

Investment-Based Corporate Bond Pricing*

Lars-Alexander Kuehn
Tepper School of Business
Carnegie Mellon University

Lukas Schmid
Fuqua School of Business
Duke University

October 17, 2011

Abstract

A standard assumption of structural models of default is that firms assets evolve exogenously. In this paper, we document the importance of accounting for investment options in models of credit risk. In the presence of financing and investment frictions, firm-level variables which proxy for asset composition carry explanatory power for credit spreads beyond leverage. As a result, cross-sectional studies of credit spreads that fail to control for the interdependence of leverage and investment decisions are unlikely to be very informative. Such frictions also give rise to a realistic term structure of credit spreads in a production economy.

JEL Classification: E22, E44, G12, G31, G32, G33.

Keywords: Real investment, dynamic capital structure, default risk, credit spreads, recursive preferences, macroeconomic risk.

*We thank David Backus, David Chapman, Hui Chen, Mike Chernov, Greg Duffee, Rick Green, Holger Kraft, Dmitry Livdan, Sheridan Titman, Toni Whited and participants at the 2010 EFA meeting, 2011 Texas Finance Festival, 2011 WFA meeting, 2011 CEPR Gerzensee European Summer Symposium on Financial Markets, HEC Montreal, BI Oslo, Bocconi University, Aalto University Helsinki, and USC for helpful comments. Contact information: kuehn@cmu.edu and lukas.schmid@duke.edu.

1 Introduction

Quantitative research on credit risk has derived much of its intuition from models in the tradition of Merton (1974) and Leland (1994). In these structural models of credit risk, firms optimally choose to default when the present value of coupon payments to bond holders is greater than the present value of future dividends.¹ This optimality condition also provides testable implications for the relation between firm-level variables and credit spreads. For instance, leverage should be positively related to credit spreads since higher leverage implies that the firm is closer to the default boundary. However, the empirical evidence is mixed.²

A key assumption of current structural models of default is that the evolution of the firms' asset values is given exogenously. This modeling approach follows the tradition of Modigliani and Miller (1958) where perfect financial markets allow the separation of financing and investment decisions. Typically, when choosing their leverage, firms trade off tax benefits of debt and bankruptcy costs. Given that assets evolve exogenously, the issued debt is used to fund changes in equity but it does not affect the asset side of the balance sheet. Empirically, however, firms issue bonds primarily to finance capital spending.³

In this paper, we document the importance of accounting for investment decisions in models of credit risk. Exercising investment options changes a firm's asset composition and hence the riskiness of its assets. We depart from the Modigliani-Miller paradigm by modeling financial market imperfections. In such a world, default probabilities and hence credit spreads will reflect the riskiness of firms' assets which reflects both idiosyncratic as well as macroeconomic factors. Our results suggest that these effects are quantitatively significant.

We provide a tractable dynamic model of credit risk and investment. While we build on the recent literature relating firms' capital structures to their investment policies (Hennessy and Whited (2005, 2007)), we introduce Epstein-Zin preferences with time varying macroeconomic

¹Prominent papers include Goldstein, Ju, and Leland (2001), Collin-Dufresne and Goldstein (2001), Hackbarth, Miao, and Morellec (2006), Broadie, Chernov, and Sundaresan (2007), and Chen (2010).

²Collin-Dufresne, Goldstein, and Martin (2001) show that structural models explain less than 25 percent of the variation in credit spread changes. Similarly, Davydenko and Strebulaev (2007) reach a similar conclusion for the level of credit spreads.

³Empirical support can be found in Mayer and Sussman (2004), Kayhan and Titman (2007), Whited (2010), and Dudley (2011).

risk in consumption and productivity in a cross-sectional production economy to price risky corporate debt.⁴ In the model, firms possess the option to expand capacity. Investment can be financed with retained earnings, equity or debt issuances. In contrast to corporate models of default, such as Leland (1994), where the tax advantage of debt leads firms to issue debt, it is the availability of real investment options in our model. We assume that firms jointly choose leverage and investment to maximize equity value. Firms can default on their outstanding debt when the option to default is more valuable than paying back bond holders. When making these dynamics decisions, firms face fixed and proportional debt and equity issuance costs.

Our paper makes three sets of contributions. First, our model quantitatively rationalizes the empirical term structure of credit spreads in a production economy. As pointed out by Huang and Huang (2003), standard models of credit risk, such as Merton (1974) and Leland (1994), are not able to generate a realistic spread of risky debt relative to safe governments bonds. While Hackbarth, Miao, and Morellec (2006), Chen, Collin-Dufresne, and Goldstein (2009), Bhamra, Kuehn, and Strebulaev (2010), and Chen (2010) demonstrate that credit risk premia are compensation for macroeconomic conditions, production economies place considerably tighter restrictions on this link. A model without real and financial frictions renders corporate debt almost riskless since firms can use corporate policies to avoid default.⁵

Quantitatively, our model generates a realistic credit spread of 101 basis points for 5 year debt and 114 basis points for 10 year debt for BBB firms, close to empirical estimates. At the same time, actual default probabilities are low as in the data. The reason for success is twofold. First, we assume that firms face real and financing frictions. Capital is firm specific and thus the resale value is zero. In a model without disinvestment costs, firms would rarely choose to default because they would sell capital to pay off their debt. Essentially, the value of the disinvestment option drives out the value of the default option. In addition, costly debt adjustment and equity issuance costs increase the option value of defaulting.

⁴Similar to Bansal and Yaron (2004), we model time varying macroeconomic risk as a mean reverting process in the first and second moments of consumption growth.

⁵Jermann (1998) and Kogan (2004) point out that explaining risk premia in production economies is much more challenging than in an endowment economy since the agent can use capital to smooth cash flows.

Second, we measure credit spreads in the cross section of firms as in Bhamra, Kuehn, and Strebulaev (2010). Cross-sectional heterogeneity in asset composition and leverage raise the average credit spread because the values of both the investment and default option are convex functions of the state variables.

Second, we provide new testable implications concerning firm-level determinants of credit spreads. Our model predicts that suitable empirical proxies for growth options should have considerable explanatory power for credit spreads and their changes, an implication not shared by standard structural models of credit risk. Specifically, the market-to-book ratio, investment rates and size are important determinants of credit spreads in our model. This is because they capture information about the composition and riskiness of firms' assets. While in a world without real and financial imperfections leverage would perfectly adjust to reflect the riskiness of assets, empirically leverage often deviates substantially from target leverage.⁶ In such a realistic setting, proxies for asset composition should carry explanatory power for credit spreads beyond leverage. We confirm and quantify this prediction by means of cross-sectional regressions in our model. As credit spreads reflect default probabilities, an analogous implication holds for logit regressions of expected default rates.

Third, we demonstrate that the link between credit risk and proxies for asset composition as well as leverage depends on macroeconomic conditions, rendering unconditional regressions uninformative. Intuitively, as growth options pay off in good times, growth firms have more volatile and cyclical cash flows and are thus riskier than value firms which derive most of their value from assets in place. For the same amount of debt, growth firms have higher default rates than value firms in good times. However, growth firms choose optimally lower leverage than value firms in the model and the data, rendering the link between leverage and credit spreads uninformative. In contrast, value firms are more risky than growth firms in bad times because of operating leverage. Value firms have excess capital and debt and thus higher default rates than growth firms. As a result, the relation between the market-to-book ratio and credit spreads is positive in booms and negative in recessions, holding leverage

⁶Theoretical and empirical support is provided in Fischer, Heinkel, and Zechner (1989), Leary and Roberts (2005), and Strebulaev (2007).

constant. Moreover, the link between leverage and credit spreads is only strong in bad times. In our setting, these subtle conditional links therefore make unconditional relationships quite uninformative and the weak empirical performance of firm-level variables in unconditional tests obtains naturally. This demonstrates the importance of accounting for the endogeneity of both investment and financing when explaining credit spreads.

Related Literature

Our paper is at the center of several converging lines of literature. First of all, our objective is to link structural models of default and financing with the literature on growth options and firm investment. In this regard, our paper is related to Miao (2005), Sundaresan and Wang (2007), Bolton, Chen, and Wang (2010), and Hackbarth and Mauer (2011). Contrary to our work, these papers do not focus on the pricing of corporate bonds and do not consider the importance of macroeconomic conditions. More recently, Barclay, Morellec, and Smith (2006), Chen and Manso (2010) and Arnold, Wagner, and Westermann (2011) also explore the effects of growth options on credit risk. These papers consider a levered firm which finances a single growth option with an infinite amount of cash on hand. While this environment allows to obtain analytic solutions, we quantitatively investigate credit spreads when firms can fully dynamically optimize their investment and capital structure decisions.

Our paper is also related to recent work using dynamic models of leverage to price corporate bonds (Hackbarth, Miao, and Morellec (2006), Chen, Collin-Dufresne, and Goldstein (2009), Bhamra, Kuehn, and Strebulaev (2010), Chen (2010), Carlson and Lazrak (2010)). Motivated by the credit spread puzzle, the observation that standard structural models of corporate finance in the tradition of Merton are unable to rationalize the historical levels of credit spreads (see Huang and Huang (2003)), this literature has stressed the importance of accounting for macroeconomic risk in explaining corporate bond prices. We add to this literature by explicitly considering the role of investment in determining corporate financing policies. While the literature considered endowment economies only, our analysis stresses that frictions to adjusting firms' assets are a crucial determinant of default decisions and therefore credit spreads.

A growing literature attempts to quantitatively understand firm level investment by linking it to corporate financial policies in settings with financial frictions. While early influential work (Gomes (2001)) was motivated by the cash-flow sensitivity of corporate investment and considered reduced form representations of the costs of external finance, more recently the literature has considered fully fledged capital structure choices, allowing for leverage, default and equity issuance (e.g., Cooley and Quadrini (2001), Moyen (2004), and Hennessy and Whited (2005, 2007)). These papers suggest that in the presence of financial frictions, the availability and pricing of external funds is a major determinant of corporate investment. The novelty in our work is the analysis of the role of macroeconomic risk for corporations' investment and financing policies. In particular, while the literature has considered settings without aggregate risk, we stress its importance in generating the observed levels and dynamics of the costs of debt. Specifically, our model is consistent with the fact that a large fraction of both level and time-variation of credit spreads is accounted for by risk premia.

Our work is also related to a growing literature on dynamic quantitative models investigating the implications of firms' policies on asset returns. A number of papers (e.g., Berk, Green, and Naik (1999), Gomes, Kogan, and Zhang (2003), Carlson, Fisher, and Giammarino (2004), and Zhang (2005)) has successfully related anomalies in the cross section of stock returns such as the value premium to firms' investment policies. Another recent line of research has focused on the link between firms' financing decisions and stock returns (some recent papers include Garlappi and Yan (2011), Livdan, Sapriza, and Zhang (2009) and Gomes and Schmid (2009)). By relating risk premia in corporate bond prices to firms' investment and financing policies, our work here is complementary. Moreover, from a methodological point of view, we add a long run risk perspective to the literature on the cross section of stock returns by providing a tractable way of modeling firms' exposure to long run movements in aggregate consumption growth in the sense of Bansal and Yaron (2004).

2 Model

The model consists of two building blocks: a representative household, from which we derive the stochastic discount factor, and a cross section of heterogeneous firms, which make optimal investment and financing decisions, given the stochastic discount factor.

We assume the representative agent has recursive preferences and the conditional first and second moments of consumption growth are time varying and follow a persistent Markov chain. An important implication of recursive preferences is that the agent is averse to intertemporal risk coming from the Markov chain. These assumptions give rise to realistic level and dynamics for the market price of risk. Firms choose optimal investment to maximize their equity value. Investment is financed by retained earnings as well as equity or debt issuances. Firms can default on their outstanding debt if prospects are sufficiently bad.

2.1 Pricing Kernel

The representative agent maximizes recursive utility, U_t , over consumption following Epstein and Zin (1989) given by

$$U_t = \left\{ (1 - \beta)C_t^\rho + \beta \left(\mathbb{E}_t[U_{t+1}^{1-\gamma}] \right)^{\rho/(1-\gamma)} \right\}^{1/\rho} \quad (1)$$

where C_t denotes consumption, $\beta \in (0, 1)$ the rate of time preference, $\rho = 1 - 1/\psi$ and ψ the elasticity of intertemporal substitution (EIS), and γ relative risk aversion (RRA). Epstein-Zin preferences provide a separation between the elasticity of intertemporal substitution and relative risk aversion. These two concepts are inversely related when the agent has power utility. Intuitively, the EIS measures the agent's willingness to postpone consumption over time, a notion well-defined under certainty. Relative risk aversion measures the agent's aversion to atemporal risk across states. Recursive preferences also imply preference for either early or late resolution of uncertainty which are crucial for the quantitative implications of this paper.

We assume that aggregate consumption follows a random walk with a time-varying drift and volatility

$$C_{t+1} = C_t \exp\{g + \mu_c(\omega_t) + \sigma_c(\omega_t)\eta_{t+1}\} \quad (2)$$

where $\mu(\omega_t)$ and $\sigma(\omega_t)$ depend on the aggregate state of the economy denoted by ω_t and η_{t+1} are i.i.d. standard normal innovations. The aggregate state, ω_t , follows a persistent Markov chain with transition matrix P .

The Epstein-Zin pricing kernel is given by

$$M_{t,t+1} = \beta^\theta \left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \left(\frac{Z_{t+1} + 1}{Z_t} \right)^{-(1-\theta)} \quad (3)$$

where Z_t denotes the wealth-consumption ratio and $\theta = \frac{1-\gamma}{1-1/\psi}$. When $\theta = 1$, the pricing kernel reduces to the one generated by a representative agent with power utility, implying that she is indifferent with respect to intertemporal macroeconomic risk. When the EIS is greater than the inverse of relative risk aversion ($\psi > 1/\gamma$), the agent prefers intertemporal risk due to the Markov chain to be resolved sooner rather than later.

In an economy which is solely driven by i.i.d. shocks, the wealth-consumption ratio is constant. In our model, however, the first and second moments of consumption growth follow a Markov chain. Consequently, the wealth-consumption ratio is a function of the state of the economy, i.e., $Z_t = Z(\omega_t)$. Based on the Euler equation for the return on wealth, the wealth-consumption ratio vector Z_t solves the system of nonlinear equations defined by

$$Z_t^\theta = \mathbb{E}_t \left[\beta^\theta \left(\frac{C_{t+1}}{C_t} \right)^{1-\gamma} (Z_{t+1} + 1)^\theta \right] \quad (4)$$

To compute credit spreads, we define the n -period risk-rate as $R_{f,t}^{(n)} = 1/\mathbb{E}_t[M_{t,t+n}]$.

2.2 Profits and Investment

We begin by considering the problem of a typical value maximizing firm in a perfectly competitive environment. The flow of after tax operating profits, Π , for firm i is described by the expression

$$\Pi_{i,t} = (1 - \tau)(X_{i,t}^{1-\alpha} K_{i,t}^\alpha - K_{i,t} f) \quad (5)$$

where $X_{i,t}$ is a productivity shock and $K_{i,t}$ denotes the book value of the firm's assets. We use τ to denote the corporate tax rate, $0 < \alpha < 1$ the capital share of production and $f \geq 0$ proportional costs of production. An important implication of a capital share less than unity is that firms possess a sequence of growth options which are decreasing in firm size.

The i -th firm productivity shock follows a random walk with a time-varying drift and volatility

$$X_{i,t+1} = X_{i,t} \exp\{g + \mu_x(\omega_t) + \sigma_x(\omega_t)\varepsilon_{i,t+1}\} \quad (6)$$

where $\mu_x(\omega_t)$ and $\sigma_x(\omega_t)$ depend on the aggregate state of the economy and $\varepsilon_{i,t+1}$ are standard normal shocks. The assumption that $\varepsilon_{i,t+1}$ is firm specific requires that

$$\mathbb{E}[\varepsilon_{i,t}\varepsilon_{j,t}] = 0, \text{ for } i \neq j$$

Systematic risk in productivity arises because productivity and consumption are both affected by the aggregate Markov state of the economy. For parsimony, we assume that the innovations to productivity, $\varepsilon_{i,t+1}$, are uncorrelated with the aggregate innovation, η_{t+1} , similar to Bansal and Yaron (2004). Allowing for a positive correlation structure will strengthen our results.⁷

Firms are allowed to scale operations by choosing the level of productive capacity $K_{i,t}$. This can be accomplished through investment, $I_{i,t}$, which is linked to productive capacity by the standard capital accumulation equation

$$K_{i,t+1} = (1 - \delta)K_{i,t} + I_{i,t} \quad (7)$$

where $\delta > 0$ denotes the depreciation rate of capital. We model real options by assuming that investment is irreversible

$$I_{i,t} \geq 0 \quad (8)$$

2.3 Financing

Corporate investment as well as any distributions can be financed with either internal funds generated by operating profits or new issues which can take the form of debt (net of repayments) or equity. We denote the book value of outstanding liabilities by $B_{i,t}$, paying a coupon $c_{i,t}$. At the beginning of period t , we define total debt liabilities as

$$L_{i,t} = (1 + (1 - \tau)c_{i,t})B_{i,t} \quad (9)$$

Note that both debt and coupon payments will exhibit potentially significant time variation and will depend on a number of firm and aggregate variables.

⁷We thank Greg Duffee for pointing this out.

When firms change the amount of debt outstanding, they incur a cost. We define debt adjustment costs in terms of changes in total liabilities, $L_{i,t+1} - L_{i,t}$. Firms face fixed and proportional debt adjustment costs denoted by ϕ_0 and ϕ_1 , respectively.⁸ Formally, these costs are given by

$$\Phi(L_{i,t}, L_{i,t+1}) = \phi_{0,t} \mathbb{I}_{\{L_{i,t+1} \neq L_{i,t}\}} + \phi_1 |L_{i,t+1} - L_{i,t}| \quad (10)$$

Costs associated with reductions in total liabilities can be interpreted as fees for calling debt.

Firms can also raise external funds by means of seasoned equity offerings. Following the existing literature, we consider fixed and proportional costs which we denote by λ_0 and λ_1 , respectively.⁹ Formally, letting $E_{i,t}$ denote the net payout to equity holders, total issuance costs are given by the function

$$\Lambda(E_{i,t}) = (\lambda_{0,t} + \lambda_1 |E_{i,t}|) \mathbb{I}_{\{E_{i,t} < 0\}} \quad (11)$$

where the indicator function $\mathbb{I}_{\{E_{i,t} < 0\}}$ implies that these costs apply only in the region where the firm is raising new equity finance, i.e., the net payout, $E_{i,t}$, is negative.

Investment, equity payout, and financing decisions must satisfy the budget constraint

$$E_{i,t} = \Pi_{i,t} + \tau \delta K_{i,t} - I_{i,t} + B_{i,t+1} - L_{i,t} - \Phi(L_{i,t}, L_{i,t+1}) \quad (12)$$

where again $E_{i,t}$ denotes the equity payout. Note that the constraint (12) recognizes the tax shielding effects of both depreciated capital and interest expenditures. Distributions to shareholders, denoted by $D_{i,t}$, are then given as equity payout net of issuance costs

$$D_{i,t} = E_{i,t} - \Lambda(E_{i,t}) \quad (13)$$

2.4 Valuation

The equity value of the firm, $V_{i,t}$, is defined as the discounted sum of all future equity distributions. We assume that equity holders will choose to close the firm and default on their debt repayments if the prospects for the firm are sufficiently bad, i.e., whenever $V_{i,t}$ reaches zero. The complexity of the problem is reflected in the dimensionality of the state space necessary

⁸Since productivity has a time trend, the fixed component is growing over time too. The same is true for the fixed equity issuance costs.

⁹See Gomes (2001) and Hennessy and Whited (2007) for a similar specification.

to construct the equity value of the firm. This includes both aggregate and idiosyncratic components of demand, productive capacity, and total debt liabilities.

We can now characterize the problem facing equity holders, taking coupon payments as given. These payments will be determined endogenously below. Shareholders jointly choose investment (the next period capital stock) and financing (next period total debt commitments) strategies to maximize the equity value of each firm, which can then be computed as the solution to the dynamic program

$$V_{i,t} = \max \left\{ 0, \max_{K_{i,t+1}, L_{i,t+1}} \{D_{i,t} + \mathbb{E}_t [M_{t,t+1} V_{i,t+1}]\} \right\} \quad (14)$$

where the expectation on the left hand side is taken by integrating over the conditional distributions of $X_{i,t+1}$. Note that the first maximum captures the possibility of default at the beginning of the current period, in which case shareholders will get nothing.¹⁰ Finally, aside from the budget constraint embedded in the definition of dividends, $D_{i,t}$, firms face the irreversibility constraint (8), debt (10) and equity issuance costs (11).

2.5 Default and Bond Pricing

We now turn to the determination of the required coupon payments, taking into account the possibility of default by equity holders. Assuming debt is issued at par, the market value of debt must satisfy the Euler condition

$$B_{i,t+1} = (1 + c_{i,t+1})B_{i,t+1}\mathbb{E}_t [M_{t,t+1}(1 - \mathbb{I}_{\{V_{i,t+1}=0\}})] + \mathbb{E}_t [M_{t,t+1}W_{i,t+1}\mathbb{I}_{\{V_{i,t+1}=0\}}] \quad (15)$$

where $W_{i,t+1}$ denotes the recovery on a bond in default and $\mathbb{I}_{\{V_{i,t+1}=0\}}$ is an indicator function that takes the value of one when the firm defaults and zero when it remains active.

Following Hennessy and Whited (2007), creditors are assumed to recover the fraction of the firm's current assets and profits net of liquidation costs. Formally, the default payoff is equal to

$$W_{i,t} = (1 - \xi)(\Pi_{i,t} + \tau\delta K_{i,t} + (1 - \delta)K_{i,t}) \quad (16)$$

in which ξ measures the proportional loss in default.

¹⁰In practice, there can be violations of the absolute priority rule, implying that shareholders in default still recover value. Garlappi and Yan (2011) analyze the asset pricing implications of such violations.

Since the equity value $V_{i,t+1}$ is endogenous and itself a function of the firm's debt commitments this equation cannot be solved explicitly to determine the value of the coupon payments, $c_{i,t}$. However, using the definition of $L_{i,t}$, we can rewrite the bond pricing equation as

$$B_{i,t+1} = \frac{\frac{1}{1-\tau} L_{i,t+1} \mathbb{E}_t [M_{t,t+1}(1 - \mathbb{I}_{\{V_{i,t+1}=0\}})] + \mathbb{E}_t [M_{t,t+1} W_{i,t+1} \mathbb{I}_{\{V_{i,t+1}=0\}}]}{1 + \frac{\tau}{1-\tau} \mathbb{E}_t [M_{t+1}(1 - \mathbb{I}_{\{V_{i,t+1}=0\}})]} \quad (17)$$

Given this expression and the definition of $L_{i,t}$, we can easily deduce the implied coupon payment

$$c_{i,t+1} = \frac{1}{1-\tau} \left(\frac{L_{i,t+1}}{B_{i,t+1}} - 1 \right) \quad (18)$$

as in Gomes and Schmid (2009).¹¹

2.6 Credit Spreads

For tractability, we model total debt liabilities as a reduced form representation of a more realistic maturity structure of corporate debt. Under the assumption that firms default when the value of total debt liabilities dominates the value of dividend payments, we can price finite maturity debt using no-arbitrage.¹² Assume firm i borrows the amount $B_{i,t}^{(n)}$ for n -periods. Under the assumption that debt is issued at par, the n -period bond price must satisfy the Euler condition

$$B_{i,t}^{(n)} = \left(1 + c_{i,t}^{(n)}\right) B_{i,t}^{(n)} \mathbb{E}_t [M_{t,t+n}(1 - \mathbb{I}_{\{V_{i,t+n}=0\}})] + \mathbb{E}_t [M_{t,t+n} W_{i,t+n} \mathbb{I}_{\{V_{i,t+n}=0\}}] \quad (19)$$

where $c_{i,t}^{(n)}$ denotes the n -period coupon rate.¹³ The bond pricing equation (19) can be solved for the arbitrage-free coupon rate $c_{i,t+1}^{(n)}$ which is given

$$1 + c_{i,t}^{(n)} = \frac{1 - \chi_{i,t}^{(n)}}{\mathbb{E}_t [M_{t,t+n}] (1 - q_{i,t}^{(n)})} \quad (20)$$

and

$$q_{i,t}^{(n)} = \mathbb{E}_t \left[\frac{M_{t,t+n}}{\mathbb{E}_t [M_{t,t+n}]} \mathbb{I}_{\{V_{i,t+n}=0\}} \right] \quad \chi_{i,t}^{(n)} = \mathbb{E}_t [M_{t,t+n} R_{i,t+n} \mathbb{I}_{\{V_{i,t+n}=0\}}]$$

¹¹By using total debt liabilities instead of the bond price as state variable, our computational procedure automatically nests the debt market equilibrium in the calculation of equity values which considerably reduces the computational burden.

¹²A similar exercise is done in Bhamra, Kuehn, and Strebulaev (2010). There the authors assume firms issue perpetual debt. Yet they also price hypothetical finite maturity debt to be able to compare the model with the data.

¹³Here we slightly abuse notation since $B_{i,t}^{(1)} = B_{i,t+1}$ and $c_{i,t}^{(1)} = c_{i,t+1}$.

where $q_{i,t}^{(n)}$ is the risk-neutral default probability, $R_{i,t+n} = W_{i,t+n}/B_{i,t}^{(n)}$ is the recovery rate in the case of default and $\chi_{i,t}^{(n)}$ its value. Since we solve the model on a grid, the coupon rate can be easily computed by iterating over the expectations operators without having to rely on Monte-Carlo simulations.

Since we price zero coupon debt, the coupon rate is also the yield on the outstanding debt. Consequently, the n -period credit spread is defined as $s_{i,t}^{(n)} = 1 + c_{i,t}^{(n)} - R_{f,t}^{(n)}$. To gain a better understanding of credit risk, we define the log credit spread as log yield minus the log risk-free rate which is approximately given by

$$\log s_{i,t}^{(n)} \approx q_{i,t}^{(n)} - \chi_{i,t}^{(n)} \quad (21)$$

This equation shows that credit spreads are zero if default does not occur in expectation, implying that both $q_{i,t}^{(n)}$ and $\chi_{i,t}^{(n)}$ are zero. On the other hand, credit spreads increase in the risk-neutral default probability $q_{i,t}^{(n)}$ and decrease in the value of the recovery rate $\chi_{i,t}^{(n)}$.

The risk-neutral probability of default can be further decomposed into the actual probability of default and a risk premium

$$q_{i,t}^{(n)} = p_{i,t}^{(n)} + \text{Cov}_t \left(\frac{M_{t,t+n}}{\mathbb{E}_t[M_{t,t+n}]}, \mathbb{I}_{\{V_{i,t+n}=0\}} \right) \quad (22)$$

where the actual default probability is defined as $p_{i,t}^{(n)} = \mathbb{E}_t[\mathbb{I}_{\{V_{i,t+n}=0\}}]$ and the covariance captures a risk compensation for default risk. Since defaults tend to occur in bad times when marginal utility is high, this covariance is positive. Consequently, credit spreads are high if the risk compensation and actual default probabilities are high. Similarly, the value of the recovery rate can be written as

$$\chi_{i,t}^{(n)} = \frac{\mathbb{E}_t[R_{i,t+n}\mathbb{I}_{\{V_{i,t+n}=0\}}]}{R_{f,t}^{(n)}} + \text{Cov}_t (M_{t,t+n}, R_{i,t+n}\mathbb{I}_{\{V_{i,t+n}=0\}}) \quad (23)$$

The first term is the expected cash flow discounted using the risk-free rate and the second term, the covariance, is a compensation for risk. Since marginal utility is countercyclical in our model and recovery rates tend to be procyclical, the covariance is negative. Thus, credit spreads are large if our model endogenously generates a procyclical recovery rate.

3 Empirical Results

In this section, we present the quantitative implications of our model. Since the model does not entail a closed-form solution, we solve it numerically. The numerical procedure is detailed in the appendix. In the following, we first explain our calibration strategy and then we provide numerical results.

3.1 Calibration

Our quarterly calibration is summarized in Table 1. For the calibration of the consumption process, we follow Bansal, Kiku, and Yaron (2007). They assume that the first and second moments of consumption growth follow two separate processes. For tractability, we model the aggregate Markov chain, ω_t , to jointly affect the drift and volatility of consumption and to consist of five states. To calibrate the Markov chain, we follow the procedure suggested by Rouwenhorst (1995). Specifically, given the estimates in Bansal, Kiku, and Yaron (2007), we assume that the Markov chain has first-order auto-correlation of 0.95. The states for the drift, $\mu(\omega_t) \in \{\mu_1, \dots, \mu_5\}$, are chosen such that the standard deviation of the innovation to the drift equals 0.0004 quarterly. Similarly, the volatility states, $\sigma(\omega_t) \in \{\sigma_1, \dots, \sigma_5\}$, are chosen to have a quarterly mean of 0.0094 and conditional standard deviation of 0.00001 quarterly.

Regarding the preference parameters of the representative agent, we assume relative risk aversion (γ) of 10, an elasticity of intertemporal substitution (ψ) of 2 and rate of time preference (β) of 0.995 which are common values in the asset pricing literature to generate a realistic market price of risk. This parameterization implies that the representative agent has a preference for early resolution of uncertainty, so that she dislikes negative shocks to expected consumption growth and positive ones to consumption volatility.

At the firm level, we set the capital share of production equal to 0.65 in line with the evidence in Cooper and Ejarque (2003). Capital depreciates at 3% quarterly rate as in Cooley and Prescott (1995). Firms face proportional costs of production of 2% similar to Gomes (2001). Since there are no direct estimates of the conditional first and second moments of the technology shock, we follow Bansal, Kiku, and Yaron (2007) and scale the drift by 2.3 and

the volatility by 6.6 relative to the respective moments of the consumption process.

Firms can issue debt and equity. We set the fixed equity issuance and debt adjustment costs at 1% and the proportional component at 2% which is consistent with Gomes (2001), Hennessy and Whited (2007) and Altinkilic and Hansen (2000). Andrade and Kaplan (1998) report default costs of about 10%-25% of asset value and Hennessy and Whited (2007) estimate default losses to be around 10%. In line with the empirical evidence, we set bankruptcy costs at 20%. The effective corporate tax rate τ is 15% which is consistent with the evidence in van Binsbergen, Graham, and Yang (2010).

Most of the following quantitative results are based on simulations. Instead of repeating the simulation procedure, we summarize it here. We simulate 1,000 economies for 100 years each consisting of 3,000 firms. We delete the first 20 years of simulated data as a burn-in period. Defaulting firms are replaced with newborn firms, which have a small capital stock and zero leverage, such that the mass of firms is constant over time.

3.2 The Price of Aggregate Consumption Risk

Before we report quantitative implications for financing policies, we are interested in whether consumption dynamics, the pricing of the market return and risk-free asset are in line with the data. Matching aggregate risk prices is important for generating a sufficient amount of risk compensations in credit spreads. To this end, we report in Table 2 unconditional moments of consumption growth and equity returns. This table shows cross simulation averages where $\mathbb{E}[\Delta c]$ denotes mean consumption growth, $\sigma(\Delta c)$ consumption growth volatility, $AC_1(\Delta c)$ the first-order autocorrelation of consumption growth, $\mathbb{E}[r_f]$ mean risk-free rate, $\sigma(r_f)$ risk-free rate volatility, $\mathbb{E}[r_m]$ average market rate, and $\sigma(r_m)$ stock market volatility. All moments are annualized. The data are taken from Bansal, Kiku, and Yaron (2007).

Our calibration for the Markov model (2) for consumption is largely consistent with the data. The unconditional mean and volatility of consumption growth match the data well but realized consumption is not sufficiently persistent. Since the asset pricing implications of recursive preferences are mainly driven by the persistence of the Markov process, this feature of the Markov process lowers the market price of risk and explains why the aggregate market

return is lower in the model than in the data. However, the calibration almost matches the empirical Sharpe ratio. Moreover, given countercyclical volatility in consumption growth, the market price of risk is time-varying and countercyclical. The average unconditional risk-free rate generated by the model is similar in the data but it is not volatile enough. In the model, the risk-free rate changes with the state of the Markov chain and its persistence causes a very stable risk-free rate over time.

3.3 Corporate Policies

We now illustrate the model's quantitative implications for optimal firm behavior. In Table 3, we report unconditional moments of optimal corporate policies generated by the model. This table shows cross simulation averages of the average annual investment to asset ratio and its volatility, the frequency of equity issuances, average new equity to asset ratio, average book to market ratio and its volatility, and market leverage. The data are from Hennessy and Whited (2007), Davydenko and Strebulaev (2007) and Covas and Den Haan (2011).

Table 3 illustrates that the corporate financing and investment policies are generally consistent with the data. Because of capital depreciation and investment irreversibility, the model is able to match the average investment to asset ratio and its volatility. The magnitude of the equity issuance costs renders a realistic frequency of equity issuances but the magnitude of equity issuance to assets in place is slightly too large. The average book to market ratio is related to the curvature in production function as well as the investment and default option. Without the default option, the market to book ratio would be lower and closer to the data.

The most important statistic of this table is market leverage. Since one goal of this paper is to generate a realistic credit spread, it is crucial that the model implied leverage ratio is compatible with empirical estimates. This is important since credit spreads are increasing in default risk coming from leverage. Market leverage is defined as the ratio of the value of outstanding debt relative to the market value of the firm, $B/(B + V)$. In the model, average market leverage is close to empirical estimates for BBB rated firms. Given the substantial tax benefits to debt, generating realistically low leverage ratios is often challenging for structural models of credit risk, an observation referred to as low-leverage puzzle. In our setup with

macroeconomic risk as well as financial and investment frictions, firms optimally choose low leverage in order to preserve borrowing capacity for bad times.

In Table 4, we illustrate firms' cyclical behavior by means of simple correlations of firm characteristics with GDP growth. While in our one-factor economy the correlations are, not surprisingly, a little high, the model broadly qualitatively replicates firms' cyclical behavior rather well. In line with the data, investment is strongly procyclical. Investment expenditures raise firms' needs for external financing, which, given the tax advantage on debt, will come through a mix of equity and debt issuance. This makes both equity and debt issuance procyclical as well. While firms will also issue equity and additional debt in order to cover financing shortfalls in downturns, investment opportunities are sufficiently procyclical to be the dominating effect. In contrast, market leverage is countercyclical in the model because equity risk premia are sufficiently countercyclical.

3.3.1 The Cross Section of Leverage

We now examine the model's implications for the cross-sectional distribution of leverage. Generating a realistic leverage distribution is crucial for obtaining reliable implications for the cross-section of credit spreads, which we will examine later. To this end, we look at the popular regressions used in the empirical capital structure literature relating corporate leverage to several financial indicators (e.g., Rajan and Zingales (1995)). Specifically, we estimate the following regression equation in our simulated data set

$$Lev_{it} = \alpha_0 + \alpha_1 \log(K_{it}) + \alpha_2 Q_{it} + \alpha_3 \frac{\Pi_{it}}{K_{it}}$$

where K_{it} proxies firm size, Q_{it} is the market-to-book ratio, defined as $(V_{it} + B_{it})/K_{it}$, and Π_{it}/K_{it} measures firm profitability.

Table 5 summarizes our findings, which are directly comparable to those in Rajan and Zingales (1995). The table confirms the positive relation between firm size and leverage. This positive relation is coming from the concavity of the production function. The decreasing returns to scale assumption implies that large firms have more stable cash flows than small firms. Hence, as firms grow they optimally increase leverage over time. Accordingly, growth

firms have low leverage in our model in line with the empirical evidence. Table 5 also shows that our model is able to reproduce the observed negative relationships between leverage and either profitability or Q. Since small firms with volatile cash flows are also highly profitable and growth firms (high Q), the model generates the empirical observed relationships.

3.4 The Term Structure of Credit Spreads

We now turn to the pricing of corporate debt. We start by examining the term structure of credit spreads, and then turn to the cross-sectional implications in the next section.

It is well known that standard structural models of corporate default, such as Merton (1974) or Leland (1994), fail to explain observed credit spreads given low historical default probabilities. This fact has been first established in Huang and Huang (2003) and is called the credit spread puzzle. The puzzle is that fairly safe BBB rated firms barely default over a finite time horizon but at the same time these bonds pay a large compensation for holding default risk in terms of a credit spread. For instance, the historical default rate of BBB rated firms is around 2% over a 5 year horizon but the yield of BBB rated firms relative to AAA rated firms is around 100 basis points. We summarize the empirical evidence in Table 6.

A common approach in the corporate bond pricing literature is to study corporate policies of an individual firm at the initial date when the firm issues debt. The reason for this approach is that in the standard Leland (1994) model firms issue debt only once and thus in the long run leverage vanishes. In contrast, in our framework firms can rebalance their outstanding debt every period. Similar to Bhamra, Kuehn, and Strebulaev (2010), we study credit spreads in the cross section of firms.

To gauge whether our model generates a realistic credit spread, we simulate panels of firms as explained above. In Table 7, we report average equally-weighted credit spreads and actual default probabilities for 5 and 10 year debt. For 5 year debt, our model generates a credit spread of 105 basis points relative to 103 basis points in the data. For 10 year debt, the model implied credit spread is close to 119 basis points relative to 130 basis points in the data. At the same time, actual default probabilities are small. Over a five year horizon, on average 1.49% of firms default and, over a 10 year horizon, 3.75% of firms. Importantly, the

model implied default rates are smaller than in the data.

Three economic mechanisms drive these results in our investment based model. First, the model generates investment, financing and, most importantly, default policies of firms that are consistent with the empirical evidence. As we will explore below, this requires a careful modeling of the costs of investing, as well as of financial transaction costs, such as equity issuance and debt adjustment costs. Second, cross-sectional heterogeneity in asset composition and leverage raise the average credit spread because the value of both the investment and default option are convex functions of the state variables. Third, as default rates are strongly countercyclical, investors require risk premia on defaultable bonds. Our model with time-varying macroeconomic risk and recursive preferences generates risk premia and a countercyclical market price of risk, allowing the model to match the term structure of credit spreads. In the following subsection, we analyze the sensitivity of these results to our modeling assumptions.

To gain a better understanding of the mechanism driving credit spreads, we use the decomposition provided in Equation (21). Figure 1 displays actual default probabilities, $p_{i,t}^{(n)}$, as a function of capital (left graphs) and total debt liabilities (right graphs). The two top graphs show results for 5 year debt and the two bottom graphs for 10 year debt. In case of the solid blue line, the aggregate Markov chain is one standard deviation below its mean and, in case of the dashed red line, one standard deviation above it. Similarly, Figure 2 displays risk-neutral default probabilities, $q_{i,t}^{(n)}$, Figure 3 the value of the recovery rate in the cause of default, $\chi_{i,t}^{(n)}$, and Figure 4 credit spreads, $s_{i,t}^{(n)}$.

Figures 1 and 2 illustrate that higher capital levels lower default probabilities by increasing collateral. In contrast, more debt liabilities raise default probabilities, which is consistent with intuition. Moreover, default probabilities are higher in recessions (blue line) than in booms (red line) when the drift in productivity is lower and idiosyncratic shocks are more volatile. Default probabilities also increase over time in booms but decrease over time in recessions. Figure 4 illustrates that credit spreads fall with capital but rise with debt. Moreover, credit spreads are countercyclical and increase over time in booms and recessions. The intuition is

simple. Default probabilities and the market price of risk are both countercyclical. The latter follows from our specification of consumption dynamics in line with the empirical evidence in Boguth and Kuehn (2011).

3.4.1 Frictions and the Term Structure of Credit Spreads

In this section, we provide a sensitivity analysis of the model implied term structure of credit spreads. In particular, we quantify the dependence of our results on real and financial frictions. Table 7 summarizes the results. It reports the term structure of default probabilities and credit spreads in our benchmark model (Model I) along with three other specifications. Model II removes any financial transactions costs by setting λ_0 , λ_1 , ϕ_0 and ϕ_1 to zero. In other words, issuing equity and debt are costless. On the other hand, Model III removes the investment irreversibility constraint, that is, making investment completely reversible, but retains financial transaction costs. Model IV, finally, removes both investment irreversibility and transaction costs.

The table shows that the results on credit spreads and default probabilities are sensitive to the underlying model of investment and financing. Removing financial transaction costs, although small in magnitude, reduces the 5 year spread by 35 basis points (Model II). Qualitatively, this result is intuitive. Removing equity issuance costs makes it cheaper for firms to roll over existing debt by issuing new equity and removing debt adjustment costs makes it cheaper to delever. Model III shows that removing any obstructions to downward adjustment of the capital stock decrease the 5 year spread by 45 basis points. When investment is reversible firms can delever very effectively by selling off their capital stock, which will naturally reduce default risk. Finally, Model IV shows that removing both disinvestment and financing obstructions reduces the spread by another 10 basis points. Quantitatively, these results suggest that disinvestment obstructions have stronger effects on spreads than refinancing frictions.

Intuitively, one would guess that removing any investment and refinancing friction would drive credit spreads essentially down to zero. However, removing such obstructions affects credit risk in two ways that work in opposite directions. On the one hand, firms increase leverage when they face fewer frictions. All else equal, this drives up default probabilities and

credit spreads. Indeed, as reported in the table, leverage ratios are increasing through model specifications.

On the other hand, firms will lever up more in expansions anticipating that they will be able to delever quickly in bad times. This effect makes leverage more volatile and reduces the countercyclicality of market leverage and default probabilities. This effect will work to reduce credit spreads through the risk premium channel: default rates become less correlated with consumption growth and risk premia fall.

In sum, these results suggest that in a production economy two ingredients are necessary to rationalize the empirical term structure of credit spreads, namely both financial and real frictions. Financial frictions involve equity issuance and debt adjustment costs, and real frictions involve obstructions to the downward adjustment of the capital stock. We will now present evidence that these frictions are also relevant for generating novel cross-sectional patterns in credit spreads.

3.5 The Cross Section of Credit Spreads and Default Risk

While Table 7 shows that our model is quantitatively consistent with the level and the dynamics of the term structure of credit spreads, our model also has implications for the cross-sectional determinants of spreads, and similarly, for the cross-sectional determinants of default probabilities. Tables 8 and 9 summarize the results. Our findings are related to a large empirical literature on the determinants of credit spreads and default prediction and highlight the role of asset composition in a model of corporate bond pricing.

We follow the empirical literature on credit risk by running cross-sectional regressions of credit spreads and default probabilities on a set of explanatory variables. Specifically, beyond leverage, we use proxies for investment opportunities such as market-to-book and investment-to-asset ratios as explanatory variables as well as size and profitability. Table 8 reports regression results for credit spreads where the relevant credit spread is the spread on 5 year corporate bonds. Panel A reports results for our benchmark specification. The first univariate regression of credit spreads on market leverage confirms that in the model leverage is an important and significant determinant of credit spreads. Regressions 2-5 suggest that

variables capturing firms' investment opportunities and behavior carry additional explanatory power for spreads beyond leverage. In particular, including the market-to-book or investment-to-asset ratio in the regressions results in significant point estimates and, more importantly, increased explanatory power of the regressors as measured by the R^2 . This finding is robust to including further variables used in standard capital structure regressions, namely size and profitability. These variables are significant as well and appear with negative coefficients, even controlling for leverage. This suggests that credit spreads are related to corporations' investment decisions in a robust way.

Investment proxies enter with a positive sign. Intuitively, firms with a high market-to-book ratio derive a large fraction of their value from growth options. Growth options represent a levered claim on assets in place, and hence are riskier. In our model, this is reflected in the concavity of the production function. On average, smaller firms with higher growth opportunities will have more volatile cash flows than large firms. Accordingly, for the same amount of debt, growth firms have higher default rates than value firms, and hence higher spreads. This mechanism yields a positive sign on market-to-book and investment rate. Since size and profitability are negatively related to growth, both variables negatively predict credit spreads.

To the extent that credit spreads reflect firms' asset composition, one would expect that this link is inherently tied to aggregate macroeconomic conditions. Indeed, aggregate investment is strongly procyclical, as shown in Table 4. Consequently, the moneyness of growth options is procyclical, while the moneyness of default options is countercyclical. In Panels B and C, we investigate the cross-sectional determinants of credit spreads conditional on macroeconomic conditions.

Panel B of Table 7 reports regressions in samples that contain exclusively prolonged expansions, while Panel C reports the corresponding results for samples containing extended recessions. Panel B illustrates that proxies for investment opportunities are considerably stronger determinants of credit spreads in long booms than across the cycle. In good times, growth options come into the money, increasing implicit leverage of the option and hence

raising the beta of the firm. Similarly, upon exercise of the growth option, financial leverage increases due to partial debt financing. This makes the firm riskier, increasing credit spreads.

Interestingly, while still positive and significant, the coefficient on leverage is smaller in booms than in unconditional samples. This reflects the inherent endogeneity of growth options and leverage in our model. Particularly during expansions, growth firms are risky and therefore endogenously choose low leverage. As a result, asset risk and leverage risk are inversely related in our model, so that unconditional regressions without controlling for the risk of assets are unlikely to be very informative. In addition, the negative link between size and spreads is more pronounced in booms, reflecting higher riskiness of smaller firms. In contrast, the link between profitability and spreads is weaker, reflecting less sensitivity of spreads to external financing.

These effects are reversed in samples containing long recessions (Panel C). In such samples, proxies for investment opportunities predict credit spreads negatively, conditional on leverage. In bad times, assets in place are more risky than growth options because of operating leverage. This makes value firms more prone to default and renders the sign on market-to-book and investment-to-asset ratios negative. At the same time, value firms are burdened with excess debt. Since the default option is more valuable for value firms, the model now generates a strong link between leverage and credit spreads. Quantitatively, these effects are exacerbated due to our assumption of irreversible investment.¹⁴ The negative link between profitability and spreads is now more pronounced, as an additional dollar of internal funds is worth more in bad times. This is in contrast to the link between size and spreads, which is less pronounced, reflecting fewer investment opportunities for smaller growth firms, and hence more stable cash flows.

Given that credit spreads reflect default probabilities, the previous results suggest that investment proxies should be useful in predicting default rates. We confirm this intuition in Table 9, where we report logit regressions of default probabilities on a set of explanatory variables. This relates to a long empirical literature on default prediction. Consistent with

¹⁴We also solved versions of the model with disinvestment options. Qualitatively, the significance of the results prevail, as long as disinvestment is more costly than investment.

the results on credit spread determinants, our model also predicts that proxies for investment opportunities are significant determinants of default probabilities, even when controlling for leverage. The intuition from above directly applies. Investment opportunities signal future financing needs, which will be reflected in future default probabilities. Since investment opportunities depend on macroeconomic conditions, this link will equally be conditional on these states. In particular, in good times firms deriving a large fraction of their value from growth opportunities will be particularly exposed to aggregate risk, exacerbating the effects of growth options on risk. Similarly, the reverse effect holds in bad times.

3.5.1 Frictions and the Cross Section of Credit Spreads

In the previous section we argued that generating a realistic term structure of credit spreads in a production economy imposes considerable discipline on the calibration of real and financial frictions. These frictions are also responsible for rich patterns in the cross section of credit spreads. In other words, in a production economy, the term structures and the cross-section of credit spreads are tightly linked.

In Table 10, we report unconditional cross-sectional credit spread regressions similar to Table 7. Model I is the benchmark specification, Model II removes any financial transaction costs by setting λ_0 , λ_1 , ϕ_0 and ϕ_1 to zero, and Model III removes the investment irreversibility constraint but retains financial transaction costs. Model IV, finally, removes both investment irreversibility and transaction costs.

While leverage enters positively and significantly in all model specifications, the explanatory power of leverage is increasing in terms of t -statistic and R^2 when firms face fewer constraints. On the contrary, the coefficient on book-to-market becomes insignificant in Models III and IV. This implies that in a model without financial transaction costs and real frictions, leverage becomes a sufficient statistic for credit spreads and proxies for investment opportunities do not add any explanatory power.

The intuition for this result is quite simple. Without real and financial adjustment costs, firms will endogenously adjust leverage such that asset risk is offset by financial risk. Firms with high (low) asset risk choose optimally low (high) leverage. Consequently, asset com-

position will no longer affect credit spreads and optimal target leverage ratios subsume all the information about credit spreads. Both real and financial adjustment costs prevent firms from adjusting to the frictionless target leverage ratio and asset risk gains predictive power for overall firm risk and thus credit spreads.

These results suggest that deviations from target leverage are reflected in credit spreads in the full model. Several authors have pointed out the importance of financial adjustment costs for capital structure dynamics, e.g., Leary and Roberts (2005). In contrast to them, we exploit the information in credit spreads to calibrate real and financial frictions. Our model suggests that deviations from target leverage should be particularly pronounced in downturns when firms have the strong need to reduce leverage. This effect arises because of the asymmetry in real adjustment cost, i.e., firms can exercise growth options but they do not possess disinvestment options.

We quantify this effect by means of target adjustment regression, following Flannery and Rangan (2006). More specifically, we estimate

$$\text{Lev}_{i,t+1} = (\lambda\beta)X_{i,t} + (1 - \lambda)\text{Lev}_{i,t} + \epsilon_{t+1}$$

where λ reflects the speed of adjustment to target leverage. Following Flannery and Rangan (2006) we parameterize target leverage as a function of a number of firm characteristics, summarized by the vector $X_{i,t}$. In our case, we include Tobin's Q, size and profitability. The results are reported in Table 11. We focus on the dynamics in expansions relative to downturns. As expected, the regression yields a higher coefficient on lagged leverage in recessions than in booms, that is, a lower λ . Accordingly, in our model the speed of adjustment is lower in recessions than in expansions.

3.6 Aggregate Investment and Credit Spreads

A growing body of empirical work indicates that aggregate credit risk predicts aggregate quantities such as investment growth (e.g., Lettau and Ludvigson (2002) and Mueller (2009)). Similarly, Philippon (2009) shows that a bond market based Tobin's Q explains most of the variation in aggregate investment whereas an equity market based Q fails.

In this section, we aim to replicate this finding with our model. In Table 12, we regress next quarter's aggregate investment growth, ΔI_{t+1} , on the aggregate credit spread, s_t ,

$$\Delta I_{t+1} = \alpha + \beta s_t + \epsilon_{t+1} \quad \epsilon \sim \mathcal{N}(0, \sigma)$$

In the data, we use quarterly real private fixed investment and as a measure of the aggregate default spread we use the difference between the yield of seasoned BBB and AAA rated firms as reported by Moody's. The data is at quarterly frequency and covers the period 1955.Q1 to 2009.Q4. We run the same regression in the data and on simulated data. In the model, aggregate investment is the sum of firm level investment decisions and the aggregate credit spread is the average equally-weighted credit spread across firms with 10 year maturity.

In Figure 5 we plot both time series. The negative correlation between the credit market and investment is apparent, meaning that more costly access to debt markets leads to a reduction in real investment. We confirm this finding by means of regressions. Specifically, the first regression of Table 12 shows that a one percent increase in the annualized credit spread leads to reduction of 1.7% in investment with an R^2 of 7.7%. This estimated sensitivity is both statistically and economically significant. Using simulated panels of firms, our model can reproduce the sensitivity of investment to the costs of borrowing. The second regression of Table 12 shows that aggregate investment falls by 1.5% after a one percent increase in the aggregate credit spread which is close to the empirical estimate.

A common approach in corporate finance as well as macroeconomic models is to ignore the pricing of aggregate risk. Typically, in these models quantity dynamics are largely unaffected by movements in risk premia, implying a separation of quantity and prices as in Tallarini (2000). To demonstrate that such a separation breaks down in the presence of financing frictions, we alternatively price debt when the agent is risk neutral. In this case, the expectations are not taken under the risk neutral but the actual measure and the bond pricing relation (19) simplifies to

$$B_{i,t}^{(n)} = \left(1 + \tilde{c}_{i,t}^{(n)}\right) B_{i,t}^{(n)} \beta^n \mathbb{E}_t \left[(1 - \mathbb{I}_{\{V_{i,t+n}=0\}}) \right] + \beta^n \mathbb{E}_t \left[W_{i,t+n} \mathbb{I}_{\{V_{i,t+n}=0\}} \right]$$

The risk neutral coupon \tilde{c} only reflects actual default probabilities but no compensation for

bearing default risk. The risk neutral credit spread is the difference between the risk neutral coupon and the risk-free rate with identical maturities.

The third regression of Table 12 shows that the risk neutral credit spread loses its ability to forecast future investment growth. This finding implies that it is the risk component in credit spreads which drives most of the time variation in aggregate investment growth. We thus highlight the importance of accounting for macroeconomic risks in jointly explaining corporate financing and investment decisions.

4 Conclusion

Recent research has considerably advanced our understanding of credit risk. In spite of these efforts, the empirical success of the leading class of corporate bond pricing models is rather limited in terms of explaining both the time series and cross section of credit spreads. While state-of-the-art structural bond pricing models take the evolution of firms' assets as exogenously given in the spirit of Modigliani and Miller (1958), we argue and provide quantitative evidence that investment options are an important determinant of credit spreads.

We provide a tractable model of firms' investment and financing decisions where optimal firm decisions are distorted by financial market imperfections as well as real investment frictions. The model delivers a realistic term structure of credit spreads while keeping actual default rates realistically low. Rationalizing the term structure of credit spreads in a production economy imposes tight restrictions on modeling both real and financial frictions. In the presence of these frictions, firms' leverage will deviate from target and asset composition becomes an important determinant of the cross sections of credit spreads and default risk. When asset composition is a determinant of credit risk, the unconditional link between leverage and credit spreads is weak. The joint endogeneity of investment and financing can thus rationalize the weak empirical performance of structural bond pricing models.

In this paper we take a step towards an integrated framework linking firms' investment and financing decisions to the pricing of corporate bonds. The model makes numerous novel empirical predictions that will provide ground for future work.

Appendix

A Stationary Problem

To save on notation, we drop the index i and ignore the default option in the following. Because of the homogeneity of the value function and the linearity of the constraints, we can rescale the value function by X_t

$$\begin{aligned}
V(K_t, L_t, X_t) &= D_t + \mathbb{E}_t[M_{t,t+1}V(K_{t+1}, L_{t+1}, X_{t+1})] \\
V\left(\frac{K_t}{X_t}, \frac{L_t}{X_t}, 1\right) &= \frac{D_t}{X_t} + \mathbb{E}_t\left[M_{t,t+1}\frac{X_{t+1}}{X_t}V\left(\frac{K_{t+1}}{X_{t+1}}, \frac{L_{t+1}}{X_{t+1}}, 1\right)\right] \\
&= d_t + \beta^\theta \mathbb{E}_t\left[e^{-\gamma(g+\mu_c(\omega_t)+\sigma_c(\omega_t)\eta_{t+1})}\left(\frac{Z(\omega_{t+1})+1}{Z(\omega_t)}\right)^{-(1-\theta)}\right. \\
&\quad \left.\times e^{g+\mu_x(\omega_t)+\sigma_x(\omega_t)\varepsilon_{t+1}}V\left(\frac{K_{t+1}}{X_{t+1}}, \frac{L_{t+1}}{X_{t+1}}, 1\right)\right] \\
&= d_t + \beta^\theta e^{-\gamma(g+\mu_c(\omega_t))+\frac{\gamma^2}{2}\sigma_c(\omega_t)^2}\mathbb{E}_t\left[\left(\frac{Z(\omega_{t+1})+1}{Z(\omega_t)}\right)^{-(1-\theta)}\right. \\
&\quad \left.\times e^{g+\mu_x(\omega_t)+\sigma_x(\omega_t)\varepsilon_{t+1}}V\left(\frac{K_{t+1}}{X_{t+1}}, \frac{L_{t+1}}{X_{t+1}}, 1\right)\right]
\end{aligned}$$

The pricing kernel is given by

$$m_{t,t+1} = \beta^\theta e^{-\gamma(g+\mu_c(\omega_t))+\frac{\gamma^2}{2}\sigma_c(\omega_t)^2}\left(\frac{Z(\omega_{t+1})+1}{Z(\omega_t)}\right)^{-(1-\theta)}$$

We can define the following stationary variables

$$k_{t+1} = \frac{K_{t+1}}{X_t} \quad b_{t+1} = \frac{b_{t+1}}{X_t} \quad l_{t+1} = \frac{L_{t+1}}{X_t} \quad d_t = \frac{D_t}{X_t} \quad e_t = \frac{E_t}{X_t} \quad i_t = \frac{I_t}{X_t}$$

and the stationary value function $v(k_t, l_t, \omega_t, \Delta x_t)$ solves

$$v(k_t, l_t, \omega_t, \Delta x_t) = d_t + \mathbb{E}_t\left[m_{t,t+1}e^{\Delta x_{t+1}}v(k_{t+1}, l_{t+1}, \omega_{t+1}, \Delta x_{t+1})\right]$$

where

$$\Delta x_{t+1} = g + \mu_x(\omega_t) + \sigma_x(\omega_t)\varepsilon_{t+1}$$

The stationary value function is four dimensional because the Markov state ω_t matters for the pricing kernel and Δx_t for detrending dividends as shown below.

The linear constraints in the model can now be expressed in terms of stationary variables

$$\begin{aligned}
d_t &= e_t - \Lambda(e_t) \\
e_t &= \pi_t + \tau \delta e^{-\Delta x_t} k_t - i_t + b_{t+1} - e^{-\Delta x_t} l_t - \Phi(\Delta l_{t+1}) \\
\pi_t &= (1 - \tau) \left[(e^{-\Delta x_t})^\alpha k_t^\alpha - e^{-\Delta x_t} k_t f \right] \\
\Lambda(e_t) &= (\lambda_0 + \lambda_1 |e_t|) \mathbb{I}_{\{e_t < 0\}} \\
\Phi(\Delta l_{t+1}) &= \phi_0 \mathbb{I}_{\{\Delta l_{t+1} \neq 0\}} + \phi_1 |\Delta l_{t+1}| \\
\Delta l_{t+1} &= l_{t+1} - e^{-\Delta x_t} l_t \\
k_{t+1} &= (1 - \delta) e^{-\Delta x_t} k_t + i_t
\end{aligned}$$

Stationary total debt liabilities are given by

$$l_t = (1 + (1 - \tau)c_t)b_t$$

implying that

$$c_{t+1} = \frac{1}{1 - \tau} \left(\frac{l_{t+1}}{b_{t+1}} - 1 \right)$$

We can also rewrite the bond pricing equation (15) in terms of stationary variables by detrending it with X_t such that

$$b_{t+1} = \frac{\mathbb{E}_t \left[m_{t,t+1} \left(\frac{1}{1-\tau} l_{t+1} \mathbb{I}_{\{v_{t+1} > 0\}} + e^{\Delta x_{t+1}} r_{t+1} \mathbb{I}_{\{v_{t+1} = 0\}} \right) \right]}{1 + \frac{\tau}{1-\tau} \left(\mathbb{E}_t \left[m_{t,t+1} \mathbb{I}_{\{v_{t+1} > 0\}} \right] \right)}$$

where the stationary recovery value in default is given by

$$r_t = \frac{R_t}{X_t} = (1 - \xi) \left[\pi_t + \tau \delta e^{-\Delta x_t} k_t + (1 - \delta) e^{-\Delta x_t} k_t \right]$$

B Numerical Solution

We solve the model numerically with value function iteration. We create a grid for capital and debt liabilities, each with 50 points. The choice vector for tomorrow's capital level and debt liabilities has 500 elements for each variable. We use two dimensional linear interpolation to evaluate the value function and bond pricing equation off grid points. The aggregate Markov chain has 5 states and changes in the technology shock are approximated with 11 elements.

References

- Altinkilic, Oya, and Robert S. Hansen, 2000, Are there economies of scale in underwriting fees? evidence of rising external financing costs, *Review of Financial Studies* 13, 191–218.
- Andrade, Gregor, and Steven N. Kaplan, 1998, How costly is financial (not economic) distress? evidence from highly leveraged transactions that became distressed, *Journal of Finance* 53, 1443–93.
- Arnold, Marc, Alexander F. Wagner, and Ramona Westermann, 2011, Macroeconomic conditions, growth options and the cross-section of credit risk, Working Paper.
- Bansal, Ravi, Dana Kiku, and Amir Yaron, 2007, Risks for the long run: Estimation and inference, Working Paper.
- Bansal, Ravi, and Amir Yaron, 2004, Risks for the long run: A potential resolution of asset pricing puzzles, *Journal of Finance* 59, 1481–1509.
- Barclay, C., Erwan Morellec, and C. W. Smith, 2006, On the debt capacity of growth options, *Journal of Business* 79, 37–59.
- Berk, Jonathan, Richard C. Green, and Vasant Naik, 1999, Optimal investment, growth options, and security returns, *Journal of Finance* 54, 1553–1607.
- Bhamra, Harjoat S., Lars-Alexander Kuehn, and Ilya A. Strebulaev, 2010, The levered equity risk premium and credit spreads: A unified framework, *Review of Financial Studies* 23, 645–703.
- Boguth, Oliver, and Lars-Alexander Kuehn, 2011, Consumption volatility risk, Working paper.
- Bolton, Patrick, Hui Chen, and Neng Wang, 2010, A unified theory of tobin’s q, corporate investment, financing, and risk management, Forthcoming, *Journal of Finance*.
- Broadie, Mark, Mikhail Chernov, and Suresh Sundaresan, 2007, Optimal debt and equity values in the presence of chapter 7 and chapter 11, *Journal of Finance* 62, 1341–1377.
- Cantor, Richard, Frank Emery, Kenneth Kim, Sharon Ou, and Jennifer Tennant, 2008, Default and recovery rates of corporate bond issuers, Moody’s Investors Service, Global Credit Research.
- Carlson, Murray, Adlai Fisher, and Ron Giammarino, 2004, Corporate investment and asset price dynamics: Implications for the cross-section of returns, *Journal of Finance* 59, 2577–2603.
- Carlson, Murray, and Ali Lazrak, 2010, Leverage choice and credit spreads when managers risk shift, *Journal of Finance* 65, 2323–2362.
- Chen, Hui, 2010, Macroeconomic conditions and the puzzles of credit spreads and capital structure, *Journal of Finance* 65, 2171–2212.
- , and Gustavo Manso, 2010, Macroeconomic risk and debt overhang, Working Paper.
- Chen, Long, Pierre Collin-Dufresne, and Robert S. Goldstein, 2009, On the relation between credit spread puzzles and the equity premium puzzle, *Review of Financial Studies* 22, 3367 – 3409.
- Collin-Dufresne, Pierre, Robert Goldstein, and J. Spencer Martin, 2001, The determinants of credit spread changes, *Journal of Finance* 56, 2177–2207.
- Collin-Dufresne, Pierre, and Robert S. Goldstein, 2001, Do credit spreads reflect stationary leverage ratios?, *Journal of Finance* 56, 1929–1957.
- Cooley, Thomas F., and Edward C. Prescott, 1995, Economic growth and business cycles, in Thomas F. Cooley, ed.: *Frontiers of Business Cycle Research* . pp. 1–38 (Princeton University Press: Princeton, NJ).

- Cooley, Thomas F., and Vincenzo Quadrini, 2001, Financial markets and firm dynamics, *American Economic Review* 91, 1286–1310.
- Cooper, Russell, and Joao Ejarque, 2003, Financial frictions and investment: A requiem in q , *Review of Economic Dynamics* 6, 710–728.
- Covas, Francisco, and Wouter J. Den Haan, 2011, The role of debt and equity finance over the business cycle, *American Economic Review* 101, 877–899.
- David, Alexander, 2008, Inflation uncertainty, asset valuations, and credit risk, *Review of Financial Studies* 21, 2487–2534.
- Davydenko, Sergei, and Ilya A. Strebulaev, 2007, Strategic actions and credit spreads: An empirical investigation, *Journal of Finance* 62, 2633 – 2671.
- Dudley, Evan, 2011, Capital structure and large investment projects, Working paper.
- Duffee, Gregory R., 1998, The relation between treasury yields and corporate bond yield spreads, *Journal of Finance* 53, 2225–2241.
- Epstein, Larry, and Stanley Zin, 1989, Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework, *Econometrica* 57, 937–969.
- Fischer, Edwin O., Robert Heinkel, and Josef Zechner, 1989, Dynamic capital structure choice: Theory and tests, *Journal of Finance* 44, 19–40.
- Flannery, Mark J., and Kasturi P. Rangan, 2006, Partial adjustment toward target capital structures, *Journal of Financial Economics* 79, 469–506.
- Garlappi, Lorenzo, and Hong Yan, 2011, Financial distress and the cross-section of equity returns, *Journal of Finance* pp. 789–822.
- Goldstein, Robert, Nengjiu Ju, and Hayne Leland, 2001, An ebit-based model of dynamic capital structure, *Journal of Business* 74, 483–512.
- Gomes, Joao, Leonid Kogan, and Lu Zhang, 2003, Equilibrium cross section of returns, *Journal of Political Economy* 111, 693–732.
- Gomes, Joao F., 2001, Financing investment, *American Economic Review* 91, 1263–1285.
- , and Lukas Schmid, 2009, Levered returns, *Journal of Finance* 65, 467–494.
- Hackbarth, Dirk, and David Mauer, 2011, Optimal priority structure, capital structure, and investment, Forthcoming, *Review of Financial Studies*.
- Hackbarth, Dirk, Jianjun Miao, and Erwan Morellec, 2006, Capital structure, credit risk and macroeconomic conditions, *Journal of Financial Economics* 82, 519–550.
- Hennessy, Christopher A., and Toni M. Whited, 2005, Debt dynamics, *Journal of Finance* 60, 1129–1165.
- Hennessy, Christopher A., and Toni M. Whited, 2007, How costly is external financing? evidence from a structural estimation, *Journal of Finance* 62, 1705 – 1745.
- Huang, J., and Ming Huang, 2003, How much of the corporate-treasury yield spread is due to credit risk? a new calibration approach, Working Paper.
- Jermann, Urban J., 1998, Asset pricing in production economies, *Journal of Monetary Economics* 41, 257–275.

- Kayhan, Ayla, and Sheridan Titman, 2007, Firms histories and their capital structures, *Journal of Financial Economics* 83, 1–32.
- Kogan, Leonid, 2004, Asset prices and real investment, *Journal of Financial Economics* 73, 411–432.
- Leary, Mark T., and Michael R.. Roberts, 2005, Do firms rebalance their capital structures?, *Journal of Finance* 60, 2575–2619.
- Leland, Hayne E., 1994, Corporate debt value, bond covenants, and optimal capital structure, *Journal of Finance* 49, 1213–52.
- Lettau, Martin, and Sydney Ludvigson, 2002, Time-varying risk premia and the cost of capital: An alternative implication of the q theory of investment, *Journal of Monetary Economics* 49, 31–66.
- Livdan, Dmitry, Horacio Sapriza, and Lu Zhang, 2009, Financially constrained stock returns, *Journal of Finance* 64, 1827–1862.
- Mayer, Colin, and Oren Sussman, 2004, A new test of capital structure, Working paper.
- Merton, Robert C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449–470.
- Miao, Jianjun, 2005, Optimal capital structure and industry dynamics, *Journal of Finance* 60, 2621–2659.
- Modigliani, Franco, and Merton H. Miller, 1958, The cost of capital, corporation finance and the theory of investment, *American Economic Review* 48, 261–297.
- Moyen, Nathalie, 2004, Investment-cash flow sensitivities: Constrained versus unconstrained firms, *Journal of Finance* 59, 2061–2092.
- Mueller, Philippe, 2009, Credit spreads and real activity, Working Paper.
- Philippon, Thomas, 2009, The bond market’s q, *Quarterly Journal of Economics*, *Forthcoming*.
- Rajan, Raghuram G., and Luigi Zingales, 1995, What do we know about capital structure? some evidence from international data, *Journal of Finance* 50, 1421–60.
- Rouwenhorst, K. Geert, 1995, Asset pricing implications of equilibrium business cycle models, in Thomas F. Cooley, ed.: *Frontiers of Business Cycle Research* . pp. 294–330 (Princeton University Press: Princeton, NJ).
- Strebulaev, Ilya, 2007, Do tests of capital structure theory mean what they say?, *Journal of Finance* 62, 1747–1787.
- Sundaresan, Suresh, and Neng Wang, 2007, Financing real options, Working Paper.
- Tallarini, Jr., Thomas D., 2000, Risk-sensitive real business cycles, *Journal of Monetary Economics* 45, 507–532.
- van Binsbergen, Jules H., John Graham, and Jie Yang, 2010, The cost of debt, *Journal of Finance* 65, 2089–2136.
- Whited, Toni, 2010, External finance constraints and the intertemporal pattern of intermittent investment, *Journal of Financial Economics* 81, 467–502.
- Zhang, Lu, 2005, The value premium, *Journal of Finance* 60, 67–103.

Figure 1: Actual Default Probabilities

This figure displays actual default probabilities as a function of capital (left graphs) and total debt liabilities (right graphs). The two top graphs show results for 5 year debt and the two bottom graphs for 10 year debt. In case of the solid blue line, the aggregate Markov chain is one standard deviation below its mean and, in case of the dashed red line, one standard deviation above.

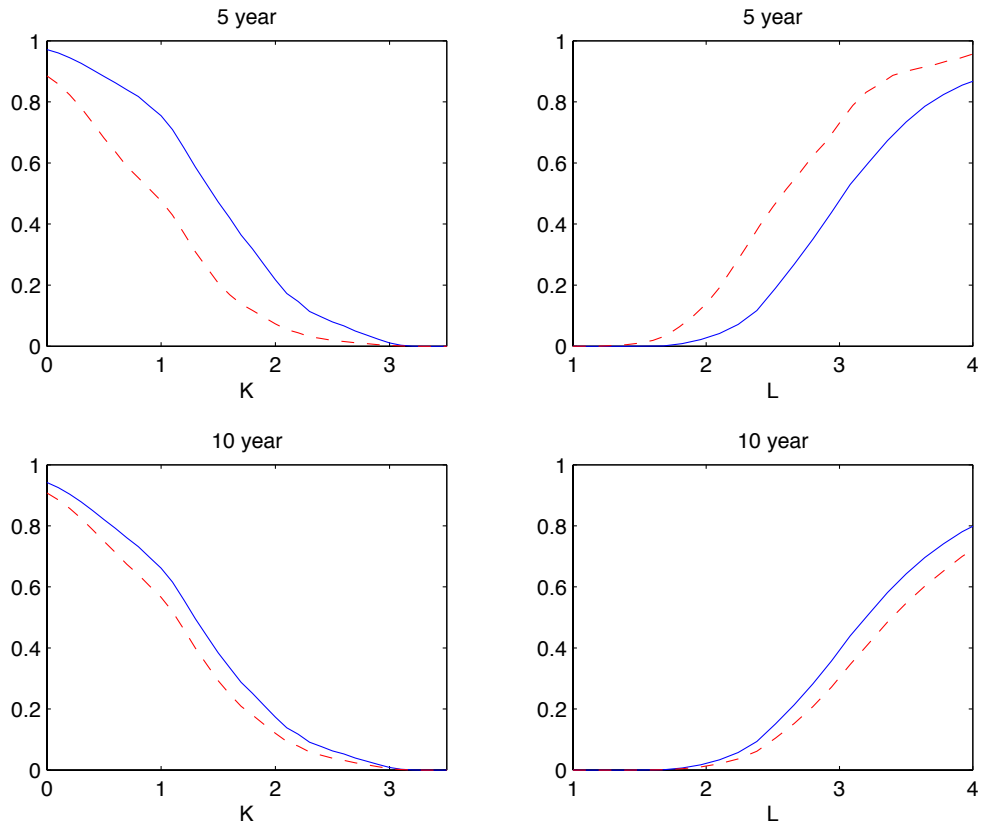


Figure 2: Risk-Neutral Default Probabilities

This figure displays risk-neutral default probabilities as a function of capital (left graphs) and total debt liabilities (right graphs). The two top graphs show results for 5 year debt and the two bottom graphs for 10 year debt. In case of the solid blue line, the aggregate Markov chain is one standard deviation below its mean and, in case of the dashed red line, one standard deviation above.

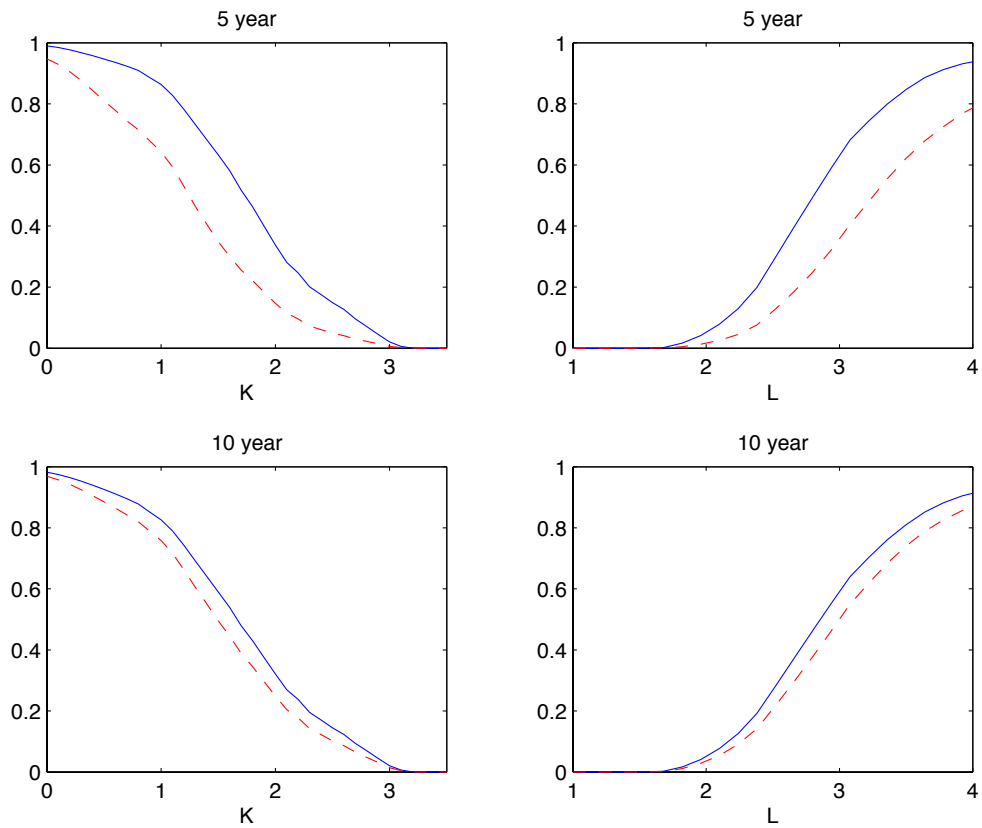


Figure 3: Recovery Rate Value

This figure displays the value of the recovery rate as a function of capital (left graphs) and total debt liabilities (right graphs). The two top graphs show results for 5 year debt and the two bottom graphs for 10 year debt. In case of the solid blue line, the aggregate Markov chain is one standard deviation below its mean and, in case of the dashed red line, one standard deviation above.

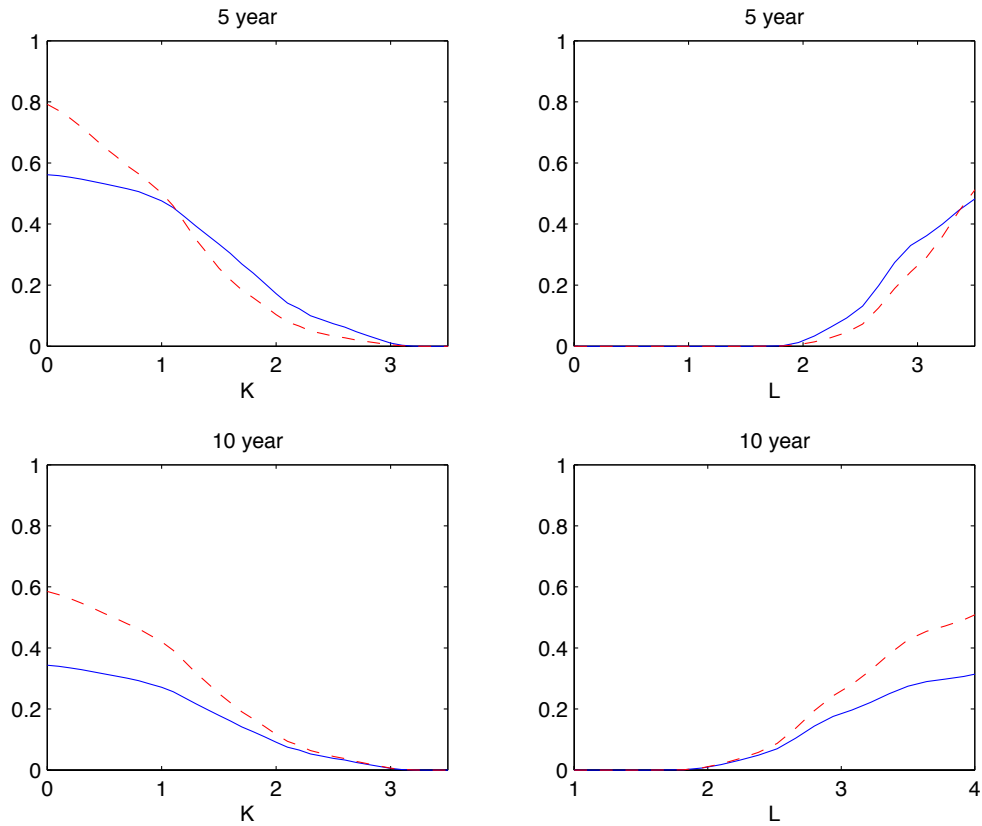


Figure 4: Credit Spreads

This figure displays credit spreads as a function of capital (left graphs) and total debt liabilities (right graphs). The two top graphs show results for 5 year debt and the two bottom graphs for 10 year debt. In case of the solid blue line, the aggregate Markov chain is one standard deviation below its mean and, in case of the dashed red line, one standard deviation above.

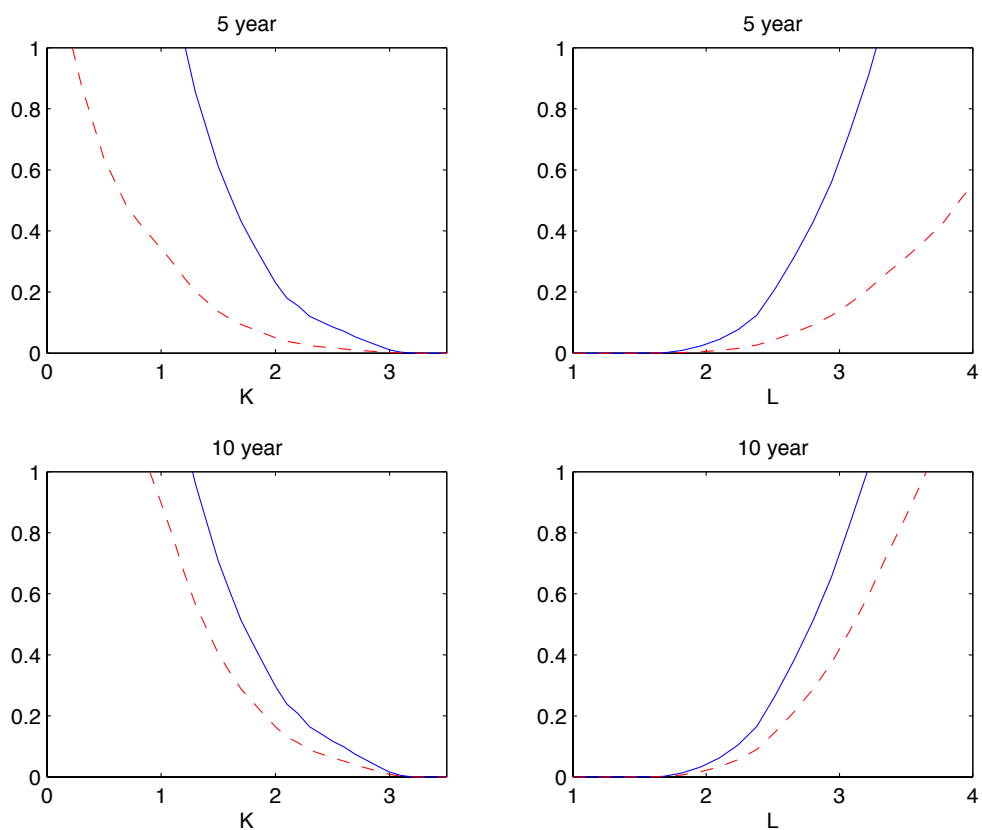


Figure 5: Investment Growth and Default Risk

This figure displays investment growth and the default spread for the US economy. We use quarterly real private fixed investment. The default spread is the difference between Moody's BBB and AAA. The data spans the period 1955.Q1-2009.Q4.

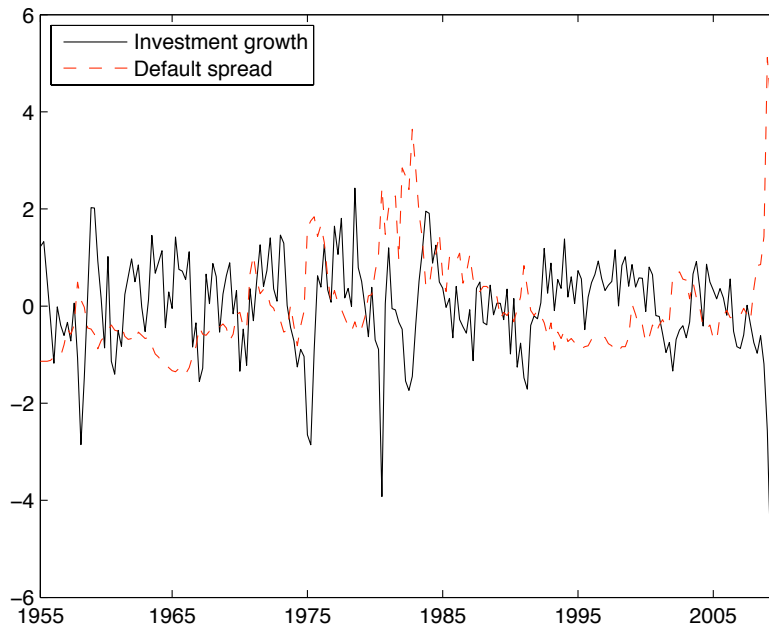


Table 1: Calibration

This table summarizes our calibration used to solve and simulate our model. All values are quarterly.

Description	Parameter	Value
Rate of time preference	β	0.995
Relative risk aversion	γ	10
Elasticity of intertemporal substitution	ψ	2
Growth rate of consumption	g	0.005
Persistence of Markov chain	ρ	0.95
Capital share	α	0.65
Depreciation rate of capital	δ	0.03
Proportional costs of production	f	0.02
Corporate tax rate	τ	0.15
Fixed equity issuance costs	λ_0	0.01
Proportional equity issuance costs	λ_1	0.02
Fixed debt adjustment costs	ϕ_0	0.01
Proportional debt adjustment costs	ϕ_1	0.02
Bankruptcy costs	ξ	0.2

Table 2: Aggregate Moments

This table reports unconditional moments of consumption growth and stock returns. We simulate 1,000 economies for 100 years each consisting of 3,000 firms. This table shows cross simulation averages where $\mathbb{E}[\Delta c]$ denotes mean consumption growth, $\sigma(\Delta c)$ consumption growth volatility, $AC_1(\Delta c)$ the first-order autocorrelation of consumption growth, $\mathbb{E}[r_f]$ mean risk-free rate, $\sigma(r_f)$ risk-free rate volatility, $\mathbb{E}[r_m]$ average market rate, and $\sigma(r_m)$ stock market volatility. All moments are annualized. The data are from Bansal, Kiku, and Yaron (2007).

Moment	Unit	Data	Model
$\mathbb{E}[\Delta c]$	%	1.96	1.96
$\sigma(\Delta c)$	%	2.21	2.08
$AC_1(\Delta c)$		0.44	0.28
$\mathbb{E}[r_f]$	%	0.76	1.10
$\sigma(r_f)$	%	1.12	0.52
$\mathbb{E}[r_m]$	%	8.27	6.84
$\sigma(r_m)$	%	20.10	17.37

Table 3: Moments of Corporate Policies

This table reports unconditional moments of corporate policies generated by the model. We simulate 1,000 economies for 100 years each consisting of 3,000 firms and the table shows cross simulation averages. The data are from Hennessy and Whited (2007), Davydenko and Strebulaev (2007) and Covas and Den Haan (2011).

Moment	Data	Model
Avg. annual investment-to-asset ratio	0.130	0.093
Volatility of investment-to-asset ratio	0.006	0.028
Frequency of equity issuances	0.099	0.127
Avg. new equity to asset ratio	0.042	0.133
Avg. market-to-book ratio	1.493	1.845
Volatility of market-to-book ratio	0.230	0.278
Market leverage	0.367	0.352

Table 4: Firm Behavior over the Business Cycle

This table reports correlation coefficients of corporate policies with aggregate output growth. We simulate 1,000 economies for 100 years each consisting of 3,000 firms and the table shows cross simulation averages. Empirical sources are the Bureau of Economic Analysis and the Board of Governors of the Federal Reserve. In the data, output is US real GDP.

Moment	Data	Model
Aggregate investment growth	0.81	0.87
Aggregate equity issuance	0.10	0.18
Average market leverage	-0.11	-0.69
Average credit spread	-0.33	-0.54
Aggregate default rate	-0.36	-0.83

Table 5: Cross-Sectional Leverage Regressions

This table reports cross-sectional Fama-Macbeth regressions of leverage on size (K), market-to-book ($(V+B)/K$) and profitability (Π/K). We simulate 1,000 economies for 100 years each consisting of 3,000 firms and the table shows cross simulation averages, where t -statistics are reported in parentheses. The first column reports regressions from unconditional simulations, including booms and recessions as generated by our shock specification. In the second column economies are in long-lasting booms, in the sense that they are exposed to above average shock realizations, whereas in last column economies are in long-lasting recessions, in the sense that they are exposed to below average shock realizations.

	Unconditional	Boom	Recession
Size	1.47 (2.29)	1.65 (2.38)	1.33 (2.23)
Market-to-book	-0.95 (-2.17)	-1.03 (-2.25)	-0.82 (-2.22)
Profitability	-0.66 (-2.28)	-0.61 (-2.19)	-0.76 (-2.29)

Table 6: Empirical Default Rates and Credit Spreads

Panel A reports average cumulative issuer-weighted annualized default rates for BBB debt over 5, 10, and 15 year horizons for US firms as reported by Cantor, Emery, Ou, and Tennant (2008). The first row shows mean historical default rates for the period 1920–2007 and the second row for 1970–2007. Panel B reports the difference between average spreads for BBB and AAA corporate debt, sorted by maturity. Data from Duffee (1998) are for bonds with no option-like features, taken from the Fixed Income Dataset, University of Houston, for the period Jan 1973 to March 1995, where maturities from 2 to 7 years are short, 7 to 15 are medium, and 15 to 30 are long. For Huang and Huang (2003), short denotes a maturity of 4 years and medium of 10 years. The data used in David (2008) are taken from Moody’s and medium denotes a maturity of 10 years. For Davydenko and Strebulaev (2007), the data are taken from the National Association of Insurance Companies; short denotes a maturity from 1 to 7 years, medium 7 to 15 years, and long 15 to 30 years.

Panel A: Historical BBB Default Probabilities				
Rating	Unit	Year 5	Year 10	Year 15
1920 – 2007	%	3.142	7.061	10.444
1970 – 2007	%	1.835	4.353	7.601
Panel B: BBB/AAA Spreads				
Rating	Unit	Short	Medium	Long
Duffee (1998)	b.p.	75	70	105
Huang and Huang (2003)	b.p.	103	131	–
David (2008)	b.p.	–	96	–
Davydenko and Strebulaev (2007)	b.p.	77	72	82

Table 7: Term Structure of Credit Spreads

In this table, we report average 5 and 10 year credit spreads and the corresponding actual default probabilities for different model specifications. Model I refers to the benchmark model, Model II features no financial adjustment costs, Model III removes the irreversible investment constraint, and Model IV features neither financial nor real adjustment costs (reversible investment). We simulate 1,000 economies for 100 years each consisting of 3,000 firms and the table reports cross simulation averages.

Moment	Unit	Data	Model I	Model II	Model III	Model IV
5 year credit spread	b.p.	103.00	105.13	71.37	59.25	49.65
5 year default probability	%	1.83	1.49	1.06	0.94	0.83
10 year credit spread	b.p.	130.00	118.62	85.14	73.51	58.29
10 year default probability	%	4.35	3.75	2.81	2.46	2.17
Leverage			0.35	0.38	0.41	0.43

Table 8: Cross Section of Credit Spreads

The table reports cross-sectional Fama-MacBeth regressions of credit spreads on sets of explanatory variables. The dependent variable is the 5 year credit spread. The regression results are obtained from simulations of 1,000 economies for 100 years each consisting of 3,000 firms. Panel A reports regressions from unconditional simulations, including booms and recessions as generated by our shock specification. In Panel B economies are in long-lasting booms, in the sense that they are exposed to above average shock realizations, whereas in Panel C economies are in long-lasting recessions, in the sense that they are exposed to below average shock realizations. t -statistics are reported in parentheses.

Panel A: Unconditional					
Leverage	1.39 (2.21)	1.66 (2.13)	1.85 (2.26)	1.79 (2.33)	1.88 (2.31)
Market-to-book		0.59 (2.11)		0.36 (2.15)	
Investment-to-asset			1.25 (2.09)		1.12 (2.18)
Size				-1.12 (-2.29)	-1.08 (-2.34)
Profitability				-0.41 (-2.15)	-0.27 (-2.12)
R^2	0.54	0.61	0.60	0.64	0.64
Panel B: Booms					
Leverage	0.88 (2.10)	1.42 (2.24)	1.71 (2.17)	1.88 (2.19)	1.43 (2.27)
Market-to-book		0.73 (2.22)		0.61 (2.20)	
Investment-to-asset			1.38 (2.19)		1.21 (2.14)
Size				-1.42 (-2.26)	-1.35 (-2.33)
Profitability				-0.29 (-2.08)	-0.23 (-2.18)
R^2	0.53	0.62	0.61	0.66	0.65
Panel C: Recessions					
Leverage	1.91 (2.32)	2.02 (2.20)	2.11 (2.28)	1.96 (2.31)	2.07 (2.34)
Market-to-book		-0.19 (-2.13)		-0.14 (-2.07)	
Investment-to-asset			-0.50 (-2.17)		-0.36 (-2.08)
Size				-0.98 (-2.25)	-0.93 (-2.16)
Profitability				-0.49 (-2.24)	-0.43 (-2.18)
R^2	0.56	0.59	0.59	0.61	0.62

Table 9: Cross Section of Default Risk

The table reports logit regressions of default probabilities on sets of explanatory variables. The dependent variable is the 1-year default probability. The regression results are obtained from simulations of 1,000 economies for 100 years each consisting of 3,000 firms. Panel A reports regressions from unconditional simulations, including booms and recessions as generated by our shock specification. In Panel B economies are in long-lasting booms, in the sense that they are exposed to above average shock realizations, whereas in Panel C economies are in long-lasting recessions, in the sense that they are exposed to below average shock realizations. t -statistics are reported in parentheses.

	Panel A: Unconditional				
Leverage	2.13	2.30	2.44	2.17	2.22
	(2.10)	(2.21)	(2.15)	(2.27)	(2.23)
Market-to-book		0.87		0.72	
		(2.05)		(2.11)	
Investment-to-asset			1.68		1.46
			(2.14)		(2.09)
Size				-1.51	-1.43
				(-2.28)	(-2.25)
Profitability				-0.77	-0.53
				(-2.17)	(-2.12)
R^2	0.52	0.60	0.62	0.63	0.62
	Panel B: Booms				
Leverage	1.37	1.94	2.26	2.31	2.09
	(2.24)	(2.18)	(2.31)	(2.25)	(2.17)
Market-to-book		1.14		0.92	
		(2.20)		(2.16)	
Investment-to-asset			1.81		1.58
			(2.31)		(2.28)
Size				-1.75	-1.63
				(-2.36)	(-2.32)
Profitability				-0.56	-0.49
				(-2.11)	(-2.19)
R^2	0.50	0.59	0.59	0.63	0.62
	Panel C: Recessions				
Leverage	3.91	4.22	4.37	4.14	4.20
	(2.42)	(2.35)	(2.40)	(2.32)	(2.36)
Market-to-book		-0.44		-0.37	
		(-2.03)		(-2.00)	
Investment-to-asset			-0.94		-0.85
			(-2.10)		(-2.13)
Size				-1.43	-1.26
				(-2.19)	(-2.15)
Profitability				-0.83	-0.73
				(-2.28)	(-2.25)
R^2	0.55	0.57	0.57	0.59	0.59

Table 10: Frictions and the Cross Section of Credit Spreads

The table reports Fama-MacBeth regressions of 5 year credit spreads on sets of explanatory variables for different model specifications. Model I refers to the benchmark model, Model II features no financial adjustment costs, Model III removes the irreversible investment constraint, and Model IV features neither financial nor real adjustment costs (reversible investment). We simulate 1,000 economies for 100 years each consisting of 3,000 firms and the table shows cross simulation averages, where t -statistics are reported in parentheses.

	Model I		Model II		Model III		Model IV	
Leverage	1.39 (2.21)	1.66 (2.13)	1.64 (2.24)	1.57 (2.20)	1.53 (2.33)	1.88 (2.26)	1.59 (2.42)	1.74 (2.31)
Market-to-book		0.59 (2.11)		0.63 (1.91)		0.71 (1.67)		0.65 (1.55)
R^2	0.54	0.61	0.56	0.60	0.60	0.60	0.62	0.62

Table 11: Target Adjustment Regressions

The table reports Fama-MacBeth target adjustment regressions of leverage on lagged leverage and explanatory variables. Following Flannery and Rangan (2005), the regressions are of the form

$$\text{Lev}_{i,t+1} = (\lambda\beta)X_{i,t} + (1 - \lambda)\text{Lev}_{i,t} + \epsilon_{t+1}$$

The regression results are obtained from simulations of 1,000 economies for 100 years each consisting of 3,000 firms. Panel A reports regressions from economies that are in long-lasting booms, whereas in Panel B economies are in long-lasting recessions. t -statistics are reported in parentheses.

Panel A: Expansion			
Leverage	Market-to-book	Size	Profitability
0.78	-0.08	0.03	-0.13
(2.33)	(-2.15)	(2.24)	(-2.18)
Panel B: Recession			
Leverage	Market-to-book	Size	Profitability
0.91	-0.04	0.01	-0.06
(2.39)	(-2.26)	(2.22)	(-2.30)

Table 12: Aggregate Investment and Credit Spreads

In this table, we regress aggregate investment growth, ΔI_{t+1} , on the aggregate credit spread, s_t ,

$$\Delta I_{t+1} = \alpha + \beta s_t + \epsilon_{t+1} \quad \epsilon \sim \mathcal{N}(0, \sigma)$$

In the data, we use quarterly real private fixed investment and the aggregate credit spread is the difference between Moody's BBB and AAA. The data is at quarterly frequency and covers the period 1955.Q1 to 2009.Q4. In the model, we simulate 1,000 economies for 100 years each consisting of 3,000 firms. We run the same regression in the data and on simulated data. The risk neutral credit spread is the difference between the yield of corporate debt priced under the actual probability measure and the risk-free rate. We report t -statistics in parentheses which are based on Newey-West standard errors with 4 lags.

	α	β	R^2
Data	0.024 (3.941)	-1.674 (-2.446)	0.077
Model	0.067 (4.518)	-1.486 (3.128)	0.058
Risk-neutral credit spread	0.097 (3.824)	-0.184 (1.429)	0.008