Systematic Risk, Debt Maturity, and the Term Structure of Credit Spreads*

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Abstract

We build a structural model to explain corporate debt maturity dynamics over the business cycle and their implications for the term structure of credit spreads. Longer-term debt helps lower firms' default risks while shorter-term debt reduces investors' exposures to liquidity shocks. The joint variations in default risks and liquidity frictions over the business cycle cause debt maturity to lengthen in economic expansions and shorten in recessions. The model predicts that firms with higher systematic risk exposures will choose longer debt maturity, and that this cross-sectional relation between systematic risk and debt maturity will be stronger when risk premium is high. It also shows that the pro-cyclical maturity dynamics induced by liquidity frictions can significantly amplify the impact of aggregate shocks on credit risk, with different effects across the term structure, and that maturity management is especially important in helping high-beta and high-leverage firms reduce the impact of a crisis event that shuts down long-term refinancing. Finally, we provide empirical evidence for the model predictions on both debt maturity and credit spreads.

Keywords: credit risk, term structure, business cycle, maturity dynamics, liquidity

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1 Introduction

The aggregate corporate debt maturity has a clear cyclical pattern: the average debt maturity is longer in economic expansions than in recessions. Using data from the Flow of Funds Accounts, we plot in Figure 1 the trend and cyclical components of the share of long-term debt for nonfinancial firms from 1952 to 2010. The cyclical component falls in every recession in the sample, with an average drop of 4% from peak to trough.[1] For individual firms, the maturity variation over time can be even stronger. For example, during the financial crisis of 2007-08, 26% of the non-financial public firms in the U.S. saw their long-term debt share falling by 20% or more.

What explains the cyclical variations in corporate debt maturity? How do the maturity dynamics affect the term structure of credit risk? And how effective is maturity management in reducing firms' credit risk exposures in a financial crisis? To address these questions, we build a dynamic capital structure model that endogenizes firms' maturity choices over the business cycle, and examine the impact of the interactions between maturity dynamics and macroeconomic conditions on credit risk.

In our model, firms face business cycle fluctuations in growth, economic uncertainty, and risk premia. They choose how much debt to issue based on the tradeoff between the tax benefits of debt and the costs of financial distress. Default occurs when equity holders are no longer willing to service the debt. The need to roll over existing risky debt (by redeeming them at par) leads to the classic debt overhang problem (Myers (1977)), which makes default more likely. A longer debt maturity helps reduce this problem, thus lowering the costs of financial distress. At the same time, investors are subject to idiosyncratic but non-diversifiable liquidity shocks, which endogenously cause longer-term bonds to have larger liquidity discounts and hence to be more costly to issue. The tradeoff between default risk and liquidity determines the optimal maturity choice.

Systematic risk affects maturity choice through two channels. For firms with high

[1] We do not study the long-term trend in debt maturity in this paper. Greenwood, Hanson, and Stein (2010) argue that this trend is consistent with firms acting as macro liquidity providers. Custodio, Ferreira, and Laureano (2012) show that the secular decline in the maturity of public firms was generated by firms with higher information asymmetry and by new public firms in the 1980s and 1990s.

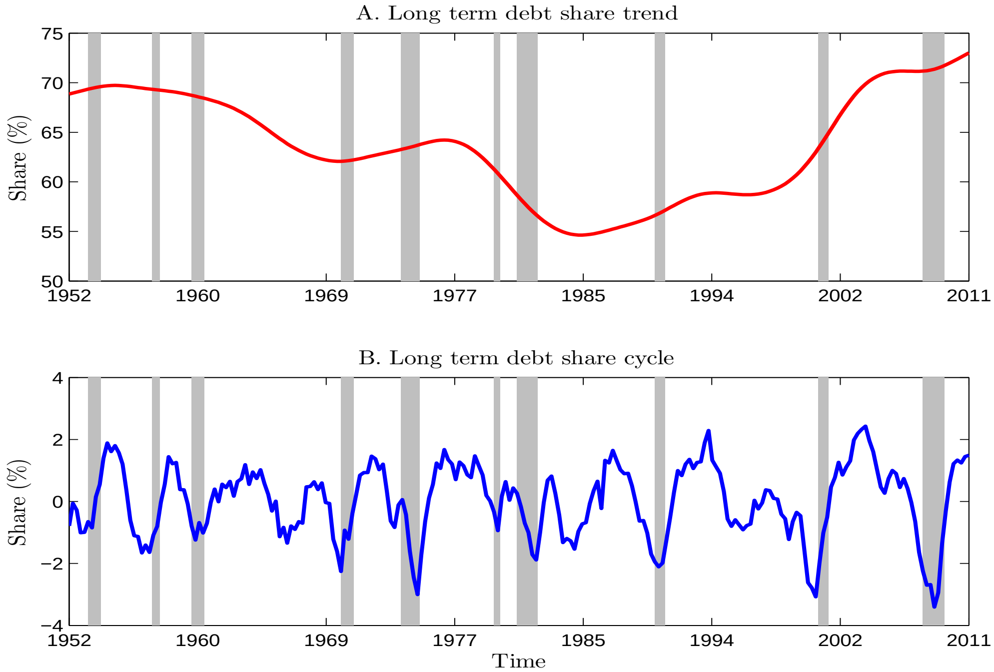

Figure 1: Long-term debt share for nonfinancial corporate business. The top panel plots the trend component (via the Hodrick-Prescott filter) of aggregate long-term debt share. The bottom panel plots the cyclical component. The shaded areas denote NBER-dated recessions. Source: Flow of Funds Accounts (Table L.102).

systematic risk, default is more likely to occur in aggregate bad times. Since the risk premium associated with the deadweight losses of default raises the expected bankruptcy costs, these firms choose longer debt maturity during normal times to reduce their default risk. As the economy moves into a recession, risk premium rises, and so do the frequency and severity of liquidity shocks. On the one hand, firms with low systematic risk exposures respond to the higher liquidity discounts of long-term bonds by replacing those matured bonds with short-term bonds, which lowers their average debt maturity. On the other hand, firms with high systematic risk become even more concerned about the default risk associated with short maturity. In response, they continue rolling over the matured long-term bonds into new long-term bonds despite the higher liquidity costs, and their maturity structures will be more stable over the business cycle as a result.

Following Duffie, Garleanu, and Pedersen (2005, 2007) and He and Milbradt (2012), we model the illiquidity of corporate bonds via search frictions. When an investor experiences a liquidity shock, she incurs a cost for holding any asset that cannot be liquidated immediately, where the holding costs represent the costs of alternative sources of financing to meet the liquidity needs (instead of using the proceeds from selling the asset). For a corporate bond, this liquidity problem lasts until either the constrained investor finds someone to trade with or until the maturity of the bond, at which point the principal is returned to the investor. For this reason, long-term bonds will have a larger liquidity discount than short-term bonds.

Our calibrated model generates reasonable predictions for leverage, default probabilities, credit spreads, and equity pricing. The model also allows us to analyze a series of questions regarding the impact of debt maturity dynamics on the term structure of credit spreads.

First, like leverage, debt maturity has first order effects on both the level and shape of the term structure of credit spreads. Everything else equal, a shorter maturity raises credit spreads at all horizons and can potentially make the credit curve change from upward-sloping to downward-sloping. For a low-leverage firm (with market leverage of 30%), cutting the average maturity from 8 to 5 years raises the credit spreads by as much as 18 bps in good times and 24 bps in bad times; for a high-leverage firm (with market leverage of 55%), the same change in maturity raises spreads by up to 74 bps in good times and 135 bps in bad times. The maturity effect is stronger at the medium-to-long horizon (8-12 years) for low-leverage firms but at short horizons (2-5 years) for high leverage firms. Moreover, the size of the maturity effect increases nonlinearly as maturity shortens.

Second, pro-cyclical maturity dynamics make a firm's credit spreads higher and more volatile over the business cycle. Thus, ignoring the maturity dynamics can lead one to underestimate the credit risk. The amplification effect of maturity dynamics is nonlinear in the size of maturity changes over the cycle. For firms with low leverage, the maturity dynamics mainly affect credit spreads at the medium horizon and almost have no impact on the short end of the credit curve. In contrast, for firms with high leverage, the effect of pro-cyclical maturity on credit risk is not only much stronger, but is highly concentrated at the short end of the credit curve, which reflects the fact that rollover-induced default risk is imminent but temporary.

Third, our model quantifies the effectiveness of maturity management in helping a firm reduce the impact of rollover risk during a financial crisis. The inability to secure long-term refinancing in a crisis means that a firm that enters into the crisis with a large amount of debt coming due can only roll these debt over using short-term debt. The resulting maturity reduction makes the firm more exposed to the crisis than a firm that manages to maintain a long average maturity before the crisis arrives. Thus, firms anticipating a crisis should try to lengthen their debt maturity, especially those with high leverage and high systematic risk exposures. For example, we find that a high leverage firm that enters into a crisis with an average maturity of 1 year experiences an increase in credit spreads of up to 660 bps. Had the same firm chosen an average maturity of 8 years entering into the crisis, the increase in spreads will only be up to 220 bps.

Fourth, our model shows that the endogenous link between systematic risk and debt maturity should be a key consideration for empirical studies of rollover risk. Firms with high systematic risk endogenously choose longer debt maturities and more stable maturity structures. However, their credit spreads (as well as earnings and investment) will likely still be more affected by aggregate shocks because of their fundamental risk exposures. Thus, instead of identifying high-rollover risk firms by comparing the levels or changes in debt maturity, one should also account for the heterogeneity in firms' systematic risk exposures.

We test the model predictions using firm-level data. Consistent with the model, we find that firms with high systematic risk choose longer debt maturity and maintain a more stable maturity structure over the business cycle. After controlling for total asset volatility and leverage, a one-standard deviation increase in asset market beta raises firm's long-term debt share (the percentage of total debt that matures in more than 3 years) by 6.6%. When macroeconomic conditions worsen, for example, during recessions or times of high market volatility, the average debt maturity falls while the sensitivity of debt maturity to systematic risk exposure becomes higher. The long-term debt share is 3.9% lower in recessions than in expansions for a firm with asset market beta at the 10th percentile, but almost unchanged for a firm with asset beta at the 90th percentile. These findings are robust to different measures of systematic risk and different proxies for debt maturity. Furthermore, using data from the recent financial crisis, we find that the effects of rollover risk on credit spreads are significantly stronger for firms with high leverage or high cashflow beta, and they are stronger at shorter horizons, which are again consistent with our model predictions.

The main contribution of our paper is two-fold. First, to our best knowledge, this paper is the first to provide both a dynamic model and empirical evidence for the link between systematic risk and firms' maturity choices over the business cycle. It adds to the growing body of research on how aggregate risk affects corporate financing decisions, which includes Hackbarth, Miao, and Morellec (2006), Almeida and Philippon (2007), Acharya, Almeida, and Campello (2012), Bhamra, Kuehn, and Strebulaev (2010a), Bhamra, Kuehn, and Strebulaev (2010b), Chen (2010), Chen and Manso (2010), and Gomes and Schmid (2010), among others.

On the empirical side, Barclay and Smith (1995) find that firms with higher asset volatility choose shorter debt maturity. They do not separately examine the effects of systematic and idiosyncratic risk on debt maturity. Baker, Greenwood, and Wurgler (2003) argue that firms choose debt maturity by looking at inflation, the short rate, and the term spread to minimize the cost of capital. Two recent empirical studies have documented that firms' debt maturity changes over the business cycle. Erel, Julio, Kim, and Weisbach (2012) show that new debt issuances shift towards shorter maturity and more security during times of poor macroeconomic conditions. Mian and Santos (2011) show that the maturity of syndicated loans is pro-cyclical, especially for credit worthy firms. They also argue that firms actively managed their loan maturity before the financial crisis through early refinancing of outstanding loans. Our measures of systematic risk exposure are different from their measures of credit quality.

Second, our paper contributes to the studies of the term structure of credit spreads.[2] Structural models can endogenously link default risk to firms' financing decisions, including leverage and maturity structure. This is valuable for credit risk modeling because, while intuitive, it is not obvious theoretically or empirically how to connect debt maturity choice to credit risk at different horizons. For simplicity, earlier models mostly restrict the maturity structure to be time-invariant. Our model allows the maturity structure to change over the

[2] Earlier contributions include structural models by Chen, Collin-Dufresne, and Goldstein (2009), Collin-Dufresne and Goldstein (2001), Leland (1994), Leland and Toft (1996), and reduced-form models by Duffie and Singleton (1999), Jarrow, Lando, and Turnbull (1997), Lando (1998), among others.

business cycle and connects the maturity dynamics to the term structure of credit risk via firms' endogenous default decisions.

Our model builds on the dynamic capital structure models with optimal choices for leverage, maturity, and default decisions. The disadvantage of short-term debt in our model is that rolling over risky debt gives rise to the debt overhang problem, which increases the risk of default. Importantly, the rollover risk of short-term debt crucially depends on the downward rigidity in leverage, without which short-term debt can actually reduce credit risk. The disadvantage of long-term debt is the illiquidity discount, which is endogenously generated in the model via search frictions (following He and Milbradt (2012)).[3] We focus on the cost of illiquidity because it can be directly calibrated to the data on liquidity spreads for corporate bonds. Bao, Pan, and Wang (2011), Chen, Lesmond, and Wei (2007), Edwards, Harris, and Piwowar (2007), and Longstaff, Mithal, and Neis (2005) have all documented a positive relation between maturity and various measures of corporate bond illiquidity.

2 Model

In this section, we present a dynamic capital structure model that allows for maturity adjustments over the business cycle. We first introduce the macroeconomic environment and then describe the firm's problem.

2.1 The Economy

The aggregate state of the economy is described by a continuous-time Markov chain with the state at time t denoted by $s_t \in \{G, B\}$. State G represents an expansion state, which is characterized by high expected growth rates, low economic uncertainty, and low risk premium, while the opposite is true in the recession state B. The physical transition intensities from state G to B and from B to G are $\widehat{\pi}_G$ and $\widehat{\pi}_B$, respectively. They imply that the probability that the economy switches from state G to B (or from B to G) in a small time interval Δ is

[3] Other possible costs for long-term debt include information asymmetry and adverse selection (Diamond (1991), Flannery (1986)), debt overhang (Myers (1977)), or asset substitution (Leland and Toft (1996)).

approximately $\widehat{\pi}_G\Delta$ (or $\widehat{\pi}_B\Delta$).

Firms generate cash flows that are subject to the large aggregate shocks that change the state of the economy, small systematic shocks, as well as firm-specific diversifiable shocks. Specifically, a firm's cash flow y_t follows the process

$$\frac{dy_t}{y_t} = \widehat{\mu}(s_t)dt + \sigma_\Lambda(s_t)dZ_t^\Lambda + \sigma_f(s_t)dZ_t^f \,. \tag{1}$$

The two independent standard Brownian motions Z_t^Λ and Z_t^f are the sources of systematic and firm-specific cash-flow shocks, respectively. The expected growth rate of cash flows is $\widehat{\mu}(s_t)$, while $\sigma_\Lambda(s_t)$ and $\sigma_f(s_t)$ denote the systematic and idiosyncratic conditional volatility of cash flows. Although a change in the aggregate state s_t does not lead to any immediate change in the level of cash flows, it changes the dynamics of y_t by altering its conditional growth rate and volatilities.

Investors in this economy are subject to idiosyncratic but uninsurable liquidity shocks. An example of such liquidity shocks is a sudden and large redemption request for banks or hedge funds. In the presence of financing frictions, a liquidity-constrained investor would prefer to sell her assets to raise funds provided there is a liquid secondary market for the asset. Otherwise, she will have to raise costly funding elsewhere or sell the asset at a discount. These financing costs are a form of shadow costs for investing in illiquid assets. Duffie, Garleanu, and Pedersen (2005, 2007) formalize this argument in a model of the over-the-counter markets with search frictions. He and Milbradt (2012) extend the model to corporate bonds and generate a liquidity spread that is increasing with bond maturity. We follow He and Milbradt (2012) to endogenize the illiquidity of long-term bonds via search frictions.

Specifically, we assume that an unconstrained investor (denoted as type U) can become constrained (type C) when she receives an idiosyncratic liquidity shock, which occurs with intensity $\lambda_U(s)$ in state s. Being liquidity-constrained means that the investor will incur a holding cost every period for holding onto an asset (as in Duffie, Garleanu, and Pedersen (2005)). If the asset has a liquid secondary market, the investor will sell it immediately to avoid the holding costs. If it is illiquid, the constrained investor will need to find an unconstrained investor to trade with. The search succeeds with intensity $\lambda_C(s)$, at which point the investor ceases to incur the holding costs.[4] Alternatively, if the asset has finite maturity, the return of principal at maturity will also resolve the liquidity problem. Thus, the constrained investor incurs holding costs until she finds someone to trade with or until the asset maturity, whichever comes first. The dependence of $\lambda_i(s)$ $(i = U, C)$ on the aggregate state s allows both the frequency of liquidity shocks and the search frictions in the over-the-counter markets to differ in good and bad times.

The presence of non-diversifiable liquidity shocks makes markets incomplete, and the equilibrium can only be solved analytically in some special cases (see e.g., Duffie, Garleanu, and Pedersen (2007)). For tractability, we assume that illiquid assets are a very small part of individual investors' portfolios. In the limit, these investors' marginal utilities are unaffected by the liquidity shocks, which means they will not demand any risk premium for the exposure to liquidity shocks. As for those investors who only hold liquid assets, we assume they effectively face complete markets because the liquidity shocks have no impact on their wealth.

It then follows that there is a unique stochastic discount factor (SDF) Λ_t that is only driven by aggregate shocks. We assume Λ_t follows the process:[5]

$$\frac{d\Lambda_t}{\Lambda_{t^-}} = -r\left(s_{t^-}\right)dt - \eta\left(s_{t^-}\right)dZ_t^{\Lambda} + \delta_G\left(s_{t^-}\right)\left(e^{\kappa}-1\right)dM_t^G - \delta_B\left(s_{t^-}\right)\left(1-e^{-\kappa}\right)dM_t^B, \tag{2}$$

with

$$\delta_G\left(G\right) = \delta_B\left(B\right) = 1, \quad \delta_G\left(B\right) = \delta_B\left(G\right) = 0,$$

where $r(s_t)$ is the state-dependent risk free rate, and $\eta(s_t)$ is the market price of risk for the aggregate Brownian shocks dZ_t^{Λ}. The compensated Poisson processes $dM_t^s \equiv dN_t^s - \widehat{\pi}_s dt$ reflect the changes of the aggregate state (away from state s), while κ determines the size of the jump in the discount factor when the aggregate state changes. To capture the notion that state B is a time with high marginal utilities and high risk prices, we set $\eta(B) > \eta(G)$ and $\kappa > 0$ so that Λ_t jumps up going into a recession and down coming out of a recession.

[4]For simplicity, we abstract away from considering dealers in the over-the-counter market, and we assume the seller has all the bargaining power when trading takes places. Reducing the bargaining power of the seller has similar effects on the model as a higher holding cost.

[5]See Chen (2010) for a general equilibrium model based on the long-run risk model of Bansal and Yaron (2004) that generates the stochastic discount factor of this form.

The SDF Λ_t in (2) implies a unique risk-neutral probability measure for all the aggregate shocks. Standard risk-neutral pricing techniques apply to the pricing of any liquid asset in the economy. The valuation of an illiquid asset will depend on the type of its investor and the liquidity shocks. Because there is no risk premium associated with the liquidity shocks, their probability distribution remains the same under the risk-neutral measure. This feature significantly simplifies the pricing of illiquid assets.

2.2 The Firm's Problem

A firm chooses the optimal leverage and debt maturity jointly. The total face value of the firm's debt is P, with corresponding coupon rate b chosen such that the debt is priced at par upon issuance at $t = 0$. The optimal leverage is primarily determined by the tradeoff between the tax benefits (interest expenses are tax-deductible) and the costs of financial distress. The effective tax rate on corporate income is τ. In bankruptcy, the absolute priority rule applies, with debt-holders recovering a fraction $\alpha(s)$ of the firm's unlevered assets and equity-holders receiving nothing. For the maturity choice, firms trade off the default risk induced by the need to roll over short-term debt against the illiquidity of long-term debt.

To fully specify a maturity structure, one needs to specify the amount of debt maturing at different horizons as well as the rollover policy for matured debt. For tractability, the existing literature mostly focuses on the time-invariant maturity structure introduced by Leland and Toft (1996) and Leland (1998). For example, Leland (1998) assumes that debt has no stated maturity but is continuously retired at face value at a constant rate m, and that all the retired debt is immediately replaced by new debt with identical face value and seniority. This implies that the average maturity of debt outstanding today is $\int_0^\infty tme^{-mt}dt = 1/m$.

Such a maturity structure has several important implications. First, the maturity structure is time-invariant, which is at odds with the empirical evidence (see e.g., Figure 1). Second, it also rules out "lumpiness" in the maturity structure so that the same amount of debt is retired at different horizons. Choi, Hackbarth, and Zechner (2012) find that lumpiness in debt maturity is common in the data, possibly for the purpose of lowering floatation costs, improving liquidity, or market timing. Third, the setting introduces downward rigidity in leverage because firms are always immediately rolling over all the retired debt.

We extend the maturity modeling in Leland (1998) by allowing a firm to roll over its retired debt into new debt of different maturity when the state of the economy changes. While this setting is still restrictive – firms should in principle be able to adjust their debt maturity at any time, it allows us to capture the business-cycle dynamics of debt maturity, which is the focus of this paper.[6]

To understand how debt maturity can change in the model, consider the following setting. The maturity structure in state G (good times) is the same as in Leland (1998): debt is retired at a constant rate m_G and is replaced by new debt with the same principal and seniority. When state B (recession) arrives, the firm can choose to replace the retired debt with new debt of a different maturity (the same seniority). This new maturity is determined by the rate $\overline{m}_B$ at which the new debt is retired. Thus, the firm will have two types of debt outstanding in state B. After t years in state B, the instantaneous rate of debt retirement is $R_B(t) = m_G e^{-m_G t} + \overline{m}_B(1 - e^{-m_G t})$. Finally, when the economy moves from state B back to state G, the firm swaps all the type-$\overline{m}_B$ debt into type-m_G debt.

The rate of debt retirement $R_B(t)$ is time dependent, which complicates this problem. To keep the problem analytically tractable, we approximate the above dynamics by assuming that all the debt will be retired at a constant rate m_B in state B, where m_B is the average rate at which debt is retired in state B:

$$m_B = \int_0^\infty \widehat{\pi}_B e^{-\widehat{\pi}_B t} \left(\frac{1}{t} \int_0^t R_B(u) du \right) dt \,. \tag{3}$$

Thus, choosing m_B will be similar to choosing $\overline{m}_B$, provided the value of $\overline{m}_B$ implied by (3) is nonnegative. Since debt will be retired at a constant rate in both states based on this approximation, we define the firm's average debt maturity conditional on being in state s as $M_s = 1/m_s$ $(s = G, B)$.

There is a liquid secondary market for the firm's equity, but the corporate bonds are traded in the over-the-counter market. As a result, equity prices are not affected by liquidity

[6]We examine the assumption of downward rigidity in leverage extensively in Section 2.3. Chen, Xu, and Yang (2012) present an extension of this model that captures lumpiness in the maturity structure.

shocks, while the corporate bond prices will reflect the risk of liquidity shocks and the holding costs that liquidity-constrained investors incur. We assume the holding cost per unit of time is proportional to the face value of the bond and takes the following functional form:

$$h(m,s) = h_0(s)\left(e^{h_1(s)/m} - 1\right). \tag{4}$$

Two key properties of the holding cost are: it is higher in bad times ($h(\cdot, G) < h(\cdot, B)$), and it is increasing with maturity (decreasing in m) ($h_0(s), h_1(s) > 0$).[7] The first property is quite intuitive. The second property is not necessary for the qualitative results in the model (a constant holding cost can already make the liquidity spread increase with maturity), but it helps with matching the model-implied term structure of liquidity spreads to the data.

The assumption that $h(m,s)$ increases with bond maturity is consistent with the notion that the holding cost rises with the amount of time the investor remains constrained. This is implied by dynamic models of financing constraints (e.g., Bolton, Chen, and Wang (2011)) where the marginal value of liquidity rises as the amount of financial slack dwindles over time. To see the intuition, consider the special case where the aggregate state does not change. The actual holding cost for the constrained investor is $f(\tau)$, with τ being the time the investor has spent in the constrained state, where $f(0) = 0$, $f'(\tau) > 0$. The average expected holding cost per unit of time for a constrained investor holding a bond with maturity $1/m$ is:

$$h(m) = \int_0^\infty (\lambda_C + m) e^{-(\lambda_C + m)t} \left(\frac{1}{t}\int_0^t f(u)du\right) dt.$$

It follows that $h(m)$ will be decreasing in m (increasing in maturity) given that $f' > 0$, and $\lim_{m\to\infty} h(m) = 0$, both of which are captured by (4).

Another implication of the specification for holding cost in (4) is that the holding cost as a fraction of the market value of the bond is increasing as the firm approaches default. This feature is consistent with Longstaff, Mithal, and Neis (2005), Bao, Pan, and Wang (2011), and others that find that bonds with higher default risk are more illiquid.

[7]Strictly speaking, the holding costs should also be bounded above so that the bond price is never negative. Otherwise the investor can simply abandon the bond. This will never be the case for the parameters and range of maturity considered in our quantitative exercises.

Finally, the firm's problem is to choose the optimal amount of debt to issue at time 0 (with face value P) and the optimal maturity structure for state G and B (m_G and m_B) to maximize the equity-holder value at time $t = 0$.[8] Ex post, the firm also chooses the optimal default policy in the two states. The default policy is characterized by a pair of default boundaries $\{y_D(G), y_D(B)\}$. In a given state, the firm defaults if its cash flow is below the default boundary for that state. In summary, the firm's policy for capital structure and default is characterized by the 5-tuple $(P, m_G, m_B, y_D(G), y_D(B))$.

In the remainder of this section, we first solve for the value of debt and equity given the firm policy for capital structure and default. Then we characterize the optimal firm policy.

2.2.1 Valuation of Debt and Equity

Due to the presence of uninsurable liquidity shocks, the pricing of illiquid assets such as corporate bonds differs from that of liquid assets such as stocks. We first discuss the pricing of liquid assets, and then present the analytical results for pricing debt and equity.

Risk-neutral pricing for liquid assets Under the risk-neutral probability measure implied by the SDF in (2), the firm's cash flow process has expected growth rate $\mu(s_t) = \widehat{\mu}(s_t) - \sigma_\Lambda(s_t)\eta(s_t)$ and total volatility $\sigma(s_t) = \sqrt{\sigma_\Lambda^2(s_t) + \sigma_f^2(s_t)}$. In addition, the risk-neutral transition intensities between the aggregate states are given by $\pi_G = e^{\kappa}\widehat{\pi}_G$ and $\pi_B = e^{-\kappa}\widehat{\pi}_B$. Because $\kappa > 0$, the risk-neutral transition intensity from state G to B is higher than the physical intensity, while the risk-neutral intensity from state B to G is lower than the physical intensity. Jointly, they imply that the bad state is both more likely to occur and tends to last longer under the risk-neutral measure than under the physical measure.

The value of a liquid claim on an unlevered firm, $V(y, s)$, which pays out a perpetual stream of cash flows y specified in (1) (without adjusting for taxes), satisfies a system of ordinary differential equations (ODE):

$$r(s)V(y,s) \quad = \quad y + \mu(s)yV_y(y,s) + \frac{1}{2}\sigma^2(s)y^2V_{yy}(y,s) + \pi_s\left(V(y,s^c) - V(y,s)\right), \qquad (5)$$

[8] This is based on the assumption that the firm can commit to the maturity policy (m_G, m_B) chosen at time $t = 0$. Letting equity holders choose the debt maturity ex post when the aggregate state changes will generate similar results.

where s^c denotes the complement state to state s. Its solution is $V(y,s) = v(s)y$, where the state-dependent price-dividend ratio $\mathbf{v} \equiv (v(G), v(B))$ is given by

$$\mathbf{v} \;=\; \begin{pmatrix} r(G) - \mu(G) + \pi_G & -\pi_G \\ -\pi_B & r(B) - \mu(B) + \pi_B \end{pmatrix}^{-1} \begin{pmatrix} 1 \\ 1 \end{pmatrix}. \tag{6}$$

This is a generalized Gordon growth formula, which takes into account the state-dependent riskfree rates $r(s)$ and risk-neutral expected growth rates $\mu(s)$, as well as possible future transitions between the states. In the special case with no transition between the states ($\pi_G = \pi_B = 0$), equation (6) reduces to the standard Gordon growth formula.

Debt pricing As in Leland (1998), it is convenient to directly compute the value of all the debt outstanding at time t. Its value to a type-i investor, $D(y_t, s_t, i)$ with $i \in \{U, C\}$, will be independent of t. The total debt value satisfies a system of ODEs:

$$\begin{aligned} r(s)D(y,s,i) = b - h(m_s,s)P1_{\{i=C\}} + \mu(s)yD_y(y,s,i) + \frac{1}{2}\sigma^2(s)y^2D_{yy}(y,s,i) \\ + m_s\left(P - D(y,s,i)\right) + \pi_s\left(D(y,s^c,i) - D(y,s,i)\right) + \lambda_i(s)\left(D(y,s,i^c) - D(y,s,i)\right), \end{aligned} \tag{7}$$

with boundary conditions at default:

$$D(y_D(s), s, i) = \alpha(s)v(s)y_D(s)\,, \tag{8}$$

where $v(s)$ is the price-dividend ratio in (6), and $\alpha(s)$ is the asset recovery rate in state s. Proposition 1 in Appendix A gives the analytical solution for $D(y,s,i)$.

By collecting the terms related to liquidity shocks and holding costs, we can rewrite (7) as

$$\begin{aligned} \left(r(s) + \ell(y, m_s, s, i)\right) D(y,s,i) = b + \mu(s)yD_y(y,s,i) + \frac{1}{2}\sigma^2(s)y^2D_{yy}(y,s,i) \\ + m_s\left(P - D(y,s,i)\right) + \pi_s\left(D(y,s^c,i) - D(y,s,i)\right), \end{aligned} \tag{9}$$

where

$$\ell(y, m_s, s, i) \equiv \frac{h(m_s, s)P1_{\{i=C\}} + \lambda_i(s)\left(D(y, s, i) - D(y, s, i^c)\right)}{D(y, s, i)} \tag{10}$$

can be viewed as the instantaneous liquidity spread that type-i investor applies to pricing the bond in state s. This liquidity spread is nonnegative for both types of investors (since $h(m, s) \geq 0$). It shows that the holding costs for constrained investors lower the market value of debt ex ante, which is a form of financing costs for corporate debt.

A shorter maturity (higher m) effectively reduces the duration of liquidity shocks: a constrained investor no longer incurs the holding costs once she receives the principal back at the maturity date. As a result, a bond with shorter maturity will have a lower liquidity discount, which is an important factor for firms' maturity choices.

Equity pricing Since equity is traded in a liquid secondary market, its value $E(y, s)$ will be not be affected by liquidity shocks. The payout for equity holders includes the cash flow net of interest expenses and taxes, as well as any costs associated with issuing new debt to replace retired debt. Whenever the firm issues new debt, unconstrained investors are the natural buyers with the highest valuation. Therefore, the value at which new debt is issued is the value to a type-U investor, $D(y, s, U)$. Thus, $E(y, s)$ satisfies the following ODEs:

$$\begin{aligned} r(s)E(y, s) &= (1 - \tau)(y - b) - m_s\left(P - D(y, s, U)\right) \\ &\quad + \mu(s)yE_y(y, s) + \frac{1}{2}\sigma(s)^2 y^2 E_{yy}(y, s) + \pi_s\left(E(y, s^c) - E(y, s)\right). \end{aligned} \tag{11}$$

Because equity holders recover nothing at default, the equity value upon default is:

$$E(y_D(s), s) = 0. \tag{12}$$

Proposition 1 in Appendix A gives the analytical solution for $E(y, s)$.

The first term on the right-hand side of equation (11), $(1 - \tau)(y - b)$, is the cash flow net of interest expenses and taxes. The second term, $m_s\left(P - D(y, s, U)\right)$, is the instantaneous rollover costs to equity holders. If old debt matures and is replaced by new debt issued under par value ($D(y, s, U) < P$), equity holders will have to incur extra costs for rolling over the debt. These rollover costs are a transfer from equity holders to debt holders, which can lead equity holders to default earlier. This is a classic debt overhang problem as described by Myers (1977). He and Xiong (2012) use this channel to show how debt market liquidity problems affect credit risk.

In our model, the size of rollover costs depends on firm-specific conditions, macroeconomic conditions, and debt maturity. Under poor macroeconomic conditions, low expected growth rates of cash flows, high systematic volatility, and high liquidity spreads will all drive the market value of debt lower, which raises the rollover costs. Moreover, a shorter debt maturity means that debt is retiring at a higher rate (m is large), which will amplify the rollover costs whenever debt is priced below par. Thus, if debt maturity is pro-cyclical as shown in Figure 1, the combination of short maturity, high aggregate risk premium, low cash flows, and high volatility can generate particularly high rollover costs and high default risk in bad times.

2.2.2 Optimal default and capital structure decisions

So far we have discussed the pricing of debt and equity for a given set of choices on debt level, maturity, and default boundaries $(P, m_G, m_B, y_D(G), y_D(B))$. We now characterize the optimal firm policies.

First, for a given choice of debt level and maturity, standard results imply that the ex-post optimal default boundaries for equity holders satisfy the smooth-pasting conditions:

$$E_y(y_D(s), s) = 0, \quad s \in \{G, B\}. \tag{13}$$

Next, at time $t = 0$, the firm chooses its capital structure (P, m_G, m_B) to maximize the initial value of the firm, which is the sum of the value of equity after debt issuance and the proceeds from debt issuance. Thus, the firm's objective function is:

$$\max_{P, m_G, m_B} E(y_0, s_0; P, m_G, m_B) + D(y_0, s_0, U; P, m_G, m_B)\,. \tag{14}$$

Our solution strategy is as follows. For any given capital structure and default policy summarized by $(P, m_G, m_B, y_D(G), y_D(B))$, we obtain closed-form solutions for the value of debt and equity. We then solve for the optimal default boundaries $\{y_D(G), y_D(B)\}$ for given (P, m_G, m_B) via a system of non-linear equations implied by (13). Finally, we solve for the optimal capital structure via (14).

The analysis of debt and equity pricing in Section 2.2.1 provides the key intuition for the maturity tradeoff. Shorter debt maturity leads to more frequent rollover and higher default risk, whereas longer debt maturity leads to higher liquidity discounts. This tradeoff is influenced by firms' systematic risk exposures and macroeconomic conditions. All else equal, firms with low exposures to systematic risk are less concerned about debt rollover raising default risk, because default is less costly for them. They will choose shorter maturity debt to reduce the financing costs. The opposite is true for firms with high systematic risk exposures. Thus, the model predicts that in the cross section, debt maturity increases with a firm's systematic risk exposure.

The maturity tradeoff also varies over the business cycle. On the one hand, debt rollover has a bigger impact on firm value in recessions due to higher default probabilities, higher costs of bankruptcy, and higher risk premium. These factors tend to cause all firms to lengthen their debt maturities in recessions. On the other hand, liquidity risk can rise in recessions as well (due to more frequent liquidity shocks and higher holding costs), which causes firms to shorten debt maturity. The net result on whether maturity will become longer or shorter in recessions is ambiguous. Moreover, since firms with high systematic risk exposures are affected more by higher systematic risk and risk premium, the cross-sectional relation between debt maturity and systematic risk exposure will become stronger in bad times. In Section 3, we analyze the quantitative predictions of the calibrated model.

2.3 Downward rigidity in leverage

Our model of debt maturity dynamics is an extension of Leland and Toft (1996) and Leland (1998), where firms are assumed to always roll over all the retired debt immediately. The direct implication is that the face value of debt outstanding is constant over time. More importantly, this assumption introduces downward rigidity in leverage, a key feature that enables structural credit risk models to generate significant default risk.[9]

The intuition is as follows. In the absence of other frictions, a firm that can freely adjust its debt level will reduce debt following negative shocks to cash flows. Then, as long as cash flows do not drop too quickly, the firm will be able to lower its leverage sufficiently to avoid default. By doing so, the firm can lower the costs of financial distress and still enjoy a large tax shield in good times. As Dangl and Zechner (2007) show, issuing short-term debt enables equity holders to commit to this type of downward debt adjustment. This is why it is difficult to generate significant default risk in models with one-period debt, which is well documented in models of corporate and sovereign default. Besides low default risk, models that allow downward adjustment in leverage also predict that firms with higher costs of financial distress will choose shorter debt maturity, which is opposite to what our model predicts.

The drastically different implications from the models with and without downward rigidity in leverage highlight the importance in demonstrating the validity of this assumption. Empirically, several studies have shown the difficulty for firms to adjust leverage downward. Asquith, Gertner, and Scharfstein (1994) find that factors including debt overhang, asymmetric information, and free-rider problems present strong impediments to out-of-court restructuring to reduce leverage. Gilson (1997) also shows that leverage of financially distressed firms remains high before Chapter 11. Welch (2004) finds that firms respond to poor performance with more debt issuing activity and to good performance with more equity issuing activity.

There is also evidence of downward rigidity in leverage that is directly related to debt maturity. Mian and Santos (2011) show that instead of rolling over long-term debt in bad times, credit-worthy firms draw down their credit line commitment. Effectively, these firms replace matured long-term debt with short-term debt instead of equity. We also show (see the Internet Appendix) that the speed of leverage adjustment is slow for both firms with long and short maturity. Moreover, the negative correlation between changes in cash flows and changes in book leverage (as in Welch (2004)) is even stronger for firms with shorter maturity, suggesting that firms with shorter maturity do not reduce leverage in bad times.

Theoretically, we can provide micro-foundation for the downward rigidity in leverage

[9]It is straightforward to allow firms to restructure their debt upward in this model.

by introducing frictions that make it difficult for firms to reduce leverage following poor performances. In Appendix B, we present a model that builds on Dangl and Zechner (2007) by adding equity issuance costs.[10] In the model, firms are not required to roll over the retired debt immediately, yet the downward rigidity in leverage arises endogenously. The intuition is as follows. If a firm does not roll over the retired debt, it has to pay back the existing debt holders using either internal funds or external equity. Thus, the firm will need to raise large amounts of equity precisely when the cash flows are low. A shorter debt maturity means that the firm needs to issue equity more frequently and at a faster rate. As a result, a convex equity issuance cost not only discourages firms from reducing leverage following poor performances, but also discourages the issuance of short-term debt.

As the results in Appendix B show, without equity issuance costs, this model generates very low credit spreads and a negative relation between systematic risk and debt maturity. After adding a convex equity issuance cost, the model is able to generate more realistic credit spreads and a positive relation between systematic risk and debt maturity.

Adding equity issuance costs is the first step towards explaining the downward rigidity in leverage. It is also important to understand what makes equity issuance difficult following poor performance. One possible reason is that uncertainty rises following poor performance, which makes the information asymmetry more severe and raises the costs of issuing equity (Myers and Majluf (1984)). We leave this question to future research.

3 Quantitative Analysis

In this section, we examine the quantitative implications of the model. We first describe the calibration procedure. Then we examine the optimal maturity choice in the cross section and over the business cycle. Finally, we examine the impact of maturity dynamics on the term structure of credit spreads.

[10]We thank an anonymous referee for suggesting this model.

3.1 Calibration

We set the transition intensities for the aggregate states of the economy to $\widehat{\pi}_G = 0.1$ and $\widehat{\pi}_B = 0.5$, which imply that an expansion is expected to last for 10 years, while a recession is expected to last for 2 years. To calibrate the stochastic discount factor, we choose the riskfree rate $r(s)$, the market prices of risk for Brownian shocks $\eta(s)$, and the market price of risk for state transition κ to match the first two moments of their counterparts in the SDF in Chen (2010).

Similarly, we calibrate the expected growth rate $\widehat{\mu}(s)$ and systematic volatility $\sigma_\Lambda(s)$ for the benchmark firm based on Chen (2010), which in turn are calibrated to the corporate profit data from the National Income and Product Accounts. The annualized idiosyncratic cash flow volatility of the benchmark firm is fixed at $\sigma_f = 23\%$. The bankruptcy recovery rates in the two states are $\alpha(G) = 0.72$ and $\alpha(B) = 0.59$. The cyclical variation in the recovery rate has important effects on the ex ante bankruptcy costs. The effective tax rate is set to $\tau = 0.2$. To define model-implied market betas and use them as a measure of firms' systematic risk exposures, we specify the dividend process for the market portfolio to be a levered-up version of the cash-flow process (1) absent idiosyncratic shocks. We choose the leverage factor so that the unlevered market beta for the benchmark firm is 0.8, the medium asset beta for U.S. public firms.

In our model, transactions in the secondary bond market occur when a liquidity-constrained investor meets with an unconstrained investor. Conditional on the aggregate state s, a fraction $\lambda_U(s)/(\lambda_U(s)+\lambda_C(s))$ of the investors are constrained on average, so that $\lambda_C(s)\lambda_U(s)/(\lambda_U(s)+\lambda_C(s))$ is the model-implied bond turnover rate. For calibration, we pick $\lambda_U(s)$ so that the idiosyncratic liquidity shock arrives 1.5 times per year during expansions and 3 times per year in recessions, and choose the intermediation intensity $\lambda_C(s)$ such that the bond turnover rate is 10% (5%) per month during expansions (recessions) based on the findings from Bao, Pan, and Wang (2011).[11]

[11] It is possible that a large part of the bond trading in good times is not due to liquidity shocks, in which case our calibration procedure would overstate $\lambda_C(G)$. However, since we calibrate the holding costs for constrained investors to match the observed liquidity spreads for corporate bonds, the impact of less frequency liquidity shocks will be largely offset by higher holding costs. See Appendix C for details.

Finally, we calibrate the four holding cost parameters $h_0(s), h_1(s)$ in equation (4) by matching the term structure of model-implied bond liquidity spreads with the data. We follow the procedure of Longstaff, Mithal, and Neis (2005) to estimate the non-default components in corporate bond spreads at different maturities, which are shown to be largely related to liquidity. We use bond price data from the Mergent Fixed Income Securities Database and CDS data from Markit for the period from 2004 to 2010. To address the possible selection bias that firms facing higher long-term non-default spreads might only issue short-term debt, we restrict the sample to firms that issue both short-term (less than 3 years) and long-term (longer than 7 years) straight corporate bonds. Details of the procedure are in Appendix C.

The short sample period (due to the availability of CDS data) makes it difficult to identify different holding cost parameters for state G and B. There is only one NBER recession in our sample (from December 2007 to June 2009), which is also the period of a major financial crisis. The average liquidity spreads for bonds with maturities of 1, 5, and 10 years are 0, 4, and 12 bps during normal times and rise to 1, 65, and 145 bps respectively during the crisis. Since state B in our model represents a typical recession rather than a financial crisis, we calibrate the baseline holding cost parameters to match the full liquidity spreads in normal times and one third of the liquidity spreads in the financial crisis. Since this choice of calibration target for recessions is admittedly ad hoc, we have also conducted sensitivity analysis to show the robustness of our results to the holding cost parameters (see the Internet Appendix).

A firm's choice of leverage and maturity structure implies a particular term structure of credit spreads. To compute the term structure of credit spreads, we take the firm's optimal default policy (default boundaries) as given and price fictitious bonds with a range of different maturities. These bonds are assumed to default at the same time as the firm, and their recovery rate is set to 44% in state G and 20% in state B, which is consistent with the business-cycle variation in bond recovery rates in the data (see Chen (2010)).

Panel A of Table 1 summarizes the parameter values for our baseline model.

3.2 Maturity Choice

The main results for the capital structure and default risk of the benchmark firm are summarized in Panel B of Table 1. We assume that the firm makes its optimal capital structure decision in state G with initial cash flow normalized to 1. The initial market leverage is 28.5% in state G. Fixing the level of cash flow, the same amount of debt will imply a market leverage of 31.6% in state B due to the fact that equity value drops more than debt value in recessions. The initial interest coverage (y_0/b) is 2.68. The optimal maturity is 5.5 years for state G and 5.0 years for state B. Based on our interpretation of maturity adjustment in equation (3), $m_B = 1/5$ corresponds to $\overline{m}_B = 0.31$. That means the firm will be replacing its 5.5-year debt that retires in state B with new 3.3-year debt.

The model-implied 10-year default probability is 4.2% in state G conditional on the initial cash flow and leverage choice. Fixing the cash flow and leverage but changing the aggregate state from G to B raises the 10-year default probability to 5.6%. The 10-year total credit spread is 115.2 bps in state G and 166.2 bps in state B (again based on initial cash flow and leverage). The default components of the 10-year spreads, which are computed by pricing the bonds using the same default boundaries and removing the liquidity shocks and holding costs, are 97.7 bps in state G and 135.2 bps in state B. These values are consistent with the historical average default rate and credit spread for Baa-rated firms. Finally, the conditional equity Sharpe ratio is 0.12 in state G and 0.22 in state B.

Next, we study how systematic risk affects firms' maturity structures. As discussed at the end of Section 2.2, the tradeoff for debt maturity is as follows. On the one hand, shorter debt maturity generates higher default risk and hence higher expected costs of default. On the other hand, long-term debt has higher liquidity spreads, which raises the cost of debt financing. Since an analytical characterization of the optimal maturity choice is not feasible in this model, we provide the intuition using a numerical example from the calibrated model.

Consider two firms with identical leverage but different levels of systematic volatility of cash flows. In Panels A and B of Figure 2, we plot the annualized liquidity spreads associated with different debt maturity in the two aggregate states. In Panels C and D, we plot the annualized default rates over a 10-year horizon. Within each aggregate state, the liquidity

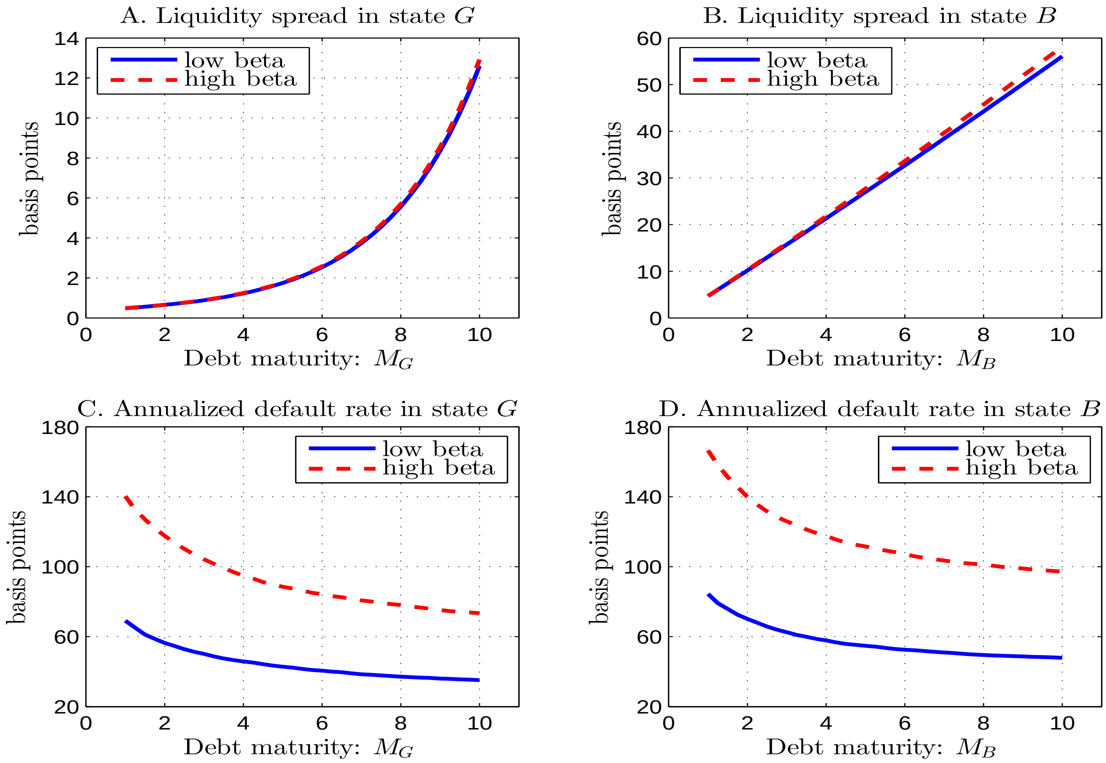

Figure 2: Debt maturity tradeoff. Panels A and B plot the model implied liquidity spreads in state G and B. For each state s, the liquidity spreads are defined as $\lambda_U(s)\left[D(y_0, s, U) - D(y_0, s, C)\right]/D(y_0, s, U)$ and computed at the initial cash flow level. Panels C and D plots the annual default rate in the next 10 years conditional on the initial aggregate state G and B. The low beta firm is the benchmark firm with asset beta of 0.8. The high beta firm has an asset beta of 1.08 by rescaling the systematic cash flow volatilities of the benchmark firm.

spread increases with debt maturity while the default rate decreases with maturity. Holding the maturity fixed and increasing the systematic risk exposure has negligible effect on the liquidity spreads (see Panels A and B), but it significantly raises the default risk, especially for short-term debt and especially in state B (see Panels C and D). These results imply that as a firm's systematic risk exposure rises, concern about default risk will cause it to choose longer debt maturity. Moreover, debt maturity will be more sensitive to systematic risk exposure in state B because default risk rises faster with asset beta in that state. Finally, because both the liquidity spread and default risk rise in state B, the net effect of a change of aggregate state on debt maturity is ambiguous.

We now examine the quantitative predictions of the model. To generate firms with

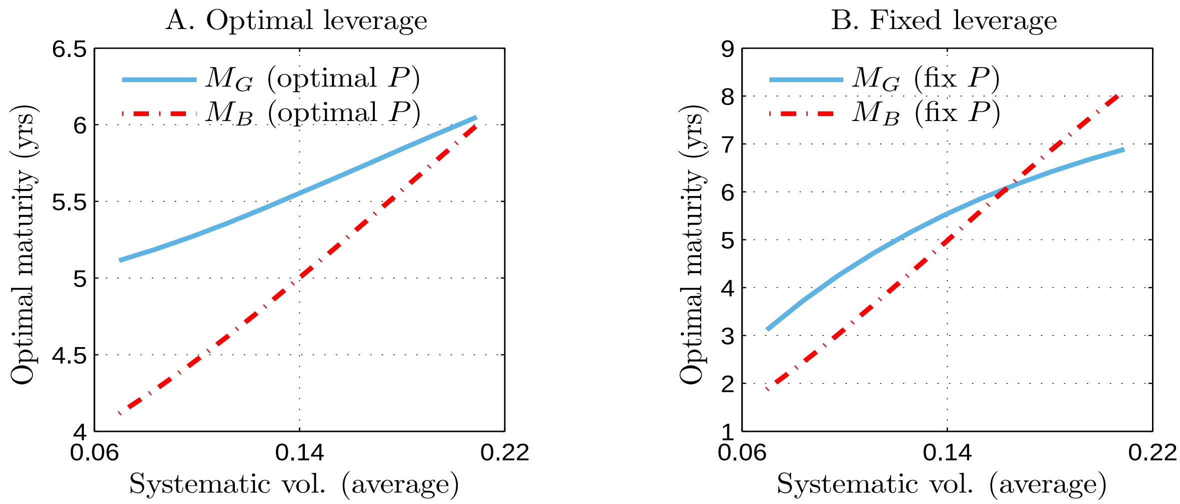

Figure 3: Optimal debt maturity. In Panel A, we hold fixed the idiosyncratic volatility of cash flow while letting the systematic volatility vary and then plot the resulting choices of the optimal average maturity in the two states under optimal leverage. In Panel B, we repeat the exercise but hold leverage fixed at the level of the benchmark firm. The benchmark firm has an average systematic volatility of 0.139 and asset beta of 0.8.

different cash flow betas, we rescale the systematic volatility of cash flows $(\sigma_\Lambda(G), \sigma_\Lambda(B))$ for the benchmark firm while keeping the idiosyncratic volatility of cash flows σ_f unchanged. We first examine the case where leverage is chosen optimally for each firm, and then the case where leverage is held constant across firms.

Figure 3 shows the results. Indeed, as Panel A shows, controlling for the idiosyncratic cash-flow volatility, the optimal debt maturity increases for firms with higher systematic volatility, and the relationship is stronger in state B than in state G. As the average systematic volatility rises from 0.07 to 0.21, the optimal maturity in state G rises from 5.1 to 6.1 years, whereas the maturity in state B rises from 4.1 to 6.0 years.

The graph also shows that the optimal debt maturity drops from state G to state B for the same firm. This result does depend on the differences of liquidity frictions in the two states. Because firms are more concerned with rollover risk in bad times, they will only reduce debt maturity if the liquidity frictions become sufficiently more severe in state B. However, the result of pro-cyclical maturity choice appears robust quantitatively. Even though we have chosen a relatively conservative target for the liquidity spread in state B (one third of the liquidity spreads in the financial crisis), it is enough to make maturity drop in recessions. The combined effect of (1) pro-cyclical maturity choice and (2) higher sensitivity of debt maturity to systematic volatility in recessions is that the debt maturity for firms with high systematic risk will be relatively stable over the business cycle, while the maturity for firms with low systematic risk will be more volatile.

Next, instead of allowing firms with different systematic risk to choose leverage optimally, we fix the leverage for all firms at the same level as the benchmark firm and re-examine the maturity choice. The results, shown in Panel B of Figure 3, are qualitatively similar. However, debt maturity in this case increases faster with systematic volatility in both state G and B. For firms with sufficiently high systematic risk exposures, the debt maturity in state B can become even higher than the maturity in state G, indicating that these firms roll their maturing debt into longer maturity in recessions.

Why does the optimal debt maturity become more sensitive to systematic risk after controlling for leverage? Because of higher expected costs of financial distress, firms with high systematic risk exposures will optimally choose lower leverage. By fixing their leverage at the level of the benchmark firm, firms with high systematic volatility end up with higher leverage than the optimal amount. As a result, it becomes more important for these firms to use long-term debt to reduce rollover risk, especially in bad times.

3.3 Maturity Dynamics and Credit Risk

So far we have analyzed how systematic risk and liquidity frictions affect the maturity dynamics over the business cycle. Existing structural credit risk models mostly consider the setting of time-invariant maturity structures (many of them only consider perpetual debt), yet it is quite intuitive that these maturity dynamics can have significant impact on credit risk at different horizons and over the business cycle. The way maturity dynamics affect default risk hinges on the endogenous responses of the firms, which are difficult to capture using reduced-form models. Our structural model provides a tractable framework to analyze these effects. We focus the analysis on the following questions.

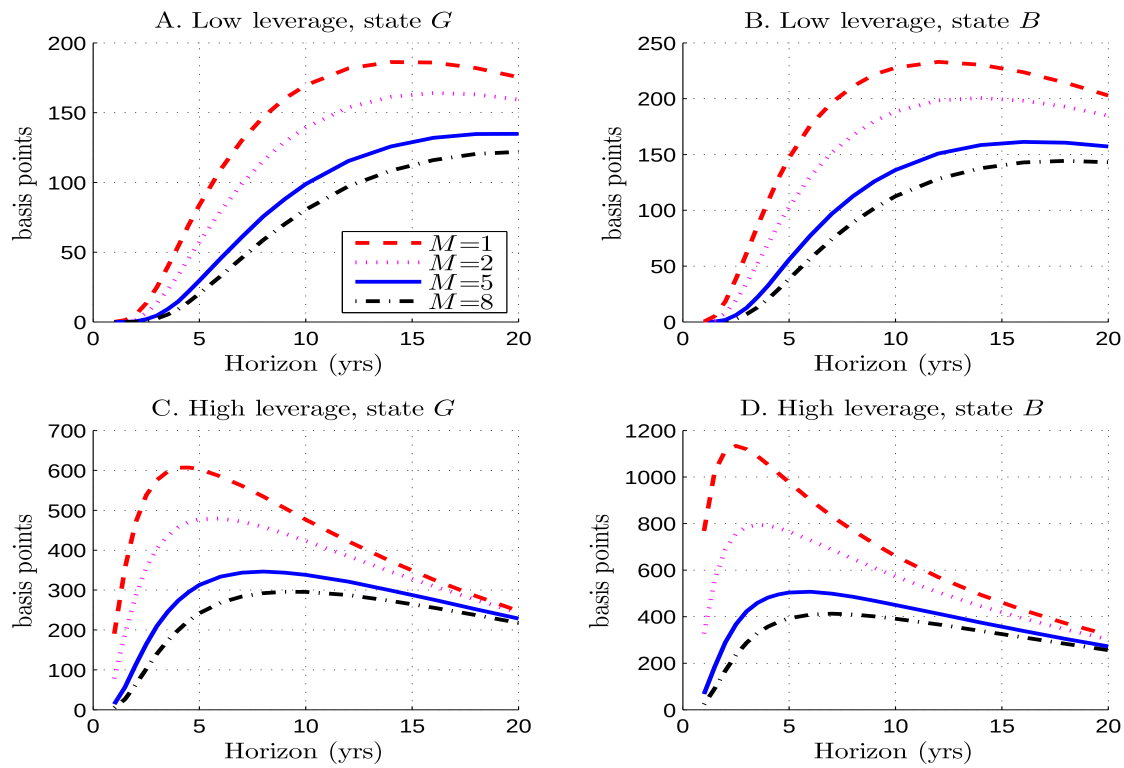

Figure 4: Maturity choice and the term structure of credit spreads. This figure plots the term structure of credit spreads as debt maturity choice varies. Debt maturity choice is fixed across states so that $M_G = M_B = M$. In Panels A and B, the firm's initial interest coverage is fixed at 2.68. In Panels C and D, the firm's initial interest coverage is fixed at 1.34.

(i) How sensitive is the term structure of credit spreads to the level of debt maturity? We fix the maturity to be the same in the two aggregate states ($M_G = M_B$) so that we can separate the effect of maturity dynamics from that of maturity level. We then compute the term structure of credit spreads in state G and B for a range of maturity choices. We are also interested in how maturity effect differs for firms with different leverage.[12] Thus, we first set the firm's interest coverage (y/b) at the optimal leverage of the benchmark firm (low leverage firm), and then repeat the exercise for a firm with half the interest coverage (high leverage firm), which can result from the original low leverage firm experiencing a sequence of negative cash flow shocks.

The results are shown in Figure 4. Panels A and B show the term structure of credit

[12]Our model can be used to study the credit risk of firms under a range of different capital structure choices, not just the optimal capital structure implied by the tradeoff we consider. Firms in practice have significant heterogeneity. Their capital structures can vary substantially due to transaction costs and other frictions.

spreads for the low leverage firm in state G and B. The credit curve is mostly upward sloping. Shortening the maturity increases the level of credit spreads at all horizons, but the effect is rather small at the 1 to 2 year horizon[13] and bigger at medium-to-long horizons (8 to 12 years). Moreover, the incremental effect of shorter maturity on credit spreads is nonlinear. By cutting maturity from 8 to 5 years, credit spreads rise by up to 18 bps in state G and 24 bps in state B; from 5 to 2 years, the increases in spreads are up to 41 bps and 55 bps; from 2 to 1 years, the increase in spreads are up to 31 bps and 46 bps.

For the firm with higher leverage, its credit curve will still be largely upward-sloping (except at the long horizons) if its average maturity is 8 years. The downward-sloping feature becomes more prominent as the maturity shortens. Unlike the low-leverage firm where shortening the maturity mostly affects credit spreads at the medium to long horizons, here the effect is the largest at short horizons (2 to 5 years), especially when the macroeconomic conditions are poor (in state B). Moreover, the size of the impact of debt maturity on credit spreads is larger for the high-leverage firm. Cutting the maturity from 5 to 2 years raises the credit spreads by up to 195 bps in state G and up to 400 bps in state B.

It is well known that structural models can generate an upward-sloping term structure of credit spreads for low-leverage firms and downward-sloping term structure for high-leverage firms. The new finding in our model is that maturity choice also has first order effect on the shape of the credit curve. Moreover, the maturity effect is nonlinear and is magnified by poor macroeconomic conditions and high leverage.

The previous analysis shows that credit spreads are counter-cyclical (i.e., higher in recessions) with constant maturity across states G and B. As equation (11) shows, if debt is already priced below par in recessions ($D(y, B, U) < P$), the fact that maturity is shorter at such times (m_B is larger) will make the rollover costs higher for equity holders, which makes default more likely and further increases the credit spreads in state B.

(ii) How much can the pro-cyclical variation in debt maturity amplify the fluctuations in credit spreads over the business cycle? To answer this question, we conduct

[13] Part of the reason is that the diffusion assumption for cash flows mechanically implies very little default risk at the shortest horizons (see Duffie and Lando (2001)). The fact that our model has additional shocks to the aggregate state alleviates this problem to some extent, especially for firms with high leverage.

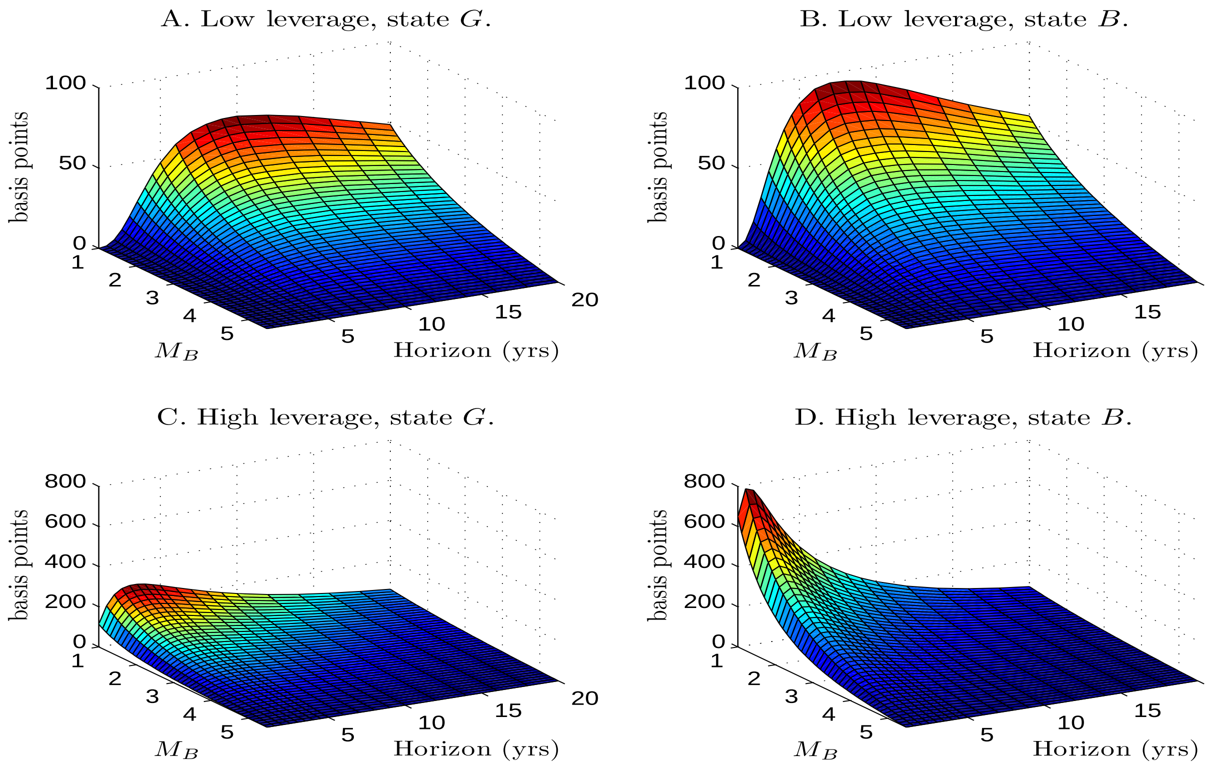

Figure 5: The amplification effect of pro-cyclical maturity on credit spreads. This figure plots the *differences* in the term structure of credit spreads between firm X with constant debt maturity $M_G = M_B = 5.5$ years and firm Y with $M_G = 5.5$ years but $M_B \leq M_G$. In Panels A and B, the initial interest coverage is 2.68. In Panels C and D, the initial interest coverage is 1.34.

the following difference-in-difference analysis. Let $CS^i(\tau, s)$ be the credit spread in state s at horizon τ for firm i. Now consider two firms: firm X has constant maturity $M_G = M_B = 5.5$; firm Y has the same maturity as X in state G, but shorter maturity in state B. As we lower M_B for firm Y, not only will its credit spreads rise in state B, they will also rise in state G due to the anticipation effect. Thus, the pro-cyclical maturity variation amplifies the fluctuations in credit spreads over the business cycle if the differences in credit spreads between the two firms are larger in state B than in state G,

$$CS^Y(\tau, G) - CS^X(\tau, G) < CS^Y(\tau, B) - CS^X(\tau, B). \tag{15}$$

Figure 5 shows the results of this analysis. In Panels A and B, we plot the differences in credit spreads between the two firms X, Y in the two aggregate states (i.e., the left and right-hand side of inequality (15)), where M_B for firm Y ranges from 5.5 years to 1 year. In Panels C and D, we do the same calculations for the two firms with higher leverage.

For any $M_B < 5.5$, firm Y has higher credit spreads than firm X at all horizons. Comparing Panel A vs. B, we do see larger differences in credit spreads between the two firms in state B, suggesting that pro-cyclical maturity dynamics indeed amplify the variation in credit spreads over the business cycle. For example, with $M_B = 2$, the credit spread of firm Y is as much as 39 bps higher than firm X in state G, and 52 bps higher in state B. With higher leverage, the amplification effect can become much stronger (see Panels C and D). When firm Y's maturity drops from 5.5 years to 5.0 years, the credit spread can rise by up to 12 bps in state G and 25 bps in state B. If firm Y's average maturity in state B drops to 1 year, credit spreads rise by up to 283 bps in state G, and by up to 782 bps in state B.

Given that the magnitude of the amplification effect is sensitive to the size of the drop in maturity, it is important to understand the mechanisms that lead to large changes in maturity from state G to B. Revisiting the mechanics for how debt maturity is adjusted in Section 2.2, we see that the average maturity will become shorter in state B if the firm rolls the retired debt into new debt with shorter maturity, and if the bad state is more persistent. For example, consider the cases where the average debt maturity falls from 5.5 years to 3 years or 1 year in state B. Based on the interpretation of maturity adjustment in equation (3) and our calibration of the transition intensities, $m_B = 1/3$ corresponds to $\overline{m}_B = 1.2$, meaning the retired bonds are rolled into new bonds with maturity of 10 months, while $m_B = 1$ corresponds to $\overline{m}_B = 5.7$ or approximately a maturity of 2 months. Alternatively, lumpy maturity structures can also lead to big maturity adjustments over the business cycle (see Choi, Hackbarth, and Zechner (2012) and Chen, Xu, and Yang (2012)).

Another interesting observation is that while the amplification effect of pro-cyclical maturity dynamics is the largest at the medium horizon (5-7 years) for the low leverage firm, it becomes the largest at the short end of the credit curve (1-3 years) for the high leverage firm. The intuition is as follows. With low leverage, the firm faces low default risk. In this case, especially in the near future, newly issued debt will be priced close to par value. Thus, there is no debt overhang problem, and more frequent rollover will not raise the burden for equity holders. As a result, the increase in credit spreads due to shorter maturity is negligible at the short end of the credit curve. In contrast, the impact of shorter maturity on default risk immediately shows up in the case of high leverage, because the newly issued bonds are priced under par already.

(iii) How much can maturity management help firms reduce the impact of a crisis episode on credit risk? Almeida, Campello, Laranjeira, and Weisbenner (2011) find that those firms with more long-term debt coming due in the 2008 financial crisis suffered deeper cuts in investment during the crisis because of the difficulty in rolling over their debt. Hu (2010) uses the same empirical strategy to identify firms facing higher rollover risk and finds that these firms experienced larger increases in credit spreads.

Our model can capture such maturity dynamics in a "crisis" episode. Suppose a financial crisis completely shuts down the demand for long-term debt and firms can only roll over matured debt into one year debt (i.e., $\overline{m}_B = 1$). Then, a firm's average debt maturity in state B will be fully determined by the average maturity in state G and the average duration of the crisis (see equation (3)). In particular, if a firm chooses a longer average maturity (smaller m_G) before entering the crisis, it will have a smaller fraction of total debt maturing during the crisis, which implies a smaller reduction in the average maturity.

To quantify this effect, we conduct another difference-in-difference analysis. Again consider two firms X and Y. Suppose firm X has a longer average maturity in state G than firm Y, $M_G^X > M_G^Y$. The impact of the "crisis" on credit spreads can be measured as the change in credit spreads from state G to state B, everything else equal. A longer maturity before the crisis reduces the impact of the rollover risk on credit risk if

$$CS^Y(\tau, B) - CS^Y(\tau, G) > CS^X(\tau, B) - CS^X(\tau, G). \tag{16}$$

We present the results of this analysis in Figure 6. Panels A and B consider the cases of low leverage and high leverage, respectively. In each panel, we consider 4 firms with different average maturity in state G, with $M_G = 1, 2, 5, 8$ years and plot the changes in credit spreads for each of them when the aggregate state changes from G to B. Indeed, maturity

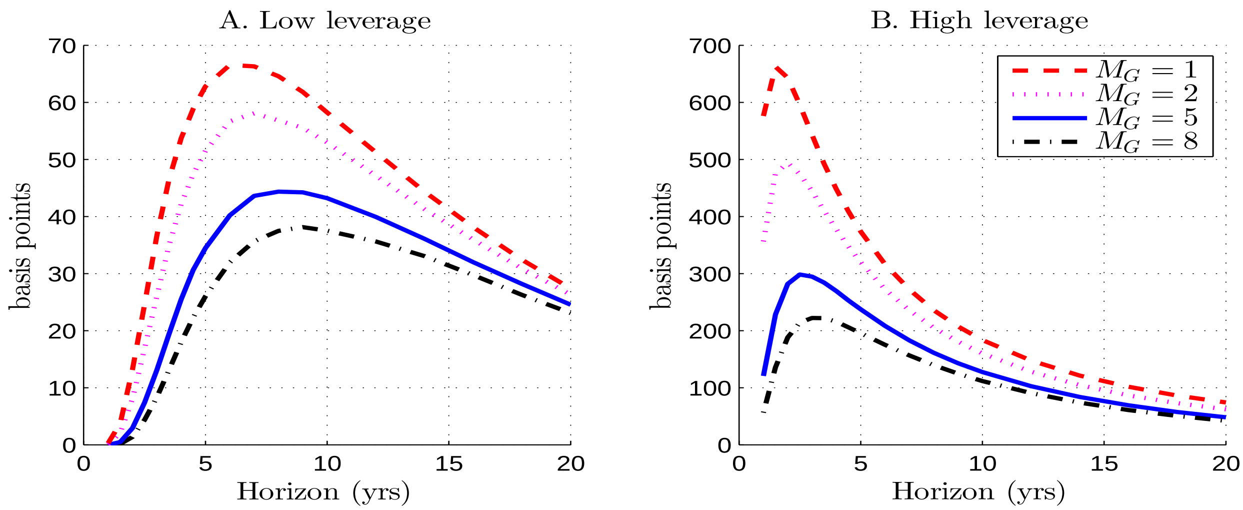

Figure 6: Maturity and rollover risk. This figure plots the *changes* in credit spreads when the aggregate state switches from G to B for an initial debt maturity ranging between $M_G = 1$ and $M_G = 8$ in state G. For each choice of M_G, the effective average maturity in state B is calculated using expression (3) with newly issued debt in state B maturing at rate $\overline{m}_B = 1$. The initial interest coverage is 2.68 for the low leverage firms, 1.34 for the high leverage firms.

management in state G matters for firms' credit risk exposure to the crisis. In the case of a low leverage firm, having an average maturity of 8 years before the crisis helps cap the impact of the crisis on credit spreads at 38 bps, while an otherwise identical firm with an average maturity of 1 year will experience an increase in the credit spreads that is almost twice as large (up to 67 bps).

In the case of the high leverage firm, maturity management becomes even more important. With an average maturity of 8 years before the crisis, the firm's credit spreads rise by as much as 220 bps entering the crisis state. An otherwise identical firm with an average maturity of 1 year will experience three times as large an increase in its credit spreads (up to 660 bps). Moreover, maturity management is particularly effective in reducing the credit risk at short horizons for a high leverage firm. Besides for firms with high leverage, we also find a stronger effect of maturity management for firms with high cash flow betas.

How can a firm avoid being caught with short average maturity entering into a crisis? The answer is not only to issue longer-term debt, but also to maintain a long average maturity over time. The latter requires the firm to evenly spread out the timing of maturity of its

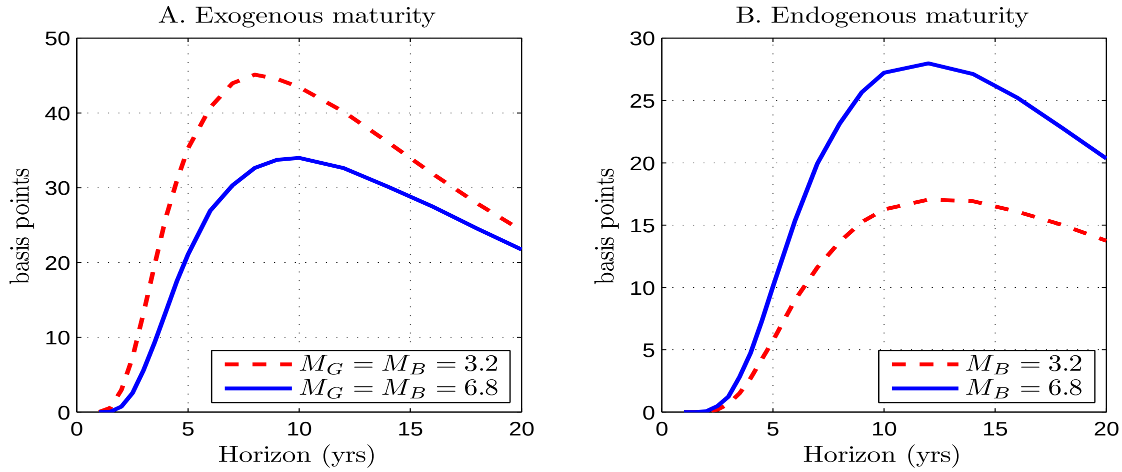

Figure 7: Credit spread changes under exogenous vs. endogenous maturity choice. This figure plots the *increase* in credit spreads at various horizons when the aggregate state switches from G to B for different firms. In Panel A, the two firms have the same systematic risk exposures but are given different debt maturity choice exogenously. In Panel B, the two firms endogenously choose different maturity structure due to differences in systematic risk.

debt rather than having a lumpy maturity structure.

(iv) How does the endogenous maturity choice affect the cross-sectional relation between debt maturity and rollover risk? The results from the previous exercise are consistent with the standard intuition that shorter maturity makes the impact of aggregate shocks on credit spreads stronger. However, this is under the condition that the firms have identical systematic risk exposures. In reality, the impact of aggregate shocks on credit risk will also depend on firms' systematic risk exposures, which as we have shown in Section 3.2, endogenously influence the firms' maturity choices in the first place.

We illustrate this point using a simple example in Figure 7. In Panel A, we take two firms with identical asset beta (the same as the benchmark firm), but fix their debt maturity exogenously at 6.8 years and 3.2 years, respectively. In Panel B, we identify two firms with different systematic volatility (but the same average total volatility), which leads them to choose different debt maturities endogenously. One firm has an average systematic volatility of 18.9% (asset beta of 1.08) and sets its debt maturity in state B optimally at 6.8 years. The other has an average systematic volatility of 8.9% (asset beta of 0.52) and sets its maturity in state B at 3.2 years. The leverage for all the firms are fixed at the same level as the benchmark firm. The figure plots the change in credit spreads from state G to B, which measures the response of the credit spreads to the aggregate shock. Panel A shows that, with exogenous maturity, the credit spread rises more for the firm with shorter maturity, which is consistent with the standard intuition of rollover risk. In Panel B, however, the firm with longer maturity actually has a bigger increase in credit spreads than the one with shorter maturity because of its larger exposure to systematic risk.

4 Empirical Evidence

In this section, we test the following predictions that the model generates about the relations between firms' systematic risk, debt maturity, and credit risk:

1. Firms with higher systematic risk exposures will choose longer debt maturity.
2. The sensitivity of debt maturity to systematic risk exposure becomes stronger after controlling for leverage.
3. The sensitivity of debt maturity to systematic risk exposure rises in times of higher risk premium.
4. A longer average maturity before entering into a crisis helps reduce the impact of the crisis on credit spreads. This effect of maturity management is stronger for firms with higher leverage or high systematic risk.

4.1 Data

We merge the data from COMPUSTAT annual industrial files and the CRSP files for the period 1974 to 2010.[14] We exclude financial firms (SIC codes 6000-6999), utilities (SIC codes 4900-4999), and quasi-public firms (SIC codes greater than 8999), whose capital structure decisions can be subject to regulation. In addition, we require firms in our sample to have total debt that represents at least 5% of their assets.[15] All the variables are winsorized at

[14] COMPUSTAT first begins to report balance sheet information used to construct our proxies for debt maturity in 1974.

[15] Lowering the threshold to 3% generates very similar results.

the 1% and 99% level. Finally, we remove firm-year observations with extreme year-to-year changes in the capital structure, defined as having changes in book leverage or long-term debt share in the lowest or highest 1%, which are likely due to major corporate events such as mergers, acquisitions, and spin-offs.

For each firm, COMPUSTAT provides information on the amount of debt in 6 maturity categories: debt due in less than 1 year (*dlc*), in years two to five (*dd*2, *dd*3, *dd*4, and *dd*5), and in more than 5 years. Following existing studies (see e.g., Barclay and Smith (1995), Guedes and Opler (1996), and Stohs and Mauer (1996)), we construct the benchmark measure of debt maturity using the long-term debt share, which is the percentage of total debt that are due in more than 3 years (*ldebt3y*). For robustness, we also construct several alternative measures of debt maturity, including the percentage of total debt due in more than n years (*ldebtny*), with $n = 1, 2, 4, 5$, and a book-value weighted numerical estimate of debt maturity (*debtmat*), based on the assumption that the average maturities of the 6 COMPUSTAT maturity categories are 0.5 year, 1.5 years, 2.5 years, 3.5 years, 4.5 years, and 10 years.

Our primary measure of firms' exposure to systematic risk is the asset market beta. Since firm asset values are not directly observable, we follow Bharath and Shumway (2008) and back out asset betas from equity betas based on the Merton (1974) model. Equity betas are computed using past 36 months of equity returns and value-weighted market returns.[16] In this process, we also obtain the systematic and idiosyncratic asset volatilities (*sys assetvol* and *id assetvol*). Following Acharya, Almeida, and Campello (2012), we also compute the "asset bank beta," which measures a firm's exposure to a banking portfolio, and the "asset tail beta," which captures a firm's exposure to large negative shocks to the market portfolio.

The various asset betas constructed above could be mechanically related to firms' leverage, which might affect firms' maturity choices. We address this concern by using two additional measures of systematic risk exposure. First, we compute firm-level cash flow betas using rolling 20-year windows. The cash flow beta is defined as the covariance between firm-level and aggregate cash flow changes (normalized by total assets from the previous year) divided by the variance of aggregate cash flow changes. Second, Gomes, Kogan, and Yogo (2009)

[16]Computing equity betas with past 12 or 24 months of equity returns generates similar results.

show that demand for durable goods is more cyclical than for nondurable goods and services. Thus, durable-good producers are exposed to higher systematic risk than non-durables and service producers. They classify industries into three groups according to the durability of a firm's output. We use their classification as another measure of systematic risk exposure.

Previous empirical studies find that debt maturity decisions are related to several firm characteristics, including firm size (log market assets, or $mkat$), abnormal earnings ($abnearn$),[17] book leverage ($bklev$), market-to-book ratio ($mk2bk$), asset maturity ($assetmat$), and profit volatility ($profitvol$). We control for these firm characteristics in our main regressions.

Table 2 provides the summary statistics for the variables used in our paper. The detailed descriptions of these variables are in the Internet Appendix. The median firm has 85% of the debt due in more than 1 year, 58% due in more than 3 years, and 32% due in more than 5 years. There is also considerable cross-sectional variation in debt maturity. The standard deviation of the long-term debt share $ldebt3y$ (the percentage of debt due in more than 3 years) is 32%, and the interquartile range of $ldebt3y$ is from 27% to 79%. Based on our numerical measure of debt maturity, the median debt maturity is 4.7 years, with an interquartile range from 2.5 years to 6.8 years. The median book leverage in our sample is 27%. The median asset market beta is 0.80, whereas the median equity beta is 1.07. The median systematic and idiosyncratic asset volatilities are 12% and 30%, respectively. The correlations among the different risk measures are reported in Panel B of Table 2.

4.2 Debt Maturity

4.2.1 Debt maturity in the cross section

To test the model's prediction on a positive relation between debt maturity and systematic risk exposures across firms, we run Fama-MacBeth regressions with the following general specification:

$$ldebt3y_{i,t} = \alpha + \beta_1 risk_{i,t} + \beta_2 X_{i,t-1} + \varepsilon_{i,t}, \tag{17}$$

[17]Following Barclay and Smith (1995), we define "abnormal earnings" as the change in earnings from year t to $t+1$ normalized by market equity at the end of year t.

where $ldebt3y$ is the long-term debt share; $risk_{i,t}$ represents various measures of firms' systematic risk exposures; $X_{i,t}$ represents firm-specific controls, including total asset volatility ($assetvol$), market assets ($mkat$), abnormal earnings ($abnearn$), book leverage ($bklev$), market-to-book ratio ($mk2bk$), asset maturity ($assetmat$), and profit volatility ($profitvol$).

The results are presented in Table 3. We compute robust t-statistics using Newey-West standard errors with 2 lags, except in the case of cash flow beta, where we use 20 lags. The coefficient of the asset market beta in column (1) is positive but insignificant in the univariate regression. After controlling for asset volatility, asset market beta becomes significantly positively correlated with debt maturity (column (2)). The coefficient estimate of 0.084 implies that a one-standard deviation increase in asset beta, keeping total asset volatility constant, is associated with a 5.4% increase in the long-term debt share. Consistent with our model prediction, the effect of asset beta on debt maturity further strengthens to 0.104 after controlling for book leverage (column (3)), implying that a one-standard deviation increase in asset beta raises the long-term debt share by 6.6%. The coefficient estimate on asset volatility is negative and statistically significant, which is consistent with Barclay and Smith (1995), Guedes and Opler (1996), and Stohs and Mauer (1996).

In the cross section, holding asset beta fixed while changing total asset volatility is equivalent to holding systematic volatility fixed while changing idiosyncratic volatility. Our results show that the negative effect of asset volatility on debt maturity as documented by the earlier studies is driven by the negative relation between idiosyncratic volatility and maturity (see column (4)). This result is consistent with the theory of debt maturity based on information asymmetries (see Diamond (1991), Flannery (1986)). Asymmetric information is more naturally associated with firm-specific uncertainty than aggregate uncertainty (managers are unlikely to know more about the market than outside investors), and firms with higher idiosyncratic risk choose shorter debt maturity to signal their quality. It is also intuitive that controlling for asset volatility is key to finding a significant effect for asset beta. Firms with high asset beta will tend to have higher idiosyncratic volatility, which offsets the effect of systematic volatility on debt maturity.

In column (5), we introduce other firm controls into the regression. The coefficient estimate of the asset market beta is 0.052, smaller than the previous specifications but still highly significant. The smaller coefficient could be due to the fact that firm characteristics such as size and book-to-market ratio are also related to systematic risk. The coefficient on asset volatility becomes much smaller than before, which is because firm controls such as size and profit volatility are highly correlated with idiosyncratic asset volatility.

Columns (6) - (8) report regression results when we replace asset market beta with asset bank beta, asset tail beta, and cash flow beta, respectively. The coefficient estimates on these alternative systematic risk measures are all positive and statistically significant. They imply that a one-standard deviation increase in a firm's corresponding beta measure lengthens its long-term debt share by 2.4%, 2.7%, and 1.0%. Column (9) reports the results when we use the industry classification for producers of durable goods, nondurable goods, and services as proxy for systematic risk exposure. Since this classification is fixed over time, we run a single cross-sectional regression in this case. The results show that the long-term debt share of durable good producers, which have more cyclical cash flows, is 2.3% larger than that of non-durable good producers, and 3.2% larger than that of service producers.

Table 4 reports the results for pooled regressions, where we add year dummies to absorb time-specific effects, and industry dummies (3-digit SIC code) to control for industry fixed-effects. We compute the standard errors by clustering the observations at the industry level.[18] The results for the pooled regressions are quantitatively similar to the Fama-MacBeth regressions and are in support of the model prediction that debt maturity is increasing in firms' systematic risk exposures.

Besides systematic risk measures, the effects of various other firm characteristics on maturity are consistent with earlier studies. Everything else equal, firms with low total asset volatility, large size, high leverage, low market-to-book ratio, long asset maturity, and low profit volatility are more likely to have longer debt maturity.

To further investigate how the cross-sectional relation between debt maturity and systematic risk changes over time, we plot in Figure 8 the time series of the coefficients on the systematic and idiosyncratic volatilities from specification (4) in Table 3. The 95% confidence

[18]We obtain very similar results adjusting standard errors by clustering the observations in the same industry and in the same year.

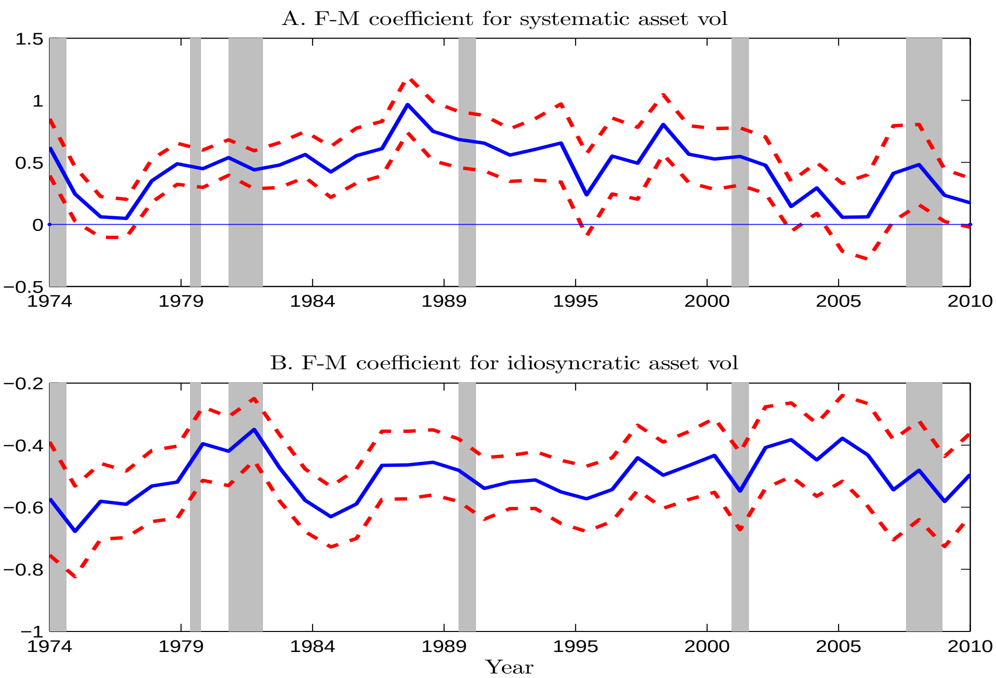

Figure 8: Time series of Fama-MacBeth coefficients for systematic and idiosyncratic volatility. This graph plots time series of coefficient estimates in a cross-sectional regression of long-term debt shares on systematic and idiosyncratic asset volatility. The confidence intervals are at 95% level. The shaded areas denote NBER-dated recessions.

intervals are computed using heteroscedasticity consistent standard errors. Panel B shows that the coefficient on the idiosyncratic asset volatility is significantly negative throughout the sample. Panel A shows that the coefficient for the systematic asset volatility is significantly positive for the majority of the sample years. The coefficient tends to rise in recessions, and it becomes insignificant in 1976-77, 1995, and 2005-06, all of which are in an economic expansion. This result is consistent with our model's prediction that the cross-sectional relation between systematic risk and debt maturity is stronger in bad times, which we test formally in the following section.

4.2.2 Impact of macroeconomic conditions

As a proxy for macroeconomic conditions, we obtain recession/expansion dates from the National Bureau of Economic Research (NBER). Since firms have different fiscal year-ends, we construct for each firm a yearly recession dummy which equals one if the fiscal year-end month for the firm is in a recession, and zero otherwise.[19] Then, we examine the impact of business cycles on debt maturity by adding a recession dummy and the interaction term between the recession dummy and the systematic risk measure to equation (17).

To measure the changes in debt maturity over the business cycle, we need to remove the time variation in maturity due to secular trends. As shown in Figure 1, the trend component of aggregate debt maturity is U-shaped over the sample period. We use either a quadratic time trend or the trend component from the Hodrick-Prescott filter to control for this effect, where we assume that the loadings on the time trend are the same for all firms. The results are presented in Table 5.

In column (1), the long-term debt share is regressed on the recession dummy, asset market beta, and their interaction term after controlling for asset volatility, book leverage, and other firm characteristics. The coefficient estimate of the recession dummy is -0.043, while the coefficient of the interaction term between asset market beta and the recession dummy is 0.025. Taken together, these values imply that (a) the long-term debt share of an average firm drops by about 2.1% from expansions to recessions (based on the average market beta of 0.879); (b) for a firm with an asset market beta at the 10th percentile, its long-term debt share is 3.9% lower from expansions to recessions, whereas the long-term debt share of a firm with asset market beta at the 90th percentile is essentially unchanged from expansions to recessions. In column (2), replacing the quadratic time trend with the trend component from the Hodrick-Prescott filter generates almost identical results.

The regression results using asset bank betas and tail betas are in columns (3) - (4). The coefficient estimates of the interaction term between the asset bank beta and the recession dummy and the interaction term between the asset tail beta and the recession dummy are both positive and statistically significant. The economic significance of the coefficient estimates are comparable to those obtained for the asset market beta.

More broadly, our model predicts that the relation between systematic risk and debt maturity is stronger in times of high aggregate risk premium. Besides recessions, another commonly used proxy of the aggregate risk premium is the market volatility index. We use

[19] The results are quantitatively similar if we categorize a fiscal year as in recession when at least three months of the fiscal year are in recession.

VXO, the implied volatility of the S&P 100 options (a close cousin to the better-known VIX index for S&P 500 options, but VXO has a longer sample), as an alternative measure of macroeconomic conditions. Columns (5) - (7) of Table 5 show that debt maturity indeed becomes more sensitive to systematic risk during times of high risk premium.

In the analysis presented so far, we allow the impact of business cycles on debt maturity to depend only on firms' exposure to systematic risk. However, changes in macroeconomic conditions could also affect the relation between debt maturity and other firm characteristics. We find that, in addition to low beta firms, firms with large size and low default probability reduce their debt maturity more from expansions to recessions. [20] This is consistent with the finding of Mian and Santos (2011) that credit worthy firms are more likely not to rollover their long-term debt in bad times. These characteristics are different from our systematic risk measures. We also find that firms with high book leverage reduce maturity more in recessions. This is consistent with Diamond (1991) in that firms with very low credit quality might only be able to issue short-term debt in bad times.

4.2.3 Robustness checks

We have conducted a series of robustness checks for the empirical tests presented above, which we summarize below.

First, in our model, firms are not allowed to hold cash. In practice, firms with high systematic risk exposures not only can choose longer debt maturity, but also maintain a larger cash reserve to reduce the rollover risks. For example, Harford, Klasa, and Maxwell (2013) show that firms increase their cash holdings and save more cash to mitigate the refinancing risk caused by shorter debt maturity. Thus, we expect the impact of firms' systematic risk exposure on debt maturity (cash holdings) to become stronger after controlling for cash holdings (debt maturity). To test this hypothesis, we estimate a system of simultaneous equations in which both debt maturity and cash holdings are endogenously determined. In the debt maturity equation, we follow Acharya, Davydenko, and Strebulaev (2012) and use the 2SLS method with the following two instrumental variales for cash holdings, the ratio of

[20] The regression results are presented in the Internet Appendix.

intangible to book assets and the median ratio of R&D expenditures to book assets in the firm's three-digit SIC industry.

Table 6 reports the estimation results for the structural equation on debt maturity.[21] Panel A shows that controlling for cash holdings indeed strengthens the effect of firms betas on debt maturity. This is especially true in the case of cash flow beta, where the coefficient nearly doubles (from 0.004 in Table 4 to 0.007) after controlling for cash holdings. Panel B shows that the result that the relation between systematic risk and debt maturity is stronger in bad times continues to hold after controlling for cash holdings.

Next, we have computed our asset beta measures by unlevering the equity betas according to the Merton model. This procedure ignores the heterogeneity in debt maturity across firms, which could mechanically generate a relation between the unlevered asset beta and debt maturity even if the true asset beta is unrelated to debt maturity. Our model shows in which direction this bias goes. For the same asset beta, a longer debt maturity lowers the firm's equity beta. This is especially true for high leverage firms. That means if we do not take into account the heterogeneity in debt maturity when unlevering the equity beta, we would understate the asset beta for those firms with long maturity, which biases us against finding a positive relationship between asset beta and debt maturity. Moreover, our results hold in the sub-sample of firms with below-median leverage, where the effects of debt maturity on the unlevering procedure is negligible.

Do high-beta firms end up with longer debt maturity by issuing longer-maturity debt in the first place? The answer is yes. Using the FISD issuance data of public bonds, we find that firms with high systematic risk are indeed more likely to issue long-term bonds in normal times. The relation between bond issuance and systematic risk is not significant in economic downturns, which could be due to firms switching from public bond issuance to bank loans and lines of credit in recessions.

Other robustness checks we have performed include the following. We show that the results on the positive relation between beta and debt maturity hold for alternative measures of debt maturity, and they hold in the sample period excluding the recent financial crisis. We

[21] The estimation results of the cash holding equation are in the Internet Appendix.

also show that the results are not affected by the callability of debt: high-beta firms do not tend to issue more callable debt than low-beta firms, which could have lowered their effective debt maturity. The details of these analyses are in the Internet Appendix.

4.3 Term Structure of Credit Spreads

In this section, we test our model's predictions of the effect of debt maturity dynamics on the term structure of credit spreads. Specifically, we treat the 2008 financial crisis/recession as a significant change in macroeconomic conditions and examine the resulting changes in credit spreads for firms with different maturity structures, leverage, and systematic risk exposures.

We obtain firm-level credit default swap (CDS) spreads with maturity 1 year, 5 years, and 10 years from Markit, and match the data with the COMPUSTAT information. Changes in the CDS spreads during the crisis are measured as the differences in the averages of daily CDS spreads between fiscal year 2007 and 2008. We use the fiscal year 2007 balance sheet information to compute the fraction of long-term debt that matures in 2008 ($ldebt08 = dd1/(dd1 + dltt)$). The larger this measure, the more the debt maturity could be reduced in the crisis, the higher the rollover risk. Following Almeida, Campello, Laranjeira, and Weisbenner (2011), we treat August 2007 as the onset of the financial crisis, and focus on firms that have the 2007 fiscal year-end month in between September 2007 and January 2008. About 87% of the 375 firms with CDS data in fiscal year 2007 and 2008 meet this criterion.

We then examine the cross-sectional relation between the changes in the CDS spreads from 2007 to 2008 (based on 1 year, 5 year, and 10 year CDS spreads) and firms' maturity structures in 2007. The financial crisis could exacerbate default risk through other firm characteristics besides maturity. Consequently, we also control for firm characteristics including market leverage, asset volatility, firm size, market-to-book ratio, profitability, tangibility, equity return (past 12 months), credit rating (from the Standard & Poor's, converted to a numerical scale), and industry dummies (1-digit SIC code) in the regression.

Our model predicts that a bigger drop in debt maturity leads to larger increases in credit spreads in the crisis. Moreover, the maturity effect on credit spreads should be more pronounced for firms with high leverage or high systematic risk. To test these predictions, we

Figure 9: Impact of long-term debt structure on credit spreads. This graph shows the impact of a one-standard deviation increase in the proportion of long-term debt that matures in 2008 on the changes in the CDS spreads between 2007 and 2008. Panels A and B display the result for firms sorted on book leverage and cash-flow beta, respectively.

split the sample into two halves based on the pre-crisis book leverage, market leverage, and cash flow beta, respectively. We then run cross-sectional regressions of changes in the CDS spreads on the fraction of long-term debt that matures in 2008 ($ldebt08$) for firms in each group separately. The regression results are presented in Table 7. We also use the regression coefficients to compute the implied impact of a one-standard deviation increase in $ldebt08$ on changes in the CDS spreads and present the results in Figure 9.

The results show that a firm that has a larger portion of its long-term debt maturing in 2008 would experience a more significant increase in CDS spreads. A one-standard deviation increase in $ldebt08$ corresponds to a 50 bps, 40 bps and 32 bps increase in the CDS spreads with maturity of 1 year, 5 years, and 10 years respectively in 2008. These results are consistent with the empirical findings in Hu (2010).

We also find evidence that the maturity drop amplifies the impact of aggregate shocks on the credit spreads more for firms with higher leverage and higher beta before the crisis.

Panel A of Figure 9 shows that a one-standard deviation increase in $ldebt08$ raises the 1-year, 5-year, and 10-year CDS spreads by 84 bps, 77 bps, and 55 bps respectively for firms with above-median book leverage, while the corresponding increase in the CDS spreads is 31 bps, 22 bps, and 21 bps respectively for firms with below-median book leverage. The results are similar if we sort firms based on market leverage. Panel B shows that a one-standard deviation increase in $ldebt08$ raises 1-year, 5-year, and 10-year the CDS spreads by 70 bps, 63 bps, and 46 bps respectively for firms with above-median cash flow beta, while the corresponding increase in the CDS spreads is negligible for firms with below-median cash flow beta.

One might be concerned that the long-term debt structure in 2007 is endogenous. Mian and Santos (2011) show that firms with good credit quality did actively manage the maturity of syndicated loans before the financial crisis through early refinancing of outstanding loans. This would imply that those firms with high rollover risk according to $ldebt08$ could be the firms with low quality (which are not captured by the controls), which would explain the larger increase in their credit spreads during the crisis. To address this concern, we compute $\widehat{ldebt08}$ based on balance sheet information from fiscal years 2004 ($dd4/(dd1 + dltt)$), 2005 ($dd3/(dd1 + dltt)$), and 2006 ($dd2/(dd1 + dltt)$). We then run cross-sectional regression of changes in the CDS spreads from 2007 to 2008 on $\widehat{ldebt08}$, industry dummies, and other firm controls measured at the end of the fiscal years 2004-2006, respectively. We obtain almost identical results based on the fiscal year 2006 information (see the Internet Appendix). The results are slightly weaker for 2005 and no longer significant for 2004.

5 Concluding Remarks

Firms' maturity choices are closely linked to their systematic risk exposures and macroeconomic conditions. We build a model to explain the maturity dynamics over the business cycle, as well as their implications for the term structure of credit risk. We also provide empirical evidence for the model predictions.

While we have focused on debt maturity in this paper, there are many dimensions in which firms can manage their exposures to macroeconomic risks, including other financing decisions such as cash holding, lines of credit, payout, and real decisions such investments and mergers and acquisitions (see e.g., Acharya, Almeida, and Campello (2012), Hugonnier, Malamud, and Morellec (2011), Bolton, Chen, and Wang (2012)). To understand the data, ultimately we need to jointly study the firms' decisions in all these dimensions. Moreover, as a starting point, our modeling of the maturity structure dynamics is still quite stylized, especially for the purpose of pricing credit-risky securities. It would be useful to extend the model to capture more realistic maturity structures.

Table 1: Baseline model parameters and results. Panel A contains the parameters used in the baseline model and the results on capital structure and credit spreads. Parameters that do not vary across the states include: $\kappa = \ln 2.5$, $\sigma_f = 0.23$, $\tau = 0.2$. All parameters are annualized if applicable. The asset beta for the unlevered firm is 0.8 and is calculated based on a market dividend process with a with a leverage ratio of $\phi = 1.25$ relative to the cashflows of the baseline firm. The initial capital structure choices are determined in state G. Panel B summarizes results from the baseline calibration.

A. Baseline parameters

	state G	state B
Aggregate state transition intensities: $\widehat{\pi}_s$	0.1	0.5
Riskfree rate: $r(s)$	0.0558	0.0261
Market price of Brownian risk: $\eta(s)$	0.156	0.24
Cash flow expected growth rate: $\widehat{\mu}(s)$	0.0617	0.0162
Cash flow systematic volatility: $\sigma_\Lambda(s)$	0.1361	0.1555
Recovery rate: $\alpha(s)$	0.72	0.59
Liquidity shock intensity: $\lambda_U(s)$	1.5	3
Intermediation intensity: $\lambda_C(s)$:	6	0.75
Holding cost parameter: $h_0(s)$	0.9884×10^{-4}	0.1774
Holding cost parameter: $h_1(s)$	0.4179	0.0043

B. Baseline model results

	state G	state B
Initial market leverage: D/V	28.5%	31.6%
Initial interest coverage: y_0/b	2.68	2.68
Debt maturity: $1/m_s$	5.5	5.0
5 year default rate	0.6%	1.1%
10 year default rate	4.2%	5.6%
5 year credit spread (default component)	29.2 bps	55.1 bps
5 year credit spread (total)	33.6 bps	67.5 bps
10 year credit spread (default component)	97.7 bps	135.2 bps
10 year credit spread (total)	115.2 bps	166.2 bps
Conditional equity Sharpe ratio	0.12	0.22

Table 2: Summary Statistics and Correlations. This table presents descriptive statistics (Panel A) of firm-level variables (definitions see Internet Appendix) and Pearson correlations (Panel B) among risk measures.

A. Summary statistics

	mean	std	median	25%	75%	obs
ldebt1y	0.737	0.287	0.852	0.612	0.954	94,204
ldebt2y	0.631	0.306	0.723	0.436	0.878	71,406
ldebt3y	0.525	0.315	0.580	0.265	0.786	71,406
ldebt4y	0.434	0.310	0.450	0.138	0.687	71,406
ldebt5y	0.349	0.295	0.324	0.046	0.582	71,406
debtmat	4.763	2.593	4.733	2.548	6.836	71,406
lncash	-3.137	1.506	-3.011	-3.987	-2.089	94,199
mkat	5.583	2.054	5.402	4.034	7.008	92,619
abnearn	0.014	0.259	0.009	-0.038	0.049	83,649
bklev	0.298	0.171	0.271	0.165	0.398	94,204
mk2bk	1.582	1.157	1.217	0.953	1.734	92,619
assetmat	8.137	6.154	6.649	3.907	10.450	90,628
profitvol	0.062	0.063	0.042	0.024	0.075	67,423
asset market beta	0.879	0.637	0.798	0.454	1.201	64,496
asset bank beta	0.507	0.450	0.472	0.230	0.746	64,496
asset tail beta	0.669	0.607	0.618	0.270	1.009	64,191
equity market beta	1.127	0.745	1.068	0.659	1.518	64,496
cash flow beta	1.770	2.575	1.410	0.113	3.252	21,331
assetvol	0.386	0.198	0.338	0.255	0.462	64,496
sys assetvol	0.138	0.095	0.121	0.068	0.187	64,496
id assetvol	0.347	0.180	0.301	0.221	0.423	64,496

B. Correlations

	market beta	bank beta	tail beta	equity beta	cf beta
bank beta	0.690				
tail beta	0.468	0.321			
equity beta	0.913	0.639	0.371		
cf beta	0.097	0.064	0.027	0.117	
asset vol	0.353	0.187	0.134	0.327	0.045

Table 3: Fama-MacBeth Regressions of Long-Term Debt Share. This table presents regressions of the fraction of debt that matures in more than 3 years on firm-specific variables: asset beta, asset volatility, firm size, abnormal earning, book leverage, market-to-book ratio, asset maturity, and profit volatility. In the Fama-MacBeth regressions (column (1) - (8)), we compute robust t-statistics using Newey-West standard errors with 2 lags, except in column (8) we use 20 lags. In the cross-sectional regression (column (9)), we compute White standard errors. Robust t-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
market beta	0.013	0.084***	0.104***		0.052***				
	(1.57)	(12.04)	(10.55)		(6.43)				
bank beta						0.054***			
						(4.14)			
tail beta							0.045***		
							(9.75)		
cf beta								0.004***	
								(3.43)	
nondurable									-0.023*
									(-1.87)
service									-0.032**
									(-1.98)
sys assetvol				0.456***					
				(8.88)					
id assetvol				-0.504***					
				(-30.52)					
assetvol		-0.524***	-0.510***		-0.058**	-0.020	-0.017		
		(-23.37)	(-21.81)		(-2.14)	(-0.67)	(-0.91)		
mkat					0.046***	0.048***	0.045***	0.039***	0.051***
					(12.01)	(12.08)	(12.54)	(4.86)	(14.56)
abnearn					-0.014*	-0.014*	-0.014*	-0.020***	0.005
					(-1.84)	(-1.90)	(-1.91)	(-2.98)	(0.09)
bklev			0.275***	0.275***	0.263***	0.256***	0.253***	0.239***	0.188***
			(5.91)	(6.00)	(6.02)	(5.89)	(5.23)	(4.29)	(4.67)
mk2bk					-0.026***	-0.024***	-0.025***	-0.056***	-0.035***
					(-7.33)	(-6.78)	(-7.20)	(-20.48)	(-4.39)
assetmat					0.007***	0.007***	0.007***	0.006***	0.009***
					(24.96)	(23.65)	(25.31)	(8.19)	(8.63)
profitvol					-0.380***	-0.381***	-0.407***	-0.329***	-0.632***
					(-8.31)	(-8.40)	(-8.32)	(-2.76)	(-5.41)
Observations	51,832	51,832	47,808	47,808	42,570	42,570	42,437	15,235	1,652
R^2	0.004	0.070	0.091	0.090	0.206	0.205	0.205	0.161	0.328

Table 4: Panel Regressions of Debt Maturity. This table presents panel regressions of the fraction of debt that matures in more than 3 years on firm-specific variables: asset beta, asset volatility, firm size, abnormal earning, book leverage, market-to-book ratio, asset maturity, and profit volatility. Industry-fixed effects and year-fixed effects are also included in the regression. We adjust standard errors by clustering the observations at the industry level. Robust t-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
market beta	0.074***	0.088***	0.041***			
	(18.88)	(21.15)	(8.97)			
bank beta				0.037***		
				(5.74)		
tail beta					0.037***	
					(10.03)	
cf beta						0.004**
						(2.29)
assetvol	-0.428***	-0.420***	-0.047***	-0.003	-0.011	
	(-22.87)	(-23.78)	(-2.70)	(-0.18)	(-0.57)	
mkat			0.047***	0.049***	0.047***	0.043***
			(17.07)	(17.53)	(17.11)	(10.92)
abnearn			-0.016***	-0.017***	-0.015***	-0.035***
			(-3.63)	(-3.74)	(-3.32)	(-3.44)
bklev		0.216***	0.253***	0.244***	0.248***	0.275***
		(8.48)	(9.32)	(9.11)	(9.23)	(7.36)
mk2bk			-0.017***	-0.015***	-0.018***	-0.035***
			(-3.92)	(-3.56)	(-4.24)	(-4.24)
assetmat			0.005***	0.005***	0.005***	0.002**
			(8.61)	(8.39)	(8.62)	(2.10)
profitvol			-0.361***	-0.368***	-0.373***	-0.325**
			(-5.27)	(-5.36)	(-5.35)	(-2.18)
Observations	51,832	47,808	42,570	42,570	42,437	13,869
R^2	0.070	0.079	0.162	0.159	0.161	0.115

Table 5: Debt Maturity: Impact of Macroeconomic Conditions. This table presents regression results of the fraction of debt that matures in more than 3 years on a macroeconomic variable, asset beta, an interaction between the macroeconomic variable and asset beta, firm controls (total asset volatility, firm size, abnormal earning, book leverage, market-to-book ratio, asset maturity, and profit volatility) and industry dummies. We measure macroeconomic conditions using either a recession dummy dated by NBER or the S&P 100 volatility index (VXO). We also include either a quadratic time trend or an aggregate trend generated by the H-P filter on the aggregate long-term debt share. We adjust standard errors by clustering the observations at the industry level. Robust t-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

	Recession				VXO		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
macro	-0.043***	-0.044***	-0.039***	-0.037***	-0.001***	-0.001***	-0.001***
	(-5.65)	(-5.85)	(-5.76)	(-6.52)	(-2.67)	(-4.10)	(-2.66)
market beta	0.047***	0.044***			0.024***		
	(10.13)	(9.25)			(2.61)		
market beta × macro	0.025***	0.023***			0.001*		
	(2.85)	(2.64)			(1.91)		
bank beta			0.041***			-0.000	
			(6.47)			(-0.02)	
bank beta × macro			0.037***			0.001**	
			(2.98)			(2.51)	
tail beta				0.041***			0.025**
				(11.10)			(2.59)
tail beta × macro				0.020***			0.001*
				(2.80)			(1.85)
assetvol	-0.090***	-0.093***	-0.047***	-0.048***	-0.069***	-0.027	-0.040**
	(-5.61)	(-5.55)	(-2.76)	(-2.92)	(-3.69)	(-1.39)	(-2.03)
mkat	0.046***	0.044***	0.048***	0.045***	0.054***	0.055***	0.052***
	(17.14)	(17.46)	(17.27)	(16.93)	(17.12)	(17.41)	(17.21)
abnearn	-0.017***	-0.017***	-0.018***	-0.016***	-0.022***	-0.022***	-0.020***
	(-3.65)	(-3.70)	(-3.84)	(-3.37)	(-3.39)	(-3.42)	(-3.02)
bklev	0.246***	0.247***	0.232***	0.237***	0.335***	0.322***	0.334***
	(8.90)	(8.93)	(8.47)	(8.65)	(10.76)	(10.56)	(11.01)
mk2bk	-0.016***	-0.016***	-0.013***	-0.017***	-0.015***	-0.013***	-0.017***
	(-3.89)	(-3.78)	(-3.23)	(-4.13)	(-3.56)	(-3.09)	(-3.88)
asset mat	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
	(8.67)	(8.70)	(8.38)	(8.66)	(5.98)	(5.76)	(5.94)
profitvol	-0.335***	-0.349***	-0.342***	-0.348***	-0.301***	-0.308***	-0.312***
	(-5.17)	(-5.63)	(-5.25)	(-5.34)	(-4.15)	(-4.20)	(-4.40)
Quadratic Trend	Yes	No	Yes	Yes	Yes	Yes	Yes
HP Trend	No	Yes	No	No	No	No	No
Observations	42,570	42,570	42,570	42,437	26,489	26,489	26,408
R^2	0.154	0.155	0.150	0.153	0.172	0.170	0.173

Table 6: The Effect of Cash Holdings on Debt Maturity. This table presents the second-stage regression results for the structural equation that explain debt maturity using the 2SLS methodology. The second-stage structural equation that explains debt maturity has the fraction of total debt maturing in more than 3 years as the dependent variable and the independent variables are the predicted value of the natural logarithm of cash holdings, asset beta, and firm controls (total asset volatility, firm size, abnormal earning, book leverage, market-to-book ratio, asset maturity, and profit volatility) and industry dummies. In Panel A, we include year dummies to control for year-fixed effects. In Panel B, we include a recession dummy dated by NBER, an interaction term of beta and the recession dummy, and either a quadratic time trend or an aggregate trend generated by the H-P filter on the aggregate long-term debt share. We adjust standard errors by clustering the observations at the industry level. Robust z-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

A. Year-Fixed Effects				
	(1)	(2)	(3)	(4)
cash holdings	-0.035	-0.027	-0.031	-0.094**
	(-1.03)	(-0.83)	(-0.91)	(-2.13)
market beta	0.045***			
	(6.96)			
bank beta		0.038***		
		(4.63)		
tail beta			0.040***	
			(7.96)	
cf beta				0.007**
				(2.56)
Observations	37,304	37,304	37,184	13,367

B. Macroeconomic Condition				
	(1)	(2)	(3)	(4)
cash holdings	-0.035	-0.015	-0.026	-0.030
	(-0.97)	(-0.60)	(-0.75)	(-0.84)
rec	-0.044***	-0.044***	-0.042***	-0.042***
	(-5.45)	(-5.69)	(-5.26)	(-5.53)
market beta	0.053***	0.046***		
	(6.90)	(7.97)		
market beta × rec	0.019*	0.019**		
	(1.86)	(2.00)		
bank beta			0.044***	
			(4.82)	
bank beta × rec			0.032**	
			(2.36)	
tail beta				0.045***
				(7.59)
tail beta × rec				0.018**
				(2.14)
Quadratic Trend	Yes	No	Yes	Yes
HP Trend	No	Yes	No	No
Observations	37,304	37,304	37,304	37,184

Table 7: Long-Term Debt Structure and Credit Spreads. This table presents cross-sectional regression results of yearly changes in CDS spreads from fiscal year 2007 to 2008 on the proportion of long-term debt maturing in 2008, firm controls (market leverage, total asset volatility, firm size, market-to-book ratio, profitability, tangible, equity return, and credit rating), and industry dummies based on the 1-digit SIC code. The regressions are estimated for the entire sample and separately for sub-samples of firms formed on the basis of firm characteristics at the end of fiscal year 2007. For three firm characteristics, the sub-samples comprise firms with market leverage, book leverage, and cash flow beta above and below the sample median, respectively. Robust t-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

	All	Book leverage		Market leverage		Cash flow beta	
		High	Low	High	Low	High	Low
	A. Changes in 1-year CDS spreads						
ldebt08	0.045***	0.072**	0.029**	0.109**	0.012	0.070***	0.006
	(2.71)	(2.00)	(1.98)	(2.17)	(1.38)	(3.35)	(0.28)
Observations	261	124	137	124	137	86	94
R^2	0.497	0.563	0.411	0.551	0.360	0.671	0.567
	B. Changes in 5-year CDS spreads						
ldebt08	0.036***	0.066**	0.021	0.098**	0.009	0.063***	0.001
	(2.67)	(2.37)	(1.48)	(2.37)	(0.97)	(3.02)	(0.04)
Observations	272	133	139	131	141	91	95
R^2	0.468	0.526	0.375	0.509	0.357	0.653	0.581
	C. Changes in 10-year CDS spreads						
ldebt08	0.029**	0.047**	0.020	0.072*	0.009	0.046***	0.002
	(2.57)	(2.06)	(1.64)	(1.98)	(1.21)	(2.87)	(0.14)
Observations	263	126	137	124	139	88	92
R^2	0.489	0.560	0.345	0.531	0.363	0.672	0.580

Appendix

A Model Solution

We first state a general result that will be the basis for analytically pricing both equity and debt.

Proposition 1. *Let $\mathbf{f} : \mathbb{R} \to \mathbb{R}^n$ be a vector-valued function satisfying the following system of ordinary differential equations:*

$$\mathbf{A}\mathbf{f}(x) = \mathbf{a}_0 + \sum_{i=1}^{\ell} g_i\left(\mathbf{a}_i e^{b_i x}\right) + \mathbf{B}\mathbf{f}'(x) + \mathbf{C}\mathbf{f}''(x) \tag{A.1}$$

where $\mathbf{A}, \mathbf{B} \in \mathbb{R}^{n\times n}$ are real-valued matrices, $\mathbf{C} \in \mathbb{R}^{n\times n}$ is a real and non-singular *matrix, $\ell \in \mathbb{N}$, $\mathbf{a}_0 \in \mathbb{R}^n$, $\mathbf{a}_i \in \mathbb{C}^n$, $b_i \in \mathbb{C}$, and g_i is either the operator $Re(\cdot)$ (the real part of a complex number) or $Im(\cdot)$ (the imaginary part). Then $\mathbf{f}(x)$ takes the following form:*

$$\mathbf{f}(x) = \mathbf{f}_0 + \sum_{i=1}^{\ell} g_i\left(\mathbf{f}_i e^{b_i x}\right) + \sum_{j=1}^{n_{\mathbb{R}}} \omega_j^{\mathbb{R}} \mathbf{v}_j^{\mathbb{R}} e^{\lambda_j^{\mathbb{R}} x} + \sum_{k=1}^{n_{\mathbb{C}}/2} \left(\omega_k^{\mathbb{C},Re} Re\left(\mathbf{v}_k^{\mathbb{C}} e^{\lambda_k^{\mathbb{C}} x}\right) + \omega_k^{\mathbb{C},Im} Im\left(\mathbf{v}_k^{\mathbb{C}} e^{\lambda_k^{\mathbb{C}} x}\right)\right) \tag{A.2}$$

with $\mathbf{f}_i$ $(i = 0, ..., \ell)$ defined by

$$\mathbf{A}\mathbf{f}_0 = \mathbf{a}_0 \tag{A.3}$$

$$\left(\mathbf{A} - b_i\mathbf{B} - b_i^2\mathbf{C}\right)\mathbf{f}_i = \mathbf{a}_i, \quad i = 1, ..., \ell \tag{A.4}$$

and $\omega_j^{\mathbb{R}}, \omega_k^{\mathbb{C},Re}, \omega_k^{\mathbb{C},Im} \in \mathbb{R}$ are real-valued coefficients.

The pairs $\left(\lambda_j^{\mathbb{R}}, \mathbf{v}_j^{\mathbb{R}}\right)$ are the real solutions to the following Quadratic Eigenvalue Problem (QEP):

$$\mathbf{A}\mathbf{v} = \lambda\mathbf{B}\mathbf{v} + \lambda^2\mathbf{C}\mathbf{v}. \tag{A.5}$$

while the pairs $\left(\lambda_k^{\mathbb{C}}, \mathbf{v}_k^{\mathbb{C}}\right)$ are the complex solutions to the QEP with $Im\left(\lambda_k^{\mathbb{C}}\right) > 0$. In total, there are $2n = n_{\mathbb{R}} + n_{\mathbb{C}}$ pairs of such solutions (unique up to scaling) with $n_{\mathbb{C}}$ being even. Furthermore, in the special case where $\mathbf{A} = (a_{ij})$ satisfies

$$a_{ij} \geq 0, \quad (i \neq j) \tag{A.6}$$

$$\sum_k a_{ik} < 0, \quad \forall\, i \tag{A.7}$$

exactly half of the eigenvalues for the QEP will be located in the left (complex) half plane with the other half in the right half plane.

Proof. The conditions (A.3), (A.4) and (A.5) are obtained after substituting (A.2) into (A.1). Next, the assumptions for **A**, **B**, and **C** imply that there are $2n$ finite eigenvalues to the QEP (A.5), with eigenvalue-eigenvector pairs either being real or in conjugate pairs (see Tisseur and Meerbergen (2001)). Since the weights $\omega_k^{\mathbb{C},Re}$ and $\omega_k^{\mathbb{C},Im}$ can be freely chosen, for each conjugate pair of solutions to (A.5), we may keep the solution with $\text{Im}\left(\lambda_k^{\mathbb{C}}\right) > 0$ w.l.o.g. Finally, the result for the location of the eigenvalues when conditions (A.6)-(A.7) are satisfied is shown in Barlow, Rogers, and Williams (1980). □

Next, we derive the analytical solutions to debt and equity. The solution forms are similar to those obtained in Jobert and Rogers (2006) and Chen (2010), but our characterization is more general in that it allows for complex eigenvalue-eigenvector solutions to the QEP.

A.1 Debt Valuation

We now characterize the solution for debt taking the default boundaries $\{y_D(G), y_D(B)\}$ as given. We will work in terms of log cash flows, which we denote by $x = \log(y)$. Given a pair of (log) default boundaries $x_D(G)$ and $x_D(B)$, we first reorder the macroeconomic states so that the default boundaries are increasing:

$$x_D(\underline{s}) \leq x_D(\overline{s}) \tag{A.8}$$

with $\underline{s}$ ($\overline{s}$) being the macroeconomic state with the lower (higher) default boundary.

The default boundaries define three regions:

$$\begin{aligned} \mathcal{R}_1 &= (-\infty, x_D(\underline{s})) && \text{(A.9)} \\ \mathcal{R}_2 &= [x_D(\underline{s}), x_D(\overline{s})] && \text{(A.10)} \\ \mathcal{R}_3 &= (x_D(\overline{s}), \infty) && \text{(A.11)} \end{aligned}$$

We will successively characterize debt values $D_{[i]}$ for each region $\mathcal{R}_i$.

Equity holders will always default when cash flows fall within region $\mathcal{R}_1$. Therefore debt value will be given by the bankruptcy recovery value in equation (8):

$$D_{[1]}(x, s, i) \quad = \quad \alpha(s) v(s) e^x \tag{A.12}$$

In region $\mathcal{R}_2$, equity holders will default whenever the state is $\overline{s}$. This gives

$$D_{[2]}(x, \overline{s}, i) \quad = \quad \alpha(\overline{s}) v(\overline{s}) e^x, \quad i = U, C. \tag{A.13}$$

When the state is $\underline{s}$, debt value in region $\mathcal{R}_2$, $\mathbf{D}_{[2]}(x, \underline{s}) = (D(x, \underline{s}, U), D(x, \underline{s}, C))'$, is characterized by the following system:

$$\mathbf{W}_{D[2]} \mathbf{D}_{[2]}(x, \underline{s}) \quad = \quad \mathbf{d}_{0[2]} + \mathbf{d}_{1[2]} e^x + \mathbf{U}_{[2]} \mathbf{D}'_{[2]}(x, \underline{s}) + \mathbf{V}_{[2]} \mathbf{D}''_{[2]}(x, \underline{s}). \tag{A.14}$$

The coefficients in (A.14) are obtained in a straightforward manner from stacking (7) in vector form, and so we do not state them explicitly. The solution is characterized by Proposition 1 and takes the following form:

$$\begin{aligned} \mathbf{D}_{[2]}(x, \underline{s}) \quad = \quad & \mathbf{D}_{0[2]} + \mathbf{D}_{1[0]} e^x + \sum_j \omega^{\mathbb{R}}_{D[2],j} \mathbf{v}^{\mathbb{R}}_{D[2],j} e^{\lambda^{\mathbb{R}}_{D[2],j} x} \\ & + \sum_k \left(\omega^{\mathbb{C},Re}_{D[2],k} \mathrm{Re} \left(\mathbf{v}^{\mathbb{C}}_{D[2],k} e^{\lambda^{\mathbb{C}}_{D[2],k} x} \right) + \omega^{\mathbb{C},Im}_{D[2],k} \mathrm{Im} \left(\mathbf{v}^{\mathbb{C}}_{D[2],k} e^{\lambda^{\mathbb{C}}_{D[2],k} x} \right) \right). \end{aligned} \tag{A.15}$$

Debt value in region $\mathcal{R}_3$, $\mathbf{D}_{[3]}(x) = (D(x, \underline{s}, U), D(x, \underline{s}, C), D(x, \overline{s}, U), D(x, \overline{s}, C))'$, is characterized by the system

$$\mathbf{W}_{D[3]}\mathbf{D}_{[3]}(x) \quad = \quad \mathbf{d}_{0[3]} + \mathbf{U}_{[3]}\mathbf{D}'_{[3]}(x) + \mathbf{V}_{[3]}\mathbf{D}''_{[3]}(x). \tag{A.16}$$

The solution here is similar to (A.15) and takes the following form:

$$\begin{aligned} \mathbf{D}(x) \quad = \quad & \mathbf{D}_{0[3]} + \sum_j \omega^{\mathbb{R}}_{D[3],j}\mathbf{v}^{\mathbb{R}}_{D[3],j}e^{\lambda^{\mathbb{R}}_{D[3],j}x} \\ & + \sum_k \left(\omega^{\mathbb{C},Re}_{D[3],k}\mathrm{Re}\left(\mathbf{v}^{\mathbb{C}}_{D[3],k}e^{\lambda^{\mathbb{C}}_{D[3],k}x}\right) + \omega^{\mathbb{C},Im}_{D[3],k}\mathrm{Im}\left(\mathbf{v}^{\mathbb{C}}_{D[3],k}e^{\lambda^{\mathbb{C}}_{D[3],k}x}\right)\right). \end{aligned} \tag{A.17}$$

Debt value needs to be bounded as x goes to infinity (where debt becomes risk-free). This condition means that those coefficients $\omega_{D[3]}$ in (A.17) corresponding to the eigenvalues that lie in the right half plane will all be equal to zero. According to Proposition 1, there are four such eigenvalues.

Finally, we are left with eight weights, four from region $\mathcal{R}_2$ and four from region $\mathcal{R}_3$:

$$\boldsymbol{\omega}_D \quad \equiv \quad \bigcup_{i=2}^{3}\left\{\omega^{\mathbb{R}}_{j[i]}\right\} \cup \left\{\omega^{\mathbb{C},Re}_{k[i]}\right\} \cup \left\{\omega^{\mathbb{C},Im}_{k[i]}\right\}. \tag{A.18}$$

These coefficients are exactly identified from eight value matching and smoothness conditions at $x_D(\underline{s})$ and $x_D(\overline{s})$:

$$D(x_D(s), s, i) \quad = \quad \alpha(s)v(s)e^{x_D(s)}, \text{ for } s \in \{\underline{s}, \overline{s}\} \text{ and } i \in \{U, C\}. \tag{A.19}$$

$$D_{[2]}(x_D(\overline{s}), \underline{s}, i) \quad = \quad D_{[3]}(x_D(\overline{s}), \underline{s}, i), \text{ for } i \in \{U, C\}. \tag{A.20}$$

$$D'_{[2]}(x_D(\overline{s}), \underline{s}, i) \quad = \quad D'_{[3]}(x_D(\overline{s}), \underline{s}, i), \text{ for } i \in \{U, C\}. \tag{A.21}$$

These boundary conditions give a system of *linear* equations for the weights $\boldsymbol{\omega}_D$ that can be solved analytically.

A.2 Equity Valuation

Similar to debt, we can analytically characterize the equity value taking the default boundaries as given. In region $\mathcal{R}_1$, equity holders will always default, and so equity will always have zero value:

$$E(x, s) = 0 \quad \text{for } x \in \mathcal{R}_1 \tag{A.22}$$

Similarly, equity holders default on region $\mathcal{R}_2$ whenever the state is $\overline{s}$ so that

$$E(x, \overline{s}) = 0 \quad \text{for } x \in \mathcal{R}_2. \tag{A.23}$$

In order to solve for the remaining equity values, notice that when we plug in our solution for debt into (11), the resulting ODE for equity satisfies the assumptions of Proposition 1. Thus, equity value takes the form

$$\begin{aligned}\mathbf{E}_{[i]}(x) &= \mathbf{E}_{0[i]} + \mathbf{E}_{1[i]}e^{x} \\ &+ \sum_j \omega^{\mathbb{R}}_{D[i],j}\mathbf{E}^{\mathbb{R}}_{D[i],j}e^{\lambda^{\mathbb{R}}_{D[i],j}x} + \sum_j \omega^{\mathbb{C},Re}_{D[i],j}\mathrm{Re}\left(\mathbf{E}^{\mathbb{C}}_{D[i],j}e^{\lambda^{\mathbb{R}}_{D[i],j}x}\right) + \sum_j \omega^{\mathbb{C},Im}_{D[i],j}\mathrm{Im}\left(\mathbf{E}^{\mathbb{C}}_{D[i],j}e^{\lambda^{\mathbb{R}}_{D[i],j}x}\right) \\ &+ \sum_k \omega^{\mathbb{R}}_{E[i],k}\mathbf{v}^{\mathbb{R}}_{E[i],k}e^{\lambda^{\mathbb{R}}_{E[i],k}x} + \sum_k \omega^{\mathbb{C},Re}_{E[i],k}\mathrm{Re}\left(\mathbf{v}^{\mathbb{C}}_{E[i],k}e^{\lambda^{\mathbb{R}}_{E[i],j}x}\right) + \sum_k \omega^{\mathbb{C},Im}_{E[i],k}\mathrm{Im}\left(\mathbf{v}^{\mathbb{C}}_{E[i],k}e^{\lambda^{\mathbb{R}}_{E[i],k}x}\right).\end{aligned} \tag{A.24}$$

The second line in (A.24) is deduced by matching terms involving the debt coefficients from (11) with the weights and exponents coming from the debt solution given in the previous section. Similar to the case of debt, asymptotic growth conditions will rule out half the eigenvalue-eigenvector pairs from region $\mathcal{R}_3$.

There remains four weights for equity, two from region $\mathcal{R}_2$ and two from $\mathcal{R}_3$, which are determined by the following value matching and smoothness conditions:

$$E(x_D(s), s) = 0, \text{ for } s \in \{\underline{s}, \overline{s}\}. \tag{A.25}$$

$$E_{[2]}(x_D(\overline{s}), \underline{s}) = E_{[3]}(x_D(\overline{s}), \underline{s}). \tag{A.26}$$

$$E'_{[2]}(x_D(\overline{s}), \underline{s}) = E'_{[3]}(x_D(\overline{s}), \underline{s}). \tag{A.27}$$

These conditions give a set of four *linear* equations for the equity weights which can be solved analytically.

Finally, the optimal default boundaries $x_D(G)$ and $x_D(B)$ are solutions to the two smooth-pasting conditions (13). This allow us to characterize the default boundaries as the solution to the following system of non-linear equations:

$$E'_{[2]}(x_D(\underline{s}), \underline{s}) = 0 \tag{A.28}$$

$$E'_{[3]}(x_D(\overline{s}), \overline{s}) = 0 \tag{A.29}$$

where the derivatives are again sums of exponential functions following from (A.24).

B Endogenizing downward rigidity in leverage

In this section, we analyze a model with endogenous rollover decisions. The model builds on Dangl and Zechner (2007), but adds equity issuance costs and liquidity spreads for corporate bonds. The key feature of the model is that the firm does not have to roll over the matured debt immediately. Instead, it can choose when to reissue the debt and how much to issue. However, the presence of convex equity issuance costs helps the model endogenously generate downward rigidity in leverage.

For simplicity, we consider a special case of the benchmark model in our paper with a single macro state. In that case, the aggregate stochastic discount factor simplifies to

$$\frac{d\Lambda_t}{\Lambda_t} = -rdt - \eta dZ^{\Lambda}_t, \tag{A.30}$$

and the firm's cash flows y_t follow the process

$$\frac{dy_t}{y_t} = \widehat{\mu}dt + \sigma dZ_t, \tag{A.31}$$

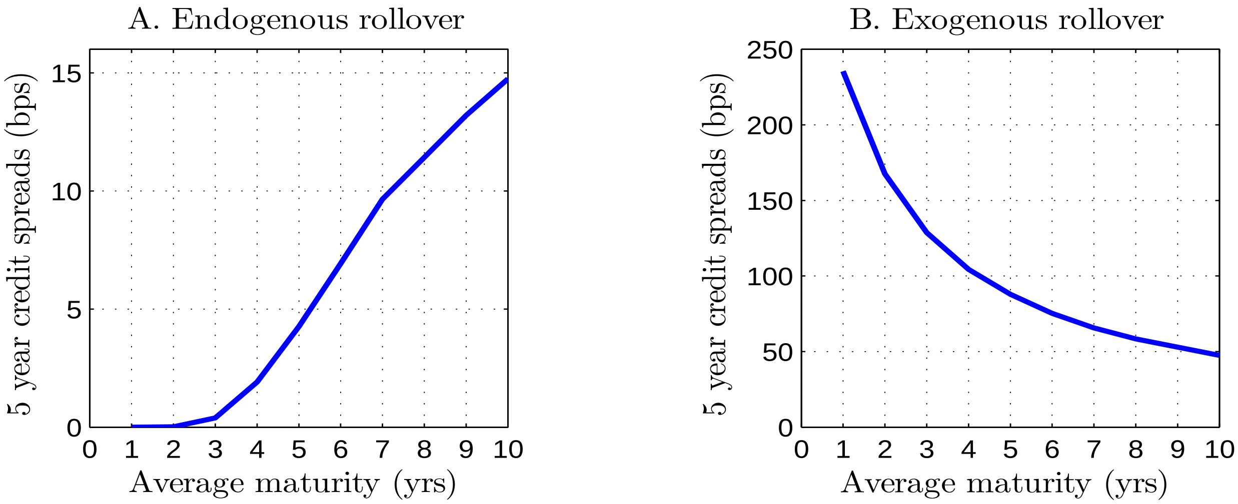

Figure A.1: Credit spreads in models with endogenous vs. exogenous rollover. Equity issuance costs are set to be zero. We fix $P_0 = 7.7$, implying an initial coverage ratio $y_0/b_0 = 2.6$.

where $cov(dZ_t^{\Lambda}, dZ_t) = \rho dt$. Then, the systematic volatility of the firm's cash flows is $\rho\sigma$, which is our measure of a firm's systematic risk exposure in this model. The growth rate of cash flow under the risk-neutral measure is $\mu = \widehat{\mu} - \rho\sigma\eta$. The tax rate on corporate income is still τ.

The initial face value of debt is P_0, with coupon b_0. Debt is retired at a constant rate m, so that the remaining face value and coupon rate at time t are $P_t = P_0 e^{-mt}$ and $b_t = b_0 e^{-mt}$, respectively. The firm can lever up at any time by buying back all the existing debt at face value and then issuing new debt with a new maturity. Debt issuance has a proportional cost q. Upon default, the asset recovery rate is α. Finally, the initial debt maturity rate m and face value P_0 are optimally chosen at $t = 0$.

Rather than endogenizing the liquidity discount via search frictions, here we take a reduced form approach and directly specify a liquidity spread that investors demand for holding a corporate bond with maturity rate m:

$$\ell(m) \quad = \quad \ell_0/m. \tag{A.32}$$

Next, we assume the proportional cost for issuing x dollars of equity is $\xi(x)$, where

$$\xi\left(x\right) \quad = \quad \frac{\theta x}{y_0 e^{-mt}} \times 1_{\{x>0\}}. \tag{A.33}$$

This specification of equity issuance costs follows Hennessy, Levy, and Whited (2007). It implies that the total dollar equity issuance cost is quadratic in the amount of issuance. We normalize the cost with y_0, the cash flow from the previous point of upward restructuring, to ensure that the marginal equity issuance cost is stationarity as the firm grows. The additional scaling factor e^{-mt} is added for analytical tractability.[22] Because the amount of equity issuance in this model is

[22]It allows for a convenient change of variable to remove the time dependence of the solution.

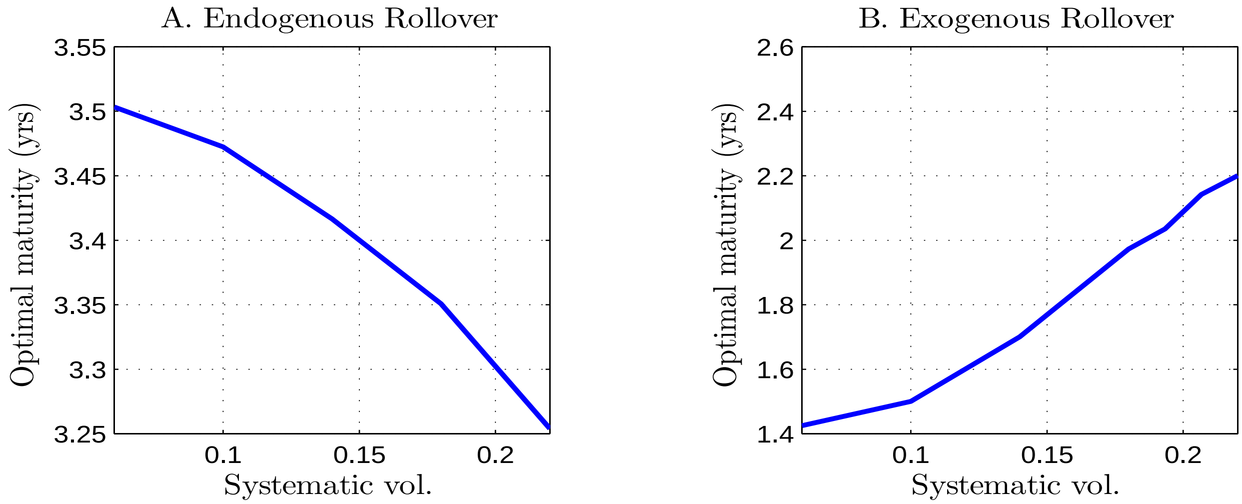

Figure A.2: Maturity choices in models with endogenous vs. exogenous rollover. Leverage is also optimally chosen.

decreasing in the firm's cash flows, equation (A.33) implies that the costs of equity injection will rise in a convex fashion as the firm moves closer to default.

The details of the solution are in the Internet Appendix. In short, after applying the scaling property as in Goldstein, Ju, and Leland (2001) and a change of variable as in Dangl and Zechner (2007), the problem becomes time-independent, and we are able to characterize the solution to debt, equity, and the default and restructuring boundaries analytically.

Before examining the results from the full model, we first consider the special case without equity issuance costs, i.e., $\xi(x) = 0$. We compare this model to a model where 100% of the retired debt are rolled over immediately, which highlights the importance of the downward rigidity in leverage to default risk and maturity choice.

In Figure A.1, we plot the 5-year credit spreads for a firm with different average debt maturity (ranging from 1 to 10 years). In the model with endogenous rollover, credit spreads are very low. They also increase with maturity, contrary to the notion of rollover risk. The spreads are only about 15 bps when the average maturity is 10 years, and fall to essentially zero when the average maturity is under 3 years. This is because leverage declines quickly with a short debt maturity, and the firm will only reissue debt if its cash flows are sufficiently high. In contrast, in the model with exogenous rollover, credit spreads are significantly higher, and they are decreasing with debt maturity.

The fact that shorter maturity helps decrease default risk in the endogenous rollover model without equity issuance costs directly affects the maturity choice. Even though issuing short-term debt increases the debt floatation costs, it is outweighed by the benefit of reducing bankruptcy costs. As a result, in the cross section, firms with higher systematic risk exposures choose shorter maturity in the model with endogenous rollover (Panel A of Figure A.2), opposite to the results in the model with exogenous rollover (Panel B).

The contrast between the results from the two models of rollover in Figure A.1 and Figure A.2 shows that (1) downward rigidity in leverage is crucial for a model to generate meaningful default risk, and (2) the channel through which default risk arises is tightly connected to the tradeoff for debt maturity. The difficulty to reduce leverage following negative cashflow shocks is why firms

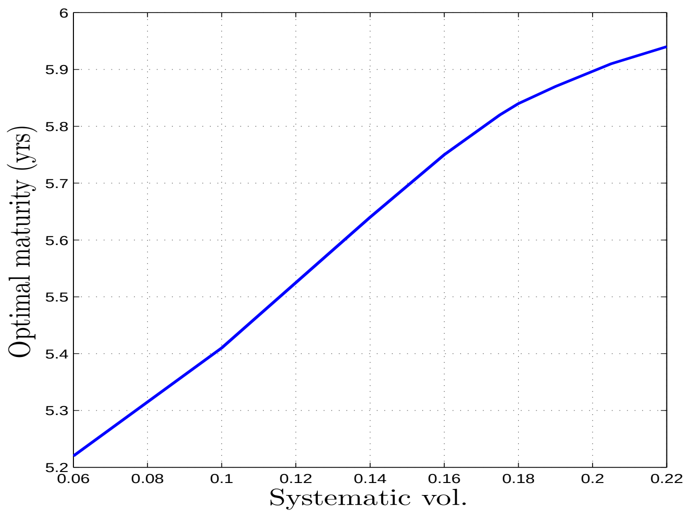

Figure A.3: Maturity choice in the model with endogenous rollover and costly equity injection. Initial interest rate coverage is fixed at 6 for all firms; this corresponds to the optimal leverage choice for the baseline firm which has a systematic volatility of 0.14. Equity issuances costs are specified with $\theta = 2/3$.

choose to default ex post. It is also why short term debt will increase default risk, as in the model of exogenous rollover, rather than decrease it, as in the model of endogenous rollover.

Finally, we study the case with equity issuance costs. In this case, after choosing short debt maturity, reducing leverage when cash flows are low will be prohibitively expensive because it requires a large amount of equity injection in a short period of time. Figure A.3 shows the result of optimal maturity choice in the endogenous rollover model with equity issuance costs. By making equity issuance more costly for firms with low cash flows, credit spreads are significantly higher, especially for firms with shorter debt maturity, and firms with higher systematic risk exposures will optimally choose longer maturity, as in our benchmark model.

C Calibrating the liquidity friction parameters

We compute the empirical targets for the liquidity spreads at different maturities as follows. First, we compute the bond-CDS spread as the difference between the bond spread and the CDS spread for the same company at the same maturity. Bond transaction data and characteristic information such as coupon rates, issue dates, maturity dates, and issue amounts are obtained from the Mergent Fixed Income Securities Database for the period between 2004 and 2010. To compute the bond-CDS spread, we focus on senior-unsecured fixed-rate straight corporate bonds with semi-annual coupon payments. We keep bonds with investment grade ratings as Mergent's coverage of transactions on speculative grade bonds is small. We delete bonds with embedded options such as callable, puttable, and convertible. We also delete bonds with credit enhancement and less than one year to maturity. The corporate spread is computed as a parallel shift of the riskless zero curve, constructed from the libor-swap rates with maturity of 3 months to 10 years, such that the present value of future cash flows equals to the current bond price under the assumption of no default. The corresponding CDS spread with the same maturity is computed by interpolating CDS spreads with maturity of 6 months, 1 year, 2years, 3 years, 4 years, 5 years, 7 years and 10 years.

Before running regressions to investigate the relation between the bond-CDS spread and bond maturity, we need to address a possible sample selection bias: firms facing higher long-term liquidity spreads will likely choose to issue short-term bonds. Following Helwege and Turner (1999), we restrict the data to firms issuing both short-term bonds (maturity less than 3 years) and long-term bonds (maturity longer than 7 years) during the sample period.[23] We then run a regression of the bond-CDS spread on bond maturity, bond characteristics (bond age, issuing amount, and coupon rate), and firm characteristics (systematic beta, size, book leverage, market-to-book ratio, and profit volatility). To identify the effects of the business cycles, we separately run the regression using the pre-crisis sample (January 2004 to June 2007) and the crisis sample (August 2007 - June 2009). The regression results are presented in Table A.1. Based on the coefficient estimates, we compute average bond-cds spreads for maturity of 1 year, 5 years and 10 years respectively in both the pre-crisis period and crisis period.

We have calibrated the intensity of liquidity shocks $\lambda_U(s)$ and the matching intensity $\lambda_C(s)$ to fit the bond turnover rate in the data. It is possible that a large part of the bond trading in good times is not due to liquidity shocks, in which case our calibration procedure would overstate $\lambda_C(G)$. However, a change in $\lambda_U(G)$ would also affect the holding cost parameters, because we calibrate the holding costs for constrained investors to match the observed liquidity spreads in the data while taking $\lambda_U(s)$ and $\lambda_C(s)$ as given. If we lower the intensity of liquidity shocks, the holding cost will have to become higher in order to keep the bond liquidity spreads unchanged. This adjustment in holding cost will largely offset the impact of lower frequency of liquidity shocks on bond pricing and maturity choices.

As a robustness check, we set $\lambda_U(G)$ to 0.15, which is one-tenth of the baseline value, while keeping $\lambda_C(G)$ unchanged. Then, we examine the following two cases: (A) leaving the holding cost parameters unchanged from the baseline case; (B) recalibrating the holding cost parameters to match the bond liquidity spreads.

Figure A.4 shows the optimal maturity choices for firms with different systematic risk exposures under these alternative calibrations. In Panel A, we see that by reducing the frequency of liquidity shocks and keeping the rest of the parameters fixed, long-term debt becomes more attractive. As a result, all firms raise their debt maturity in state G, while the maturity choice in state B remains approximately the same as before. Notice that it is still true that the sensitivity of debt maturity to systematic risk is stronger in state B than in state G. Next, if we recalibrate the holding costs so that the model-implied liquidity spreads still match the data, then the optimal maturity choices across firms become essentially identical to those in the benchmark case (Figure 3, Panel A).

[23] However, restricting the sample to firms that have issued both short-term and long-term bonds introduces another selection bias in that it rules out firms with really high liquidity spreads for long-term bonds. Our estimate can be biased downward.

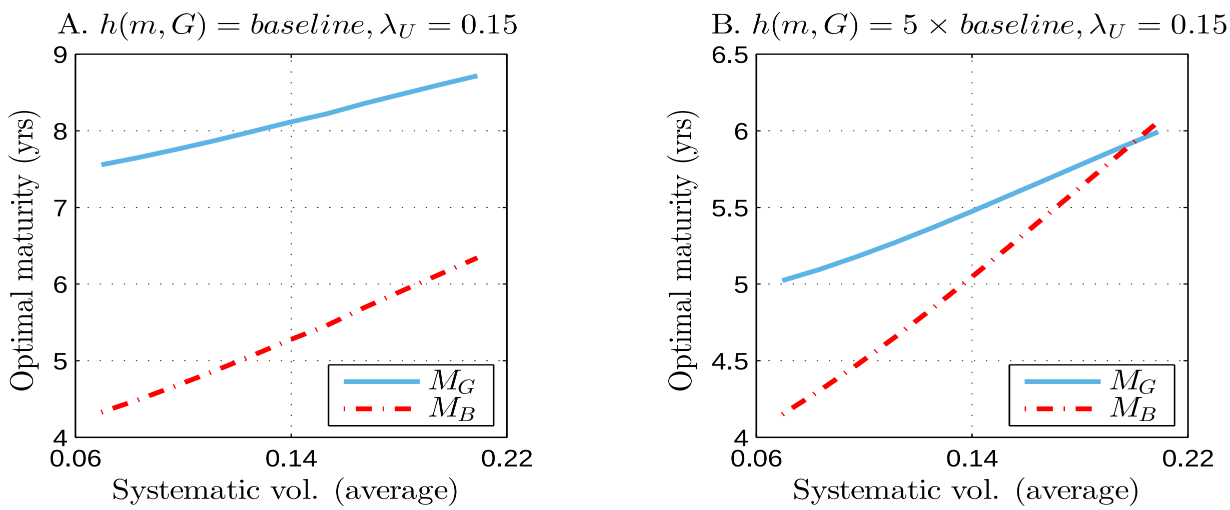

Figure A.4: Sensitivity analysis on the holding costs in state G.

Table A.1: Liquidity Spread and Bond Maturity. This table presents regression results of the bond-CDS spread on bond maturity, asset beta, bond characteristics (rating, bond age, issuing amount, and coupon rate), and firm controls (firm size, book leverage, market-to-book ratio, and profit volatility) in two sample periods: before the crisis (January 2004 - July 2007) and during the crisis (August 2007 - June 2009). We restrict the sample to firms that have issued both short-term bonds (maturity less than 3 years) and long-term bonds (maturity longer than 7 years) straight corporate bonds in the period of 2004 - 2010. We adjust standard errors by clustering the observations at the bond issue level. Robust t-statistics are presented in parentheses below parameter estimates. Significance at the 10%, 5%, and 1% levels is indicated by *, **, ***, respectively.

	Jan 04 - Jul 07	Aug 07 - Jun 09
bndmat	0.012**	0.161*
	(2.67)	(2.13)
beta	0.022	3.197***
	(0.33)	(12.28)
spltratg	0.052**	-2.245***
	(2.11)	(-12.80)
bndage	-0.001	0.370**
	(-0.33)	(3.14)
offamt	-0.015**	0.827**
	(-2.25)	(2.70)
coupon	0.037***	-1.218**
	(3.59)	(-2.73)
mkat	0.208	-32.305***
	(1.69)	(-17.64)
bklev	-0.644	32.187***
	(-1.34)	(5.48)
mk2bk	0.074***	7.279***
	(2.88)	(6.40)
profitvol	-7.774**	608.899***
	(-2.52)	(23.46)
Constant	-2.718*	331.276***
	(-1.90)	(16.81)
Observations	794	143
R^2	0.062	0.689

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