67	0.85	-0.61	-1.74	2.66
β_{MKT}	1.10	1.07	1.10	1.11	1.08	0.03
(t)	19.82	21.75	24.43	30.89	23.11	0.35
β_{HML}	-0.56	-0.50	-0.19	-0.14	-0.00	-0.55
(t)	-7.23	-7.46	-2.71	-1.85	-0.04	-3.68
β_{SMB}	1.40	1.12	1.05	0.97	0.81	0.59
(t)	14.95	16.91	18.30	14.51	6.09	3.07
β_{OMK}	-0.02	0.01	0.01	-0.04	-0.14	0.13
(t)	-0.31	0.23	0.14	-0.99	-2.33	1.29
R^2	0.86	0.87	0.88	0.89	0.83	0.29

Table 7: Fama Macbeth Regressions

This table reports the results for Fama-MacBeth regressions of annual cumulative individual firm (raw) stock returns on lagged firm characteristics. The numbers reported in the table are the time-series averages of the slope coefficients from year-by-year cross-sectional regressions. The reported R^2 is the time-series average of the cross-sectional R^2. The columns labeled "SA", "WW", and "Non-Dividend" refer to the samples, where firms are classified as financially constrained using the SA index (Hadlock and Pierce (2010)), the WW index (Whited and Wu (2006)), or the fact that they did not pay dividends in the given year. ROA is Compustat item IB divided by book assets. OG/AT is organizational capital over total book assets, XRD/AT is R&D expenditure over total book assets. The t-statistics (in parentheses) are adjusted following Newey and West (1987). The sample period is from 1979 to 2016.

	(1) SA	(2) WW	(3) No-Dividend	(4) SA	(5) WW	(6) No-Dividend	(7) SA	(8) WW	(9) No-Dividend
Collateralizability	-0.114***	-0.117***	-0.0914***	-0.0831**	-0.102***	-0.0815***	-0.0567**	-0.0552**	-0.0444**
	(-3.95)	(-4.23)	(-3.74)	(-2.52)	(-3.28)	(-3.48)	(-2.68)	(-2.47)	(-2.50)
log(ME)	-0.139***	-0.134***	-0.0692***	-0.135***	-0.131***	-0.0658***	-0.145***	-0.143***	-0.0735***
	(-4.29)	(-5.04)	(-3.64)	(-4.22)	(-5.04)	(-3.54)	(-4.41)	(-5.19)	(-3.75)
BM	0.0405**	0.0292*	0.0492***	0.0468**	0.0321**	0.0523***	0.0467***	0.0371**	0.0547***
	(2.36)	(2.02)	(4.10)	(2.59)	(2.10)	(4.02)	(2.88)	(2.67)	(4.48)
Lagged return	0.0109	0.00289	0.0167	0.00903	0.00151	0.0144	0.0111	0.00399	0.0170
	(0.72)	(0.19)	(0.96)	(0.61)	(0.10)	(0.86)	(0.72)	(0.25)	(0.95)
ROA	0.0744	0.0628	0.0911	0.0879	0.0766	0.104	0.190***	0.199***	0.213***
	(1.17)	(1.16)	(1.56)	(1.31)	(1.34)	(1.67)	(3.25)	(3.75)	(4.09)
Book Leverage	-0.0893*	-0.0347	-0.0165	-0.0699	-0.0224	-0.00274	-0.0435	0.0161	0.0378
	(-1.74)	(-0.77)	(-0.32)	(-1.38)	(-0.48)	(-0.05)	(-0.94)	(0.40)	(0.78)
OG/AT				0.105***	0.0637**	0.0709**			
				(3.90)	(2.26)	(2.37)			
XRD/AT							0.636***	0.760***	0.581***
							(2.91)	(3.15)	(2.99)
Constant	0.705***	0.695***	0.471***	0.639***	0.654***	0.430***	0.657***	0.643***	0.417***
	(5.32)	(6.46)	(4.88)	(5.08)	(6.39)	(4.50)	(5.22)	(6.45)	(4.41)
Observations	34487	39059	45125	34487	39059	45125	34487	39059	45125
R-square	0.0828	0.0809	0.0626	0.0864	0.0836	0.0662	0.0886	0.0870	0.0688

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

Table 8: Cash Flow Sensitivity to Macroeconomic Shocks and Fama-French Factors

This table shows the sensitivity of the cash flow of collateralizability-sorted portfolios to aggregate shocks. Our construction of the dividend series is the same as that in Bansal et al. (2005). We firstly use the observations of returns with and without dividends to construct the level of dividends for all the portfolios on a monthly basis, and then construct annual levels of dividends by summing up the level of dividends within a portfolio in a given year. Panel A reports the regression coefficients from regressing portfolio-level cash flow growth on each macroeconomic shock. Panel B reports the regression coefficients from regressing portfolio-level cash flow growth on Fama-French five factors. The procedure of portfolio formation is the same as in Table 1. We include four different macroeconomic shocks. LRR is the long-run risks shock, which is the moving average of past 4 years' consumption growth, as in Bansal et al. (2005). TFP is the TFP shock, which is from Feenstra et al. (2015). The ICS is the equity issuance cost shock from Belo et al. (2017). ExF is the external financing cost from Eisfeldt and Muir (2016). JQ is the financial shock from Jermann and Quadrini (2012). All series are at annual frequency. The numbers in parenthesis are t-statistics, which are estimated following Newey and West (1987).

Panel A: Cash Flow Sensitivity to Macroeconomic Shocks

CF Portfolio	1	2	3	4	5	1-5
LRR	-7.23	-16.63	-4.50	-14.33	-2.78	-4.46
	(-0.68)	(-1.87)	(-0.31)	(-2.13)	(-0.45)	(-0.41)
TFP	17.41	18.88	16.03	25.43	7.74	9.67
	(1.09)	(12.8)	(0.86)	(1.58)	(0.78)	(0.56)
ICS	2.42	11.05	4.59	7.52	-8.91	11.33
	(0.40)	(0.83)	(0.60)	(0.85)	(-1.24)	(1.54)
ExF	4.47	13.21	28.17	4.49	-0.61	5.08
	(0.52)	(0.95)	(2.26)	(0.64)	(-0.04)	(0.26)
JQ	-1.41	-23.72	-11.19	1.42	-21.42	20.01
	(-0.19)	(-1.21)	(-0.77)	(0.13)	(-1.53)	(1.63)

Panel B: Cash Flow Sensitivity to Fama-French Five Factors

CF Portfolio	1	2	3	4	5	1-5
Mkt	0.56	0.01	0.08	0.09	-0.72	1.28
	(0.65)	(0.01)	(0.08)	(0.19)	(-0.57)	(1.05)
SMB	-1.00	0.65	0.18	1.55	0.49	-1.49
	(-1.21)	(0.64)	(0.11)	(1.23)	(0.69)	(-1.44)
HML	-0.11	-0.29	0.96	2.40	0.33	-0.45
	(-0.11)	(-0.31)	(0.53)	(1.62)	(0.33)	(-0.35)
RMW	-0.04	0.98	1.03	-0.08	-1.39	1.35
	(-0.05)	(0.55)	(0.52)	(-0.07)	(-0.96)	(0.85)
CMA	1.28	0.56	-0.19	-4.51	-1.19	2.47
	(0.65)	(0.36)	(-0.07)	(-1.46)	(-0.85)	(1.17)

Table 9: Beta and Price of Risk of the Financial Shock

This table presents the risk price estimates for shocks to wealth share. The factors included are the market return (denoted by Mkt) and the percentage change in the wealth share of the wealthiest 1% of US households (Gomez (2017)). Panel A presents the first-stage estimates of the portfolio exposures for the quintile portfolios sorted on collateralizability. Panel B shows the estimates of the market prices of risk obtained from the second stage. The risk prices reported in Panel B are the mean slopes of period-by-period cross-sectional regressions of portfolio excess returns on risk exposures (betas). The mean absolute pricing errors (MAE) across the test assets in Panel B are expressed in percentage.

Panel A: Factor Exposures of Collateralizability-Sorted Portfolios

	1	2	3	4	5	1-5
Mkt	1.185	1.091	1.117	1.170	1.100	0.0854
	(7.10)	(4.72)	(5.48)	(7.40)	(7.08)	(0.55)
$\Delta WS\%$	1.188	0.765	-1.389	-3.966	-7.359	8.547
	(0.36)	(0.23)	(-0.49)	(-2.14)	(-2.87)	(2.49)
α	2.000	0.0476	0.359	-3.039	-4.763	6.763
	(0.63)	(0.01)	(0.10)	(-1.33)	(-1.85)	(3.00)

Panel B: Market Prices of Risk

	CAPM	CAPM+$\Delta WS\%$
λ_{Mkt}	0.372	0.139
	(2.517)	(1.102)
$\lambda_{\Delta WS\%}$		0.731
		(2.107)
Intercept	-0.317	-0.050
	(-2.020)	(-0.341)
MAE	0.943	0.615
R^2	0.830	0.941

Online Appendix for
"The Collateralizability Premium"

A: Proof of Proposition 1

To prove Proposition 1, we need to prove the following: first, given prices, the quantities satisfy the household's and the entrepreneurs' optimality conditions; second, the quantities satisfy the market clearing conditions.

First, the household's first-order condition (3) and the resource constraint (15) are satisfied by construction, since their normalized versions represent two of the functional equations listed in Proposition 1.

Second, we prove that the entrepreneur i's allocations $\{N_{i,t}, B_{i,t}, K_{i,t}, H_{i,t}, L_{i,t}\}$ as constructed in Proposition 1 are indeed optimal solutions to his optimization problem (8). Note that the entrepreneur's optimization problem is a standard convex programming problem. Therefore, the first order conditions, i.e., equations (20) to (23), together with the constraints (4), (5), and (7), constitute both necessary and sufficient conditions for optimality. It is easy to show that, given prices, the equilibrium quantities $\{N_{i,t}, B_{i,t}, K_{i,t}, H_{i,t}, L_{i,t}\}$ as constructed in Proposition 1 satisfy the above conditions.

Finally, we show the market clearing conditions hold. Given the initial conditions (initial net worth N_0, $\frac{K_1}{H_1} = \frac{\phi}{1-\phi}$, $N_{i,0} = z_{i,1}N_0$) and the net worth injection rule for the new entrant firms ($N_{t+1}^{entrant} = \chi N_t$ for all t), we can prove the following lemma:

Lemma 1. *The optimal allocations $\{N_{i,t}, B_{i,t}, K_{i,t+1}, H_{i,t+1}\}$ constructed as in Proposition 1 satisfy the market clearing conditions, i.e.,*

$$K_{t+1} = \int K_{i,t+1}\, di, \quad H_{t+1} = \int H_{i,t+1}\, di, \quad N_t = \int N_{i,t}\, di \tag{A1}$$

for all $t \geq 0$.

First, in each period t, given prices and $N_{i,t}$, the individual entrepreneur i's capital decisions $\{K_{i,t+1}, H_{i,t+1}\}$ must satisfy the condition

$$N_{i,t} = (1-\zeta)\, q_{K,t} K_{i,t+1} + q_{H,t} H_{i,t+1} \tag{A2}$$

and the optimal decision rule (18). Equation (A2) is obtained by combining the entrepreneur's budget constraint (4) with a binding borrowing constraint (5).

Next, we show that, given the initial conditions, market clearing conditions (A1) hold for all $t \geq 0$. In period 0, we start from the initial conditions. First, $N_{i,0} = z_{i,1} N_0$, where $z_{i,1}$ is chosen from the stationary distribution of z. Then, given $z_{i,1}$ for each firm i, we use equations (A2) and (18) to solve for $K_{i,1}$ and $H_{i,1}$. Clearly, $K_{i,1} = z_{i,1} K_1$ and $H_{i,1} = z_{i,1} H_1$. Therefore, the market clearing conditions (A1) hold for $t = 0$, i.e.,

$$\int K_{i,1}\, di = K_1, \quad \int H_{i,1}\, di = H_1, \quad \int N_{i,0}\, di = N_0. \tag{A3}$$

We then show the market clearing conditions (A1) also hold for $t > 0$. In particular, we prove the following claim:

Claim 1. *Suppose* $\int K_{i,t+1}\, di = K_{t+1}$, $\int H_{i,t+1}\, di = H_{t+1}$, $\int N_{i,t}\, di = N_t$, *and* $N_{t+1}^{entrant} = \chi N_t$, *then*

$$\int K_{i,t+2} di = K_{t+2} \quad \int H_{i,t+2} di = H_{t+2} \quad \int N_{i,t+1} di = N_{t+1} \tag{A4}$$

for all $t \geq 0$.

1. Using the law of motion for the net worth of existing firms, one can show that the total net worth of all surviving firms can be rewritten as follows:

$$\begin{aligned} &(1-\lambda)\int N_{i,t+1} di \\ &= (1-\lambda)\int \left[A_{t+1}\left(K_{i,t+1}+H_{i,t+1}\right) + (1-\delta)\, q_{K,t+1} K_{i,t+1} + (1-\delta)\, q_{H,t+1} H_{i,t+1} - R_{f,t+1} B_{i,t}\right] di, \\ &= (1-\lambda)\left[A_{t+1}\left(K_{t+1}+H_{t+1}\right) + (1-\delta)\, q_{K,t} K_{t+1} + (1-\delta)\, q_{H,t} H_{t+1} - R_{f,t+1} B_t\right], \end{aligned}$$

since by assumption $\int K_{i,t+1}\, di = K_{t+1}$, $\int H_{i,t+1}\, di = H_{t+1}$, and $\int B_{i,t}\, di = B_t = \zeta q_{K,t} K_{t+1}$. Using the assignment rule for the net worth of new entrants, $N_{t+1}^{entrant} = \chi N_t$, we can show that the total net worth at the end of period $t+1$ across survivors and new entrants together satisfies $\int N_{i,t+1}\,di = N_{t+1}$, where aggregate net worth N_{t+1} is given by equation (9).

2. At the end of period $t+1$, we have a pool of firms consisting of old ones with net worth given by (7) and new entrants. All of them will observe $z_{i,t+2}$ (for the new entrants $z_{i,t+2} = \bar{z}$) and produce at the beginning of the period $t+1$.

   We compute the capital holdings for period $t+2$ for each firm i using (A2) and (18). At this point, the capital holdings and the net worth of all existing firms will not be proportional to $z_{i,t+2}$ due to heterogeneity in the shocks. However, we know that $\int N_{i,t+1}\,di = N_{t+1}$, and $\int z_{i,t+2}\,di = 1$. Integrating (A2) and (18) across all i yields the two equations

$$(1-\zeta)\,q_{K,t+1}\int K_{i,t+2}\,di + q_{H,t+1}\int H_{i,t+2}\,di = N_{t+1} \tag{A5}$$

$$\int K_{i,t+2}\,di + \int H_{i,t+2}\,di = K_{t+2} + H_{t+2}, \tag{A6}$$

   where we have used $\int N_{i,t+1}\,di = N_{t+1}$ and $\int z_{i,t+2}\,di = 1$. Given that the constraints of all entrepreneurs are binding, the budget constraint (A2) also holds at the aggregate level, i.e.,

$$N_{t+1} = (1-\zeta)\,q_{K,t+1}K_{t+2} + q_{H,t+1}H_{t+2}.$$

   Together with the above system, this implies $\int K_{i,t+2}di = K_{t+2}$ and $\int H_{i,t+2}di = H_{t+2}$. Therefore, the claim is proved.

In summary, we have proved that the equilibrium prices and quantities constructed in Proposition 1 satisfy the household's and entrepreneur's optimality conditions, and that the quantities satisfy market clearing conditions. Therefore, the proof of Proposition 1 is complete.

B: Sensitivity analysis

In this section, we discuss the sensitivity of our quantitative results to several important parameters. To save space, we only discuss the moments which are sensitive to the respective each parameter. The results are reported in Table B.1.

Collateralizability parameter (ζ) The parameter ζ determines the collateralizability of type-K capital. We vary this parameter by $\pm 10\%$ around the benchmark value of 0.517 from Table 3 and make the following observations.

First, since we assume the collateral constraint is binding, higher collateralizability mechanically increases the average leverage ratio. Second, higher collateralizability leads to a lower risk premium for type-K capital, but to a higher risk premium for type-H capital, which overall implies a higher collateralizability premium. This is consistent with our model mechanism. Note that the price of type-K capital contains not only the present value of future cash flows, but also the present value of Lagrangian multipliers. According to equation (31), an increase in ζ makes the second component more important, which in turn makes the hedging channel more important and type-K capital less risky. On the other hand, a higher leverage ratio makes the entrepreneur's net worth more volatile, and therefore increases the risk premium of type-H capital.

Type-K and type-H capital ratio (ϕ) We vary this parameter by $\pm 10\%$. A higher ϕ implies a larger proportion of collateralizable assets in the economy, and as a result, it mechanically increases the leverage ratio and the overall asset collateralizability. A higher leverage ratio in turn leads to a more volatile entrepreneur's net worth, and therefore, increases the risk premia for both types of capital. Note that an increase in ϕ is structurally different from an increase in the degree of collateralizability, ζ. An increase in ζ lowers down the risk premium of type-K capital. As shown in the Panel B, $R^K - R^f$ decreases if ζ increases. The impact of increasing in ϕ only works through the leverage channel, thus it increases the risk premium of all risky assets.

Shock correlation ($\rho_{x,A}$) As explained in Section 5.1, we assume a negative correlation between the aggregate productivity shock and the financial shock in order for the model to generate a positive correlation between consumption and investment growth, consistent with the data. For parsimony, we had imposed a perfectly negative correlation in our benchmark calibration. We vary this parameter and consider the cases $\rho_{x,A} = -0.8$ and -0.9.

In terms of results, the correlation between consumption and investment growth becomes less positive, confirming our model intuition presented in Section 5.1. Furthermore, varying this correlation parameter does not qualitatively change the collateralizability spread and has limited effects on various risk premia as well.

Persistence parameters of exogenous shocks (ρ_x and ρ_A) We vary persistence parameters of exogenous shocks (ρ_x and ρ_A) one at a time. The parameter variations we consider change the half-life of a shock to x or a by $\pm 20\%$.

First, an increase in ρ_x has opposite effects on the risk premia of type-K and type-H capital. On the one hand, a more persistent financial shock makes type-K capital an even better hedging device, which reduces the equilibrium risk premium. On the other hand, entrepreneurs' net worth becomes more volatile, and as a result, the risk premium of type-H capital increases. Put together, this leads to a higher risk premium for the aggregate market and to a larger collateralizability spread. Second, an increase in ρ_A generates a stronger long-run risk channel in cash flows, and as a result, we observe higher risk premia for both type-K and type-H capital. The effects of lower ρ_x and ρ_A are exactly opposite to those generated by higher values for these parameters.

Shock volatilities (σ_x and σ_A) We vary the shock volatilities σ_x and σ_A, one at a time, by $\pm 10\%$. We observe that the effect caused by increasing the two shock volatilities are very similar. A higher σ_x or σ_A leads to an increase in the risk premia for both types of capital, which is intuitively clear, since the economy in general becomes riskier.

Table B.1: Sensitivity Analysis

The table shows the results of sensitivity analyses, where key parameters of the model are varied around the values from the benchmark calibration shown in Table 3. A star superscript denotes the parameter value from the benchmark calibration.

Panel A: Collateralizability parameter ζ

	Data	Benchmark	$0.9\zeta^*$	$1.1\zeta^*$
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.84	2.84
Collateralizability	0.38 (0.03)	0.33	0.29	0.36
$E[\frac{B_t}{K_t+H_t}]$	0.32(0.01)	0.33	0.29	0.37
$E[R^M - R^f]$	5.71 (2.25)	7.00	6.39	7.62
$\sigma(R^M - R^f)$	20.89 (2.21)	3.76	3.58	3.97
$E[R^H - R^f]$		8.90	8.10	9.71
$E[R^K - R^f]$		1.99	2.14	1.82
$E[R^{K,Lev} - R^H]$		-4.78	-4.09	-5.51

Panel B: Capital composition ϕ

	Data	Benchmark	$0.9\phi^*$	$1.1\phi^*$
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.86	2.82
Collateralizability	0.38 (0.03)	0.33	0.30	0.35
$E[\frac{B_t}{K_t+H_t}]$	0.32(0.01)	0.33	0.30	0.36
$E[R^M - R^f]$	5.71 (2.25)	7.00	6.87	7.11
$\sigma(R^M - R^f)$	20.89 (2.21)	3.76	3.72	3.78
$E[R^H - R^f]$		8.90	8.49	9.32
$E[R^K - R^f]$		1.99	1.86	2.15
$E[R^{K,Lev} - R^H]$		-4.78	-4.64	-4.86

Panel C: Shock correlation $\rho_{x,A}$

	Data	Benchmark	$\rho_{x,A} = -0.8$	$\rho_{x,A} = -0.9$
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.98	3.01
$\sigma(\Delta i)$	10.30 (2.36)	6.86	7.02	7.11
$corr(\Delta c, \Delta i)$	0.40 (0.28)	0.44	0.33	0.37
$E[R^M - R^f]$	5.71 (2.25)	7.00	7.47	7.25
$\sigma(R^M - R^f)$	20.89 (2.21)	3.76	3.93	3.85
$E[R^H - R^f]$		8.90	9.00	8.95
$E[R^K - R^f]$		1.99	2.47	2.25
$E[R^{K,Lev} - R^H]$		-4.78	-3.88	-4.28

Table B.1: Sensitivity Analysis (Continued)

Panel D: Persistence of financial shock ρ_x				
	Data	Benchmark	80% half life	120% half life
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.73	2.94
$AC1(\Delta y)$	0.49 (0.15)	0.53	0.50	0.56
$AC1(\frac{B_t}{K_t+H_t})$	0.86 (0.33)	0.89	0.89	0.89
$E[R^M - R^f]$	5.71 (2.25)	7.00	6.90	7.15
$E[R^H - R^f]$		8.90	8.60	9.23
$E[R^K - R^f]$		1.99	2.08	1.94
$E[R^{K,Lev} - R^H]$		-4.78	-4.28	-5.22

Panel E: Persistence of productivity shock ρ_A				
	Data	Benchmark	80% half life	120% half life
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.82	2.85
$AC1(\Delta y)$	0.49 (0.15)	0.53	0.53	0.54
$AC1(\frac{B_t}{K_t+H_t})$	0.86 (0.33)	0.89	0.88	0.89
$E[R^M - R^f]$	5.71 (2.25)	7.00	6.43	7.67
$E[R^H - R^f]$		8.90	8.03	9.87
$E[R^K - R^f]$		1.99	1.93	2.11
$E[R^{K,Lev} - R^H]$		-4.78	-4.02	-5.50

Panel F: Volatility of financial shock σ_x				
	Data	Benchmark	$0.9\sigma_x^*$	$1.1\sigma_x^*$
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.77	2.92
$\sigma(\Delta i)$	10.30 (2.36)	6.86	6.33	7.42
$E[R^M - R^f]$	5.71 (2.25)	7.00	7.21	6.78
$E[R^{K,Lev} - R^H]$		-4.78	-4.23	-5.33

Panel G: Volatility of productivity shock σ_A				
	Data	Benchmark	$0.9\sigma_A^*$	$1.1\sigma_A^*$
$\sigma(\Delta y)$	3.05 (0.60)	2.84	2.63	3.06
$\sigma(\Delta i)$	10.30 (2.36)	6.86	6.67	7.06
$E[R^M - R^f]$	5.71 (2.25)	7.00	6.51	7.56
$E[R^{K,Lev} - R^H]$		-4.78	-4.38	-5.17

C: Additional empirical evidence

In this section, we provide additional empirical evidence regarding the collateralizability premium. First, we demonstrate the robustness of our findings by forming collateralizability portfolios within industries to make sure that our baseline result is not driven by industry-specific effects, and by performing a rolling-window estimation of the collateralizability parameters. Second, we present correlations between collateralizability and firm characteristics. Finally, we perform double sorts with respect to collateralizability and financial leverage.

C.1. Alternative portfolio sorts

To implement the first robustness check, we consider the Fama-French industry classification with 17 sectors. We sort firms into collateralizability quintiles according to their collateralizability score within their respective industry. Portfolio 1 will thus contain all firms which are in the lowest quintile relative to their industry peers, and so on for portfolios 2 to 5. By doing so, we essentially control for industry fixed effects. Table C.2 reports the results of this exercise, and one can see that the results are very close to the findings of our benchmark analysis presented in Table 1.

In our benchmark analysis, we estimate the collateralizability coefficients for structure and equipment capital, ζ_S and ζ_E, using the whole sample. One might argue that this introduces a look-ahead bias, since the estimation is based on data not observable at the time when decisions are made. To see whether a potential look-ahead bias indeed has an effect on our results, we now perform the portfolio sort in year t exclusively on information up to $t-1$. In more detail, we use estimates denoted by $\widehat{\zeta}_{S,t-1}$ and $\widehat{\zeta}_{E,t-1}$ derived from expanding window regressions using data available up to the end of year $t-1$. The first window consists of data for the period from 1975 to 1980.[18].

Table C.3 presents the results in a fashion analogous to Table 1. For all three measures for financial constraints, the collateralizability spread is positive, large, and significant. This

[18]The regressor, marginal tax rate, is only available after 1980, therefore we drop this regressor. All other regressors are available from 1975 onwards. The results are similar if we start our sample in 1980 with marginal tax rate.

Table C.2: Portfolios Sorted on Collateralizability within Industries

This table reports annualized average monthly value-weighted excess returns ($E[R]-R^f$) for portfolios sorted on collateralizability, and their alphas with respect to different factor models. The sample period is from July 1979 to December 2016. We annualize returns by multiplying with 12. $\alpha^{FF3+MOM}$ and α^{FF5} are the alphas with respect to the Carhart (1997) four-factor model and the Fama and French (2015) five-factor model, respectively. At the end of June each year t, we consider each of the 17 Fama-French industries and sort the constrained firms in a given industry into quintiles based on their collateralizability scores at the end of year $t-1$. We hold the portfolios for a year, from July of year t until the June of year $t+1$. Portfolios are rebalanced in July every year. Firms are classified as constrained in year t, if their year end WW or SA index are higher than the corresponding median in year $t-1$, or if the firms do not pay dividends in year $t-1$. The WW and the SA index are constructed according to Whited and Wu (2006) and Hadlock and Pierce (2010), respectively. Additionally, we consider a subsample where the firms are classified as constrained by all three measures jointly. The t-statistics are estimated following Newey and West (1987).

	1	2	3	4	5	1-5
	Financially constrained firms - All measures					
$E[R]-R_f(\%)$	13.14	10.46	11.67	7.97	6.86	6.28
(t)	2.63	2.22	2.41	1.79	1.46	2.60
$\alpha^{FF3+MOM}$	4.59	2.06	2.64	-1.31	-2.74	7.33
(t)	2.48	0.98	1.35	-0.68	-1.47	3.21
α^{FF5}	13.87	10.94	13.01	10.97	7.04	6.83
(t)	2.75	2.31	2.52	2.36	1.38	2.85
	Financially constrained firms - WW index					
$E[R]-R_f(\%)$	12.53	11.77	9.83	8.36	6.02	6.51
(t)	2.68	2.71	2.22	1.99	1.41	3.07
$\alpha^{FF3+MOM}$	4.23	2.83	1.62	-0.76	-3.05	7.28
(t)	2.51	1.78	0.97	-0.50	-2.37	3.57
α^{FF5}	14.25	12.26	11.76	10.28	6.37	7.88
(t)	2.97	2.75	2.56	2.35	1.33	3.58
	Financially constrained firms, SA index					
$E[R]-R_f(\%)$	11.28	11.51	8.08	8.32	6.02	5.26
(t)	2.35	2.41	1.77	1.94	1.35	2.54
$\alpha^{FF3+MOM}$	3.58	4.65	-0.62	-0.49	-2.50	6.08
(t)	1.99	2.25	-0.41	-0.33	-1.50	2.99
α^{FF5}	12.20	13.36	10.07	9.54	7.37	4.83
(t)	2.60	2.57	2.08	2.09	1.58	2.22
	Financially constrained firms, Non-Dividend					
$E[R]-R_f(\%)$	14.99	12.98	6.99	7.92	9.69	5.30
(t)	3.50	2.83	1.70	1.98	2.12	2.27
$\alpha^{FF3+MOM}$	7.39	5.23	0.39	-0.12	2.24	5.15
(t)	3.90	2.59	0.23	-0.08	1.22	2.18
α^{FF5}	14.90	14.95	8.16	8.88	11.45	3.44
(t)	3.59	3.59	2.16	2.16	2.61	1.47

shows that our baseline results do not suffer from a look-ahead bias with respect to the estimation of the collateralizability coefficients.

In order to capture the fact that structure capital is more collateralizable than equipment capital (Rampini and Viswanathan (2010), Campello and Giambona (2013)), we employ a constrained version of the leverage regression in Table 2 by estimating the equation

$$\frac{B_{i,t}}{AT_{i,t}} = (\zeta_E + e^{\Delta})StructShare_{l,t} + \zeta_E EquipShare_{l,t} + \gamma X_{i,t} + \varepsilon_{i,t},$$

i.e., we impose the restriction $\zeta_S = \zeta_E + e^{\Delta} > \zeta_E$. Then we perform a maximum likelihood estimation of above equation to obtain the time series of the estimates of ζ_E and Δ. In our sample, the estimated e^{Δ} across expanding windows is of mean 0.15 with standard error of 0.02.

As a further note, one advantage of our approach to sort stocks into portfolios does not rely on absolute precision in the estimation of ζ_E and ζ_S (which could potentially be subject to various sources of biases, e.g., due to endogeneity of capital structure choices, measurement errors in capital etc.). The outcome of the portfolio sort only depends on the ranking of the collateralizability measure for a given firm, not on its exact magnitude. In our empirical construction of the collateralizability measure, we consider three types of capital according to BEA, structure, equipment, and intellectual capital. As long as $\zeta_S > \zeta_E$ and intellectual capital does not contribute to collateralizability, the rank of a firm with respect to asset collateralizability will depend only on the composition of its capital, not on the numerical values of the estimated ζ-coefficients.

C.2. Collateralizability and additional firm characteristics

As indicated by the results in Table 5, our model can quantitatively replicate the patterns of leverage, asset growth and the investment rate. In Table C.4, we now present additional characteristics of the firms in our collateralizability-sorted portfolios.

Cash flow and size are relatively flat across the five portfolios, low collateralizability firms on average hold more cash. Although cash is not modeled in our paper, this empirical finding

Table C.3: Portfolios Sorting based on Expanding Window Estimated Collateralizability

This table reports average value-weighted monthly excess returns (in percent and annualized) for portfolios sorted on collateralizability. The sample period is from July 1981 to December 2016. At the end of June of each year t, we sort the constrained firms into five quintiles based on their collateralizability measures (estimated using expanding window) at the end of year $t-1$, where quintile 1 (quintile 5) contains the firms with the lowest (highest) share of collateralizable assets. We hold the portfolios for a year, from July of year t until the June of year $t+1$. A firm is considered as financially constrained in year t, if its WW or its SA index are higher than the corresponding cross-sectional median in year end $t-1$, or if the firm has not paid dividends in year $t-1$. The WW and SA indices are constructed according to Whited and Wu (2006) and Hadlock and Pierce (2010), respectively. Standard errors are estimated using Newey-West estimator. The table reports average excess returns $E[R]-R_f$, as well as the associated t-statistics, and Sharpe ratios (SR). We annualize returns by multiplying with 12.

	1	2	3	4	5	1-5
	Financially constrained firms - WW index					
$E[R]-R_f(\%)$	11.76	10.68	9.80	7.18	5.20	6.55
(t)	2.33	2.31	2.24	1.71	1.30	2.18
SR	0.41	0.41	0.40	0.30	0.24	0.38
	Financially constrained firms - SA index					
$E[R]-R_f(\%)$	9.61	10.74	9.36	7.82	3.64	5.97
(t)	1.84	2.21	2.11	1.74	0.88	2.07
SR	0.32	0.40	0.38	0.31	0.16	0.35
	Financially constrained firms - Non-Dividend					
$E[R]-R_f(\%)$	14.32	9.18	6.93	7.13	6.75	7.57
(t)	3.11	2.07	1.59	1.59	1.63	2.83
SR	0.54	0.36	0.28	0.28	0.29	0.49

is still consistent with our model intuition. Firms with less collaterizable assets hold more cash to compensate for the fact that they can hardly obtain collateralized loans, and even less so in recessions. The probability of debt issuance is increasing with asset collateralizability, while the probability of equity financing shows the opposite tendency. This reflects the substitution effect between the two types of external financing. Additionally, firms with more collateralizable assets on average have more short-term and long-term debt.

In Table C.5, we report the correlations of the collateralizability measure with other firm characteristics which have been shown in the past literature to predict the cross-section of stock returns, including the book-to-market ratio (BM) , the $R\&D$-to-asset ratio (XRD/AT), the organizational capital-to-asset ratio (OG/AT), (log) size (log(ME)), the investment rate, i.e., the ratio of investment to capital (I/K), and the return on assets (ROA). Notably, the collateralizability measure and these firm characteristics are only weakly correlated, with the correlation coefficients ranging between -33% to 16%.

C.3. Double sorting on collateralizability and leverage

As discussed in the main text, firms with higher asset collateralizablility have higher debt capacity and thus tend to have higher financial leverage. When a firm is highly levered, its equity is more exposed to aggregate risks. The effects of collateralizability and leverage can thus offset each other in determining the overall riskiness of the firm and consequently its expected equity return.

In order to disentangle these two effects, we conduct an independent double sort on collateralizability and financial leverage. The average returns for the resulting portfolios are reported in Table C.6. First, within each quintile sorted on book leverage, the collateralizability spread is always significantly positive. Second, the average returns of the high-minus-low leverage portfolios within each collateralizability quintile are not statistically significant.

Table C.4: Firm Characteristics

This table reports the median of firm characteristics across portfolios of firms sorted on collateralizability. The sample starts in 1979 and ends in 2016. Collateralizability is defined as in Section D.2. Book leverage is lease adjusted following Li, Whited, and Wu (2016). BM is the book-to-market ratio. $\frac{I}{K+H}$ is the sum of physical investments (CAPX), R&D and organizational capital investments over the sum of PPEGT and intangible capital. More details on the definition of R&D and organizational capital investments can be found Appendix D.3. $\log(ME)$ is the nature log of the market capitalization. Cash flow is defined as OIBDP to total asset ratio. Gross profitability is defined as revenue minus cost of goods denominated by total assets. ROE is the return on equity, which is the OIBDP divided by book equity. Asset growth is the growth rate of total assets. Growth K is the growth rate of PPEGT. Age is defined as the years a firm being recorded in COMPUSTAT. WW and SA index are following Whited and Wu (2006) and Hadlock and Pierce (2010), respectively. Dividend is calculated as the mean of the dividend dummy within each portfolio, which represents the probability of a firm paying dividend within each portfolio. Cash/AT is defined as cash and cash equivalents over total asset ratio. The probability of equity (debt) issuance is defined as the mean of a dummy variable within that quintile, which takes value of one when the flow to equity (debt) is negative. Flow to equity is defined as purchases of common stock plus dividends less sale of common stock. Flow to debt is defined as debt reduction plus changes in current debt plus interest paid, less debt issuance. Probability of external financing is defined as the mean of a dummy variable within that quintile, which takes value of one when the sum of flow to debt and equity are negative.

	1	2	3	4	5
Collateralizability	0.081	0.168	0.260	0.377	0.619
Book Leverage	0.104	0.163	0.228	0.343	0.460
BM	0.441	0.576	0.611	0.673	0.670
$\frac{I}{K+H}$	0.174	0.169	0.162	0.165	0.191
$\log(ME)$	3.822	3.988	4.000	4.153	4.178
Cash Flow	0.037	0.094	0.110	0.113	0.098
Gross Profitability	0.478	0.423	0.375	0.339	0.276
ROE	0.060	0.164	0.204	0.231	0.223
Asset Growth	0.003	0.048	0.068	0.079	0.116
Growth K	0.075	0.092	0.100	0.108	0.129
Age	7.000	9.000	9.000	8.000	8.000
WW	-0.159	-0.183	-0.189	-0.194	-0.191
SA	-2.284	-2.506	-2.540	-2.576	-2.580
Prob(Dividend)	0.136	0.146	0.178	0.172	0.162
Cash/AT	0.246	0.142	0.114	0.087	0.104
Prob(Equity Issuance)	0.665	0.594	0.523	0.501	0.496
Prob(Debt Issuance)	0.097	0.118	0.114	0.122	0.143
Prob(External Fin)	0.240	0.215	0.191	0.190	0.208
Short-term Debt/AT	0.007	0.011	0.012	0.015	0.017
Long-term Debt/AT	0.006	0.011	0.014	0.019	0.012

Table C.5: Correlations Among Firm Characteristics

This table reports the correlation between collateralizability and other firm characteristics. The sample period is from 1978 to 2016, it focuses on constrained firms identified using Whited and Wu (2006) index. Log(ME) is the log of market capitalization deflated by CPI. BM is the book-to-market ratio. XRD/AT is R&D expenditure over total book assets. OG/AT is organizational capital over total book assets. I/K is the investment rate, it is calculated as the Compustat item CAPX divided by PPENT. ROA is Compustat item IB divided by book assets.

Variables	Collateralizability	BM	XRD/AT	OG/AT	log(ME)	I/K	ROA
Collateralizability	1.000						
BM	0.105	1.000					
XRD/AT	-0.333	-0.180	1.000				
OG/AT	-0.233	-0.065	0.117	1.000			
log(ME)	-0.013	-0.159	-0.006	-0.207	1.000		
I/K	0.011	-0.021	0.008	-0.001	0.004	1.000	
ROA	0.161	-0.041	-0.456	-0.154	0.126	-0.015	1.000

Table C.6: Independent Double Sort on Collateralizability and Leverage

This table reports annualized average value-weighted monthly excess returns for portfolios double-sorted independently on collateralizability and leverage. The sample starts in July 1979 and ends in December 2016. At the end of June in each year t, we independently sort financially constrained firms into quintiles based on collateralizability (horizontal direction) and into quintiles based on book financial leverage (vertical direction), then we compute the value-weighted returns of each portfolio. The book financial leverage is defined as financial debt over total asset ratio. A firm is considered financially constrained in year t, if its WW index (Whited and Wu (2006)) is above the respective median at the end of year $t-1$. The t-statistics are estimated following Newey and West (1987). All returns are annualized by multiplying with 12.

	L Col	2	3	4	H Col	L-H	t-stat
L Lev	11.96	7.58	10.51	10.14	5.48	6.48	1.81
2	13.84	11.38	11.19	5.31	5.98	7.85	1.96
3	13.07	14.16	11.05	9.70	4.50	8.57	2.06
4	15.48	10.10	11.73	5.39	5.04	10.43	2.51
H Lev	16.94	10.82	10.74	8.39	7.25	9.69	2.09
H-L	4.98	3.24	0.23	-1.75	1.76		
t-stat	1.17	0.81	0.06	-0.55	0.60		

D: Data and measurement

We now provide details on the data sources, the construction of our empirical collateralizability measure, and on the measurement of intangible capital.

D.1. Data sources

Our major sources of data are (1) firm level balance sheet data from the CRSP/Compustat Merged Fundamentals Annual Files, (2) monthly stock returns from CRSP, and (3) industry level non-residential capital stock data from the BEA table.[19] We adopt the standard screening process for the CRSP/Compustat Merged Database. We exclude utilities and financial firms (SIC codes between 4900 and 4999 and between 6000 and 6999, respectively). Additionally, we only keep common stocks that are traded on NYSE, AMEX and NASDAQ. The accounting treatment of R&D expenses was standardized in 1975, and we allow three years for firms to adjust to the new accounting rules, so that our sample starts in 1978. Following Campello and Giambona (2013), we exclude firm-year observations for which the value of total assets or sales is less than $1 million. We focus on the impact of asset collateralizability on debt capacity of firms, therefore we drop small firms, which do not have much debt in the first place. In practice, we drop firm-year observations with market capitalization below $8 million, which roughly corresponds to the bottom 5% of firms. All firm characteristics are winsorized at the 1% level. The potential delisting bias of stock returns is corrected following Shumway (1997) and Shumway and Warther (1999).

In order to obtain a long sample with broader coverage,[20] we use the narrowly defined industry level non-residential fixed asset (structure, equipment and intellectual) from the BEA tables to back out industry level structure and equipment capital shares.

In Table D.7, we provide the definitions of the variables used in our empirical analyses.

[19] The BEA table is from "private fixed asset by industry", Table 3.1ESI.

[20] COMPUSTAT shows the components of physical capital (PPEGT) only for the period from 1969 to 1997. However, even for the years between 1969 and 1997, only 40% of the observations have non-missing entries for the components of PPEGT, which are buildings (PPENB), machinery and equipment (PPENME), land and improvements (PPENLI).

D.2. Measurement of collateralizability

This section provides details on the construction of the firm specific collateralizability measure, complementing the description of the methodology provided in Section 2.

We first construct proxies for the share of the two types of capital, denoted by $StructShare$ and $EquipShare$. Then we run the leverage regression (2), which allows us to later calculate the firm-specific collateralizability score.

The BEA classification features 63 industries. We match the BEA data to Compustat firm level data using NAICS codes, assuming that, for a given year, firms in the same industry have the same structure and equipment capital shares. We construct measures of structure and equipment shares for industry l in year t as

$$StructShare_{l,t} = \frac{\text{Structure}_{l,t}^{BEA}}{\text{Fixed Asset}_{l,t}^{BEA}} \frac{\text{Fixed Asset}_{l,t}^{\text{Compustat}}}{\text{PPEGT}_{l,t}^{\text{Compustat}} + \text{Intangible}_{l,t}^{\text{Compustat}}}$$

and

$$EquipShare_{l,t} = \frac{\text{Equipment}_{l,t}^{BEA}}{\text{Fixed Asset}_{l,t}^{BEA}} \frac{\text{Fixed Asset}_{l,t}^{\text{Compustat}}}{\text{PPEGT}_{l,t}^{\text{Compustat}} + \text{Intangible}_{l,t}^{\text{Compustat}}},$$

where $AT_{l,t}$ are total assets in industry l in year t, i.e., the sum of assets across all firms in our sample belonging to industry l in year t. The first component on the right hand side refers to the structure (equipment) share from BEA data, which is given as the ratio of structure (equipment) to fixed assets at the industry level. The second component refers to the industry level fixed asset to total asset ratio in Compustat. We use PPEGT in Compustat as the equivalent for fixed assets in the BEA data. By doing so, we map the BEA industry level measure of structure (equipment) to fixed asset ratio to corresponding measures in the Compustat, at the industry level. Since we distinguish assets by their collateralizability, we normalize fixed assets by the total value of physical and intangible capital.

We interpret the weighted sum, $\zeta_S StructShare_{l,t} + \zeta_E EquipShare_{l,t}$, as the contribution of structure and equipment capital to financial leverage. The product of this sum and the book value of assets, $(\zeta_S StructShare_{l,t} + \zeta_E EquipShare_{l,t}) \cdot AT_{i,t}$, then represents the total collateralizable capital of firm i in year t.[21] Given this, the collateralizability score for firm i in year t is computed as

$$\zeta_{i,t} = \frac{(\zeta_S \cdot StructShare_{l,t} + \zeta_E \cdot EquipShare_{l,t}) \cdot AT_{i,t}}{PPEGT_{i,t} + Intangible_{i,t}}, \quad \text{(D7)}$$

where $PPEGT_{i,t}$ and $Intangible_{i,t}$ are the physical capital and intangible capital of firm i in year t, respectively. The importance of taking intangible capital into account has been emphasized in the recent literature, e.g., by Eisfeldt and Papanikolaou (2013) and Peters and Taylor (2017). The asset-specific collateralizablity parameters ζ_S and ζ_E we adopt in our empirical analyses are the ones shown in the last column of Table 2, where firms are classified as constrained based jointly on all three measures (SA index, WW index, and non-dividend paying).

In the above collateralizability measure, we implicitly assume the collateralizability parameter for intangible capital to be equal to zero. We do this based on empirical evidence that intangible capital can hardly be used as collateral, since only 3% of the total value of loans to companies are actually collateralized by intangibles like patents or brands (Falato et al. (2013)). Our results remain qualitatively very similar when we exclude intangible capital from the denominator of the collateralizability measure in (D7) and only exploit the differences in collateralizability between structure and equipment capital.

D.3. Measuring intangible capital

In this section, we provide details regarding the construction of firm-specific intangible capital. The total amount of intangible capital of a firm is given by the sum of externally acquired and internally created intangible capital, where the latter consists of R&D capital and organizational capital.

Externally acquired intangible capital is given by item *INTAN* in Compustat. Firms typically capitalize this type of asset on the balance sheet as part of intangible assets. For

[21] Alternatively, we also used the market value of assets to compute total collateralizable capital. The empirical collteralizability spread based on this sorting measure is even stronger than that obtained in our benchmark analysis.

the average firm in our sample, $INTAN$ amounts to about 19% of total intangible capital with a median of 3%, consistent with Peters and Taylor (2017). We set externally acquired intangibel capital to zero, whenever the entry for INTAN is missing.

Concerning internally created intangible capital, R&D capital does not appear on the firm's balance sheet, but it can be estimated by accumulating past expenditures. Following Falato et al. (2013) and Peters and Taylor (2017), we capitalize past R&D expenditures (Compustat item XRD) using the so-called perpetual inventory method, i.e.,[22]

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

where δ_{RD} is the depreciation rate of R&D capital. Following Peters and Taylor (2017), we set the depreciation rates for different industries following Li and Hall (2016). For unclassified industries, the depreciation rate is set to 15%.[23]

Finally, we also need the initial value RD_0. We use the first non-missing R&D expenditure, XRD_1, as the first R&D investment, and specify RD_0 as

$$RD_0 = \frac{XRD_1}{g_{RD} + \delta_{RD}}, \tag{D8}$$

where g_{RD} is the average annual growth rate of firm level R&D expenditure. In our sample, g_{RD} is around 29%.

Following Eisfeldt and Papanikolaou (2013) and Peters and Taylor (2017), our organizational capital is constructed by accumulating a fraction of Compustat item $XSGA$, "Selling, General and Administrative Expense", which indirectly reflects the reputation or human capital of a firm. However, as documented by Peters and Taylor (2017), $XSGA$ also includes R&D expenses XRD, unless they are included in the cost of goods sold (Compustat item $COGS$). Additionally, $XSGA$ sometimes also incorporates the in-process R&D expense (Compustat item $RDIP$). Hence, following Peters and Taylor (2017), we subtract XRD and $RDIP$ from $XSGA$.[24] Additionally, also following Peters and Taylor (2017), we add the

[22] This method is also used by the BEA R&D satellite account.

[23] Our results are not sensitive to the choice of depreciation rates.

[24] $RDIP$ (in-process R&D expense) is coded as negative in Compustat. Subtracting RDIP from XSGA

filter that when XRD exceeds $XSGA$, but is less than $COGS$, or when $XSGA$ is missing, we keep XSGA with no further adjustment. Afterwards, we replace missing XSGA with zero. As in Hulten and Hao (2008), Eisfeldt and Papanikolaou (2014), and Peters and Taylor (2017), we count only 30% of SGA expenses as investment in organizational capital, the rest is treated as operating costs.

Using a procedure analogous to the one described above for internally created R&D capital, organizational capital is constructed as

$$OG_{t+1} = (1 - \delta_{OG})OG_t + SGA_t,$$

where $SGA_t = 0.3(XSGA_t - XRD_t - RDIP_t)$ and the depreciation rate δ_{OG} is set to 20%, consistent with Falato, Kadyrzhanova, and Sim (2013) and Peters and Taylor (2017). Again analogous to the case of R&D capital we set the initial level of organizational capital OG_0 according to

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

The average annual growth rate of firm level $XSGA$, g_{OG}, is 18.9% in our sample.

means RDIP is added to XSGA. As discussed in Peters and Taylor (2017), XSGA does not include this component, so we add this component back to XSGA, then subtract the total amount of R&D expenditures.

Table D.7: Definition of Variables

Variables	Definition	Sources
Structure share	We first construct the structure shares from BEA industry capital stock data, defined as structure capital over total fixed asset ratio. Then we rescale the structure shares by the corresponding industry average of physical asset (PPEGT) to book asset ratio (AT).	BEA + Compustat
Equipment share	We first construct the equipment shares from BEA industry capital stock data, defined as equipment capital over total fixed asset ratio. Then we rescale the equipment shares by the corresponding industry average of physical asset (PPEGT) to book asset ratio (AT).	BEA + Compustat
Intangible capital	Intangible capital is defined following Peters and Taylor (2017). We capitalize R&D and SGA expenditures using the perpetual inventory method.	Compustat
Collateralizability	Collateralizable capital divided by PPEGT + Intangible. Collateralizable capital and intangible capital are defined in Section D.2.	BEA + Compustat
BE	Book value of equity, computed as the book value of stockholders equity, plus balance sheet deferred taxes and investment tax credit (if available), minus the book value of preferred stock. Depending on availability, we use the redemption, liquidation, or par value (in that order) as the book value of preferred stock.	Compustat
ME	Market value of equity is copmputed as price per share times the number of shares outstanding. The share price is taken from CRSP, the number of shares outstandings from Compustat or CRSP, depending on availability.	CRSP+Compustat
BM	Book to market value of equity ratio.	Compustat
Tangibility	Physical capital (PPEGT) to the sum of physical (PPEGT) and intangible capital ratio.	Compustat
Book size	Natural log of the sum of PPEGT and intangible capital.	Compustat
Gross profitability	Compustat item REVT minus COGS divided by AT.	Compustat
OG/AT	Organizational capital divided by total assets (AT).	Compustat
XRD/AT	R&D expenditure to book asset ratio.	Compustat
Book leverage	Lease adjusted book leverage is defined as lease adjusted debt over total asset ratio (AT). The lease adjusted debt is the financial debt (DLTT+DLC) plus the net present value of capital lease as in Li, Whited, and Wu (2016).	Compustat
Dividend Dummy	Dummy variable equal to 1, if the firm's dividend payment (DVT, DVC or DVP) over the year was positive.	Compustat
Sales Grth Volatility	Rolling window standard deviation of past 4 year's sales growth.	Compustat
Rating Dummy	Dummy variable equal to 1, if the firm has either a bond rating or a commercial paper rating, and 0 otherwise.	Compustat
Marginal Tax Rate	Following Graham (2000).	John Graham's website
WW index	Following Whited and Wu (2006).	Compustat
SA index	Following Hadlock and Pierce (2010).	Compustat
ROA	Income before extraordinary items (IB) divided by total assets (AT).	Compustat

Table D.7: Definition of Variables (Continued)

Variables	Definition	Sources
Cash	Compustat item CHE.	Compustat
Equity Issuance	The negative of flow to debt. Compustat item -(PRSTKC+DV-SSTK).	Compustat
Debt Issuance	The negative of flow to debt. Compustat item -(DLTR+DLCCH+XINT-DLTIS).	Compustat
External Fin	The sum of equity and debt issuance.	Compustat
Short-term Debt	Compustat item DLC.	Compustat
Long-term Debt	Compustat item DLTR.	Compustat
ROE	Compustat item EBITDA over book equity ratio.	Compustat
Financial Leverage	Total financial debt (DLTT + DLC) over total book asset (AT) ratio.	Compustat
Age	The current year minus the year where a firm has the first non-missing observation.	Compustat