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JEL Classification: G12, G32, G33

Keywords: Maturity, value premium, Debt overhang, Cross-section of stock returns, CAPM

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The Maturity Premium *

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January 15, 2020

Abstract

This paper shows that firms with longer debt maturities earn risk premia not explained by unconditional standard factor models. We develop a dynamic capital structure model and find that firms with long-term debt exhibit more countercyclical leverage, making them more highly levered in downturns, when the market price of risk is high. The induced covariance between risk exposure and the market price of risk generates a maturity premium which we estimate at 0.21% per month. Empirical results from a conditional CAPM as well as observed beta dynamics are consistent with the model. We also exploit exogenous variation of debt maturities at the onset of the financial crisis and find that firms with shorter debt maturities experienced a smaller increase in leverage during the crisis. Also, after an initial spike, the betas of short-maturity firms reverted to levels below those of long-maturity firms by the end of 2008.

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1 Introduction

Firms' leverage is not constant through time. On average, it is higher in recessions and tends to decrease during economic booms, but there is substantial cross-sectional variation (see, e.g., Halling et al., 2016). This raises the question whether these dynamics are affected by debt maturity and how they are related to equity risk premia. Specifically, does the need to repay short-term debt during bad times, such as the recent financial crisis, expose equityholders to more risk and thus to higher required risk premia, or does the stickiness of long-term debt lead to larger swings in exposure to systematic risk? This paper sheds light on these questions.

Building on Dangl and Zechner (2016) and DeMarzo and He (2019), we show that long-term financing makes leverage more countercyclical. Firms financed with long-term debt are more highly levered in downturns, when the market price of risk is high, resulting in unconditionally higher expected returns in the cross-section. The intuition for this result is shareholders' reluctance to repurchase debt when corporate profitability falls, although this could increase total firm value. Injecting new equity to repurchase debt would imply a transfer of wealth from shareholders to the remaining bondholders, since they profit from the reduced leverage. Thus, in the absence of ex-ante commitments, such leverage reductions do not occur. This conflict of interest, as described in Admati et al. (2018), is similar in spirit to the debt overhang problem of Myers (1977), except that the distortion is with respect to the liability side of the balance sheet, instead of the assets. By contrast, firms with sufficiently short-term debt do not wish to roll over their maturing debt in a downturn, even if covenants do not prevent them from doing so. As a consequence, leverage of firms with short debt maturities is less countercyclical.

We begin by investigating the empirical relation between corporate debt maturity and the cross-section of equity returns. As a measure of maturity we use the fraction of debt that matures in more than three years (as in Custódio et al., 2013), using COMPUSTAT information. We then sort firms into portfolios based on their debt maturity, controlling for size. For our sample of CRSP firms from January 1976 to December 2017, we find that firms with long debt maturities earn a premium of 0.21% per month relative to firms with short debt maturities, controlling for their unconditional exposure to market risk. We call this return difference 'Maturity Premium'.

To ensure that the maturity premium is not driven by known firm characteristics or factor exposures that could be related to the differences in maturities between firms, we examine the exposure of the portfolio returns to the Fama and French (1993) three factors and the Fama and French (2016) five factors. We find that the maturity premium is not subsumed by the standard factors and remains statistically significant even after controlling for the factor exposures of long- and short-maturity financed firms. The magnitude of the maturity premium is economically significant, comparable to the size of the value premium (0.37% per month in our sample). Several robustness tests confirm our results.[1]

To explain the empirical findings, we propose a theoretical conditional CAPM with a dynamic corporate finance foundation. Extending the framework of Dangl and Zechner (2016) and DeMarzo and He (2019), we develop a partial equilibrium dynamic trade-off model and study its implications for the cyclicality of leverage and stock returns. As in Admati et al. (2018), Dangl and Zechner (2016), and DeMarzo and He (2019), it is never optimal in our model for equityholders to actively repurchase existing debt. This is due to a debt overhang problem, since such a debt repurchase transfers wealth from shareholders to remaining debtholders, who benefit from lower default probability without participating in the leverage reduction. This debt overhang problem is mitigated when some debt matures. Following profitability drops, shareholders optimally choose not to rollover part of the maturing debt, thereby reducing leverage. Shorter maturity strengthens this effect, since it implies a higher rollover rate. Shareholders of firms financed with short-term credit suffer less from the mis-alignment of incentives with creditors and, as a consequence, their leverage decreases more quickly when profitability falls. This is in contrast to firms financed with long-term debt because their debt level decreases very slowly after a negative profitability shock and thus, their leverage stays elevated for a substantial period of time.

While short-maturity financed firms delever faster in the course of extended downturns, they initially exhibit larger spikes in beta when firm productivity falls sharply, since firms with short debt maturities default at higher cash flow levels. Thus, a sharp, sudden drop in cash flows initially pushes firms with short maturities closer to default, as the debt reduction via expiring debt has not yet had time to take effect. However, as time passes, these firms quickly reduce leverage by not rolling over maturing debt. In contrast, long-maturity financed firms experience a more modest spike in market leverage initially, but due to their low rollover rate their leverage stays elevated for a long period of time.

In our model this matters to shareholders, since they assign a higher price to systematic risk in downturns. Long-term financed firms expose shareholders to more systematic risk during downturns than short-term financed firms and shareholders require compensation for this. While the conditional CAPM holds in our setting, one observes a maturity premium if one only controls for the average level of systematic exposure, i.e. if the unconditional CAPM is applied. In this case, a portfolio that is long long-maturity financed firms and short short-maturity financed firms earns an alpha relative to CAPM. This is so since long-term financed firms have higher levels of leverage, and therefore, higher levels of equity beta exactly when the market price of risk is high. Short-term

[1] We provide alternative portfolio sorts in the Internet Appendix in Section A.

financed firms exhibit lower covariance between their market beta and the market price of risk, and therefore generate a smaller unconditional alpha.

Our model replicates both the direction and the magnitude of the empirical relation between debt maturity and equity returns. In a simulated panel of firms, the alpha in the unconditional CAPM increases monotonously in maturity. Moreover, in the calibrated version of the model where characteristics (maturity, idiosyncratic risk and marginal tax rates) of short- and long-maturity financed firms resemble those we see in the data, we find that a long-short portfolio earns an alpha of 0.19% monthly. This is close to the maturity premium of 0.21% we observe empirically.

The last part of the paper provides specific empirical evidence for the predictions of our model. First, we conduct a direct test of the mechanism driving the maturity premium. We hereby exploit the arguably exogenous variation in the debt maturity of firms at the onset of the financial crisis in 2008 due to the lumpiness of firms' debt. The idea is that two firms that optimally choose the same debt maturity when the debt instrument, say the bond, is issued may have different effective debt maturities at a given point of time, since the issue date of the debt components differs randomly across firms. For example, a firm that has issued its seven-year bond five years ago has a two year remaining debt maturity, whereas a firm that has issued a similar bond one year ago has a six-year remaining maturity. We use this variation to test for the causal link between maturity and the dynamics of leverage and betas.

Using data from Capital IQ, we select firms that typically use debt instruments of five- to seven-year maturity at the time of issuance. We then sort them into three bins based on the remaining maturity at the end of 2007, i.e. at the beginning of the financial crisis. Consistent with the model predictions, we find that firms that had relatively short remaining debt maturities had a larger initial spike in their betas in 2008, but their systematic risk exposure fell quickly back to the pre-crisis levels. On the other hand, firms that had longer-maturity debt at the end of 2007 initially experienced a more modest increase in market leverage and beta, but both their leverage as well as their risk exposures stayed elevated for a longer period of time. In 2009 the levels of both leverage and estimated market betas of long-maturity firms were still higher than those of short-maturity firms, and the difference stayed positive for a few more years. Thus, consistent with our model predictions, an arguably exogenous shorter maturity of debt at the end of 2007 led to more dynamic drops in leverage and betas subsequent to the initial shock of the financial crisis, whereas firms with longer maturities continued to exhibit higher leverage and systematic risk exposures for an extended period of time.

Second, we estimate a conditional CAPM by using information in macro-variables to predict the market price of risk, as in Choi (2013). We find that our portfolio that is long long-maturity financed firms and short short-maturity financed firms indeed has higher exposure to systematic risk when the market price of risk is high, i.e. in downturns. Although the predictive regressions for the market price of risk are quite noisy, the drop in the alpha estimate in the conditional CAPM is statistically significant. This result is consistent with our model prediction that the maturity premium is a compensation for higher systematic exposure during downturns. In addition, we find that it is the long leg of the portfolio that is responsible for the increase of the systematic exposure in downturns, while the short leg shows no evidence of cyclicality. We also find that the maturity premium is most pronounced among highly-levered firms. To verify that our findings are robust to the information-conditioning in the beta estimation, we obtain an additional conditional beta estimate using short-window CAPM-regressions. We find that the estimated beta of the long-short maturity portfolio co-moves positively with the estimated market price of risk. This finding provides additional support for the robustness of the finding that long-term financed firms are more exposed to systematic risk in downturns, as the time series of beta is estimated without pre-selecting conditioning macro-variables.

Our paper is related to work on the effects of operating leverage on the value risk premium. Since value firms have exercised their growth options, they tend to exhibit higher operating leverage, whereas growth firms tend to have low overhead costs and operating leverage (Zhang, 2005; Cooper, 2006). If operating leverage is sticky, then decreasing revenues have a bigger impact on the equity of value firms than on the equity of growth firms due to the difference in their operating leverage. Consequently, the beta of growth firms is more stable over time, while the beta of value firms increases substantially in crises (Lettau and Ludvigson, 2001). Due to the fact that value firms are riskier in crises, they may command an unconditionally higher required rate of return on their assets. While plausible, the operating leverage alone cannot account for the entire size of value premium observed empirically. To match the magnitude of the value premium, an extreme assumption of investment irreversibility is required, which contradicts empirical evidence on the sales of assets in the secondary market on average by more than 18% of firms in every given quarter (Clementi and Palazzo, 2019).

Rather than taking the stickiness of operating leverage as exogenously given to explain risk premia, we develop a model where leverage dynamics are chosen optimally by firms. We demonstrate that optimal leverage adjustments and thus equity risk premia depend on debt maturity. Therefore, the extent to which financial leverage in our model can give rise to a value premium depends on the difference in maturity choices of value and growth firms. Empirically, growth firms borrow with shorter maturities than value firms (Barclay and Smith, 1995; Barclay et al., 2003; Custódio et al., 2013). Thus, the long-term debt of value firms creates a convex shape of equity's beta as a function of the aggregate state. It is precisely this time variation in beta, which is not captured by the standard unconditional CAPM equation, that creates a value premium through a maturity and leverage dynamics channel. Consistent with the idea that financial leverage contributes to the value premium, Doshi et al. (2019) find that unlevered equity returns exhibit no value premium.

More broadly, our paper contributes to the literature exploring asset pricing implications of capital structure and investment decisions. For example, Choi (2013) shows that a higher level of financial leverage of value firms contributes to the value premium. We argue that beyond the current level of debt, the maturity of the debt liabilities plays a crucial role in generating an equity premium. Friewald et al. (2018) document an equity premium for rollover risk of firms with a larger fraction of their debt maturing within one year. While this result might appear to contradict our findings, it is in fact fully consistent with our hypothesis that short-maturity financed firms are risky over short holding horizons. Friewald et al. (2018) isolate the effect of rollover risk on firms over short horizons, considering leverage as fixed. Our analysis focuses on the combination of debt maturity and the dynamic adjustments of leverage. Cao (2018) argues that firms that borrow from the bond market are more risky than firms that borrow predominantly from banks because they have more difficulty re-negotiating their debt, and this risk is priced by equityholders. Berk, Green and Naik (1999), Gomes and Schmid (2010), Kuehn and Schmid (2014), Babenko, Boguth and Tserlukevich (2016), and Gu, Hackbarth and Johnson (2017), among others, explore the implications of investment decisions and exercised growth options on equity returns but do not account for dynamic leverage adjustments, as we do.

Chen, Hackbarth and Strebulaev (2018) analyze the distress risk puzzle based on a dynamic capital structure model. In their model, firms are exposed to time-varying indirect distress costs, which drive the apparent under-performance of distressed firms. In contrast to their paper, we focus on the role of finite debt maturity, while their firms issue perpetual debt. Our setup provides a complementary rational explanation for the distress risk puzzle. In our model, short-maturity financed firms have higher leverage and default probabilities, but their betas co-vary less with the market price of risk. Relative to the unconditional CAPM, short-maturity financed firms seem to under-perform long-maturity financed firms, consistent with the return pattern that gave rise to the distress risk puzzle.

Our paper also contributes to the literature on leverage adjustments. In particular, differences in maturity in our model explain differences in the speed of leverage adjustments between firms. In that sense, our paper is related to the literature on sticky leverage (Gomes et al., 2016) and transitory deviations of debt from the long-term target (DeAngelo et al., 2011; Ippolito et al., 2018).

Mao and Tserlukevich (2014) explore leverage adjustments in a model where firms can use some of their assets, such as cash or other liquid assets, to repurchase debt.[2] In our model we instead focus on the role of debt maturity and assume that equityholders cannot sell corporate assets to fund debt repurchases. Jungherr and Schott (2019) investigate the business-cycle implications of the sticky leverage caused by long maturity of debt, arguing that the failure to delever in downturn by long-maturity financed firms depresses aggregate investments. They do not, however, consider asset-pricing implications of the sticky long-term leverage.

Chen et al. (2019) document that maturity is pro-cyclical. They argue that this is due to liquidity shocks to bond holders, which become more pronounced in crises and affect long-term bond holders more severely. In our setting, we abstract from optimal maturity adjustments.[3] However, it is likely that our results would be strengthened by a potential shortening of maturities during downturns because, ceteris paribus, firms' betas increase with shorter maturities. In addition, firms' optimal leverage increases with shorter debt maturities in our framework. Thus, shorter maturities plus higher debt face values imply that firms would experience even sharper increases in betas during crises than fixed long-maturity firms do in our model.

Finally, other aspects of corporate policy decisions, such as the fraction of secured and convertible debt (Valta, 2016), cash holdings (Simutin, 2010), debt capacity (Hahn and Lee, 2009), and competition in the production chain (Gofman et al., 2019) have been shown to be related to equity risk premia. We contribute to this literature by demonstrating that the maturity choices by firms influence future leverage dynamics and therefore command an equity premium. Capital structure adjustments in our model vary over the business cycle. Hackbarth et al. (2006) also derive a model where firms' capital structures vary with the business cycle.

We contribute to the dynamic corporate finance literature by extending the framework of Dangl and Zechner (2016) and DeMarzo and He (2019) by explicitly modeling time-varying market risk premia and analyzing the asset-pricing implications of leverage dynamics in such a setting.

The rest of the paper is organized as follows. Section 2 provides motivating empirical evidence on the maturity premium. The theoretical model is developed in Section 3, and its implications for the maturity premium are explored in Section 4. Section 5 presents direct empirical evidence supporting the model implications, and Section 6 concludes.

[2] See also Julio (2013) for the empirical investigation of debt repurchases.

[3] Recent papers that tackle the question of maturity dynamics include Brunnermeier and Oehmke (2013); He and Milbradt (2016); Chaderina (2018) among others.

2 Empirical Results

We first document a positive relation between debt maturity and equity returns. We establish this result by analysing a portfolio that is long long-maturity financed firms and short short-maturity financed firms, controlling for various risk factors including the Fama and French (1993) three factors and Fama and French (2015) five factors.

2.1 Data

We use CRSP monthly returns on common equity of US-based enterprises from NYSE, AMEX, and NASDAQ and accounting data from Compustat's North America Fundamentals Annual file. Firms are included when all items for computing a firm's debt maturity are available.[4] This restriction limits our sample, as COMPUSTAT does not provide all items required for the debt maturity proxy for fiscal years ending before 1974. To ensure consistency, we truncate the matched sample by excluding observations before 1976.

2.2 Debt Maturity and Firm Characteristics

The key variable in our analysis is debt maturity (DM).[5] Following Barclay and Smith (1995) and Custódio et al. (2013) we define debt maturity as the relative amount of long-term debt maturing in more than 3 years.[6] Given recent empirical evidence on the use of credit lines (Korteweg et al., 2019), we believe that the cut-off of 3 years is justified as it allows us to exclude most of the debt from credit lines, which is arguably short-term in nature.

In addition, for every firm we compute leverage (L) as the ratio of book debt to the sum of book debt and market equity. Moreover, we compute market capitalization (ME) as the price per share times the number of shares outstanding. Following Fama and French (1992, 1993) we compute book equity and the book-to-market ratio (BM). To be included in our sample, we require observations to have positive values for book equity, debt maturity, and leverage.

[4] In the current analysis we include financials and utilities. However, the main results are robust to excluding them from the sample as shown in Table IA-1 of the Internet Appendix.

[5] For detailed definitions on all variables, including the exact items used, we refer to Appendix D.

[6] While we could have used alternative measures of debt maturity, we chose to follow the previous literature. Incorporating information on the dispersion between different maturity buckets by calculating a weighted average maturity in years from COMPUSTAT did not change our main results.

Table 1: Summary Statistics. We compute mean, standard deviation, as well as the 25%-, 50%-, and 75%-quantiles on a monthly frequency for the cross-section of firm characteristics. The table presents time series averages of the monthly statistics. Excess returns, leverage and debt maturity are displayed in % and market equity in million USD. The underlying data set comprises matched observations from CRSP and COMPUSTAT from January 1976 until December 2017. In total, the panel consists of 1,840,640 firm-month observations of 18,392 unique firms.

	Mean	SD	Q_{25}	Median	Q_{75}
Excess Returns	0.92	15.64	−6.08	0.01	6.45
Market Equity (ME)	2,365.89	9,903.90	59.10	260.15	1,111.80
Book-to-Market Ratio (BM)	0.93	0.94	0.43	0.74	1.16
Leverage (L)	31.33	23.92	10.71	27.08	48.55
Debt Maturity (DM)	53.15	33.87	21.55	58.87	83.32

The final sample consists of 1,840,640 firm-month observations for a total of 18,392 unique firms over a time horizon from January 1976 until December 2017. Table 1 presents summary statistics for this sample. Long-maturity debt is an important source of funds for firms. On average, about half of the outstanding debt for our representative firm is maturing in more than 3 years.

We ensure that accounting information on debt maturity, leverage, and book equity is publicly available upon portfolio assignment by following the procedures of Fama and French (1992, 1993). Thus, we consider information from year t for portfolio assignments at the end of June of year $t+1$ until the following June.

Table 2 summarizes the characteristics of firms across five debt maturity buckets. We notice that there is a substantial heterogeneity in the maturity profiles. On average, firms with the shortest maturity have roughly 95% of debt maturing in the next three years, while firms with the longest maturity have more than 95% of debt maturing in more than three years. Moreover, firms in the shortest maturity bucket are substantially smaller than firms in the longest maturity bucket. However, their book-to-market ratios, a proxy for the exposure of assets to systematic risk, are almost the same. Also, shorter-maturity financed firms have lower leverage and higher idiosyncratic volatility than longer-maturity financed firms.

Table 2: Firm Characteristics Across Debt Maturity. We compute average characteristics across five debt maturity buckets. The table presents time-series averages of the annual characteristics within each bucket. Idiosyncratic volatility is estimated from rolling CAPM regressions on monthly returns with a five year window. Market equity in million USD. The marginal tax rates are based on Blouin et al. (2010). The underlying data set comprises matched observations from CRSP and COMPUSTAT over the time horizon January 1976 until December 2017.

Debt Maturity	Short	···	Medium	···	Long
Debt Maturity (%)	5.18	32.86	60.23	79.59	95.25
Market Equity	520.59	2,815.75	3,368.51	2,529.03	1,492.49
Book-To-Market	0.92	0.98	0.96	0.96	0.93
Leverage (%)	23.89	32.97	34.23	35.11	32.08
IVOL (%)	14.93	12.29	10.93	10.40	11.25
Tax Rate (%)	19.71	23.50	26.10	27.68	27.67

2.3 Portfolio Sorts

We construct portfolios double-sorted on debt maturity and size. At the end of each month, we rank stocks into quintiles by their size (ME) and then into conditional quintiles by their debt maturity (DM). We use conditional sorts since debt maturity varies with firm size. In our sample, smaller firms tend to borrow with shorter-maturity debt than larger firms, as can be seen from Table 2. An unconditional portfolio sort would ignore this heterogeneity and introduce a size effect in maturity-sorted portfolios.[7]

Panel A in Table 3 shows the average monthly excess return on the resulting 25 portfolios. Within each size quintile we create a long-short portfolio that is long the long-maturity bucket and short the short-maturity bucket (long-minus-short or *LMS* portfolio). Panel B in Table 3 summarizes the excess returns, alphas, and betas of the five LMS portfolios. Moreover, we also create an overall LMS portfolio, which invests equally across the five size groups. To control for differences in risk across the portfolios, we present beta estimates and corresponding alphas from the CAPM, the Fama and French (1993) three-factor model and the Fama and French (2015) five-factor model. The betas shown at the bottom of the table correspond to the estimates from the five-factor model.

Both raw and risk-adjusted returns in Table 3 indicate a positive relation between debt maturity and stock returns. Firms financed with long-term debt outperform firms financed with short-term debt on average by 0.21% per month, controlling for differences in systematic risk. Specifically, the

[7] While there are good reasons to use conditional portfolio sorts, the results are qualitatively similar to sorting unconditionally, as shown in Table IA-2 in the Internet Appendix.

double-sorted long-minus-short portfolios have statistically significant CAPM alphas in the smallest three size quintiles. Moreover, in the smallest size-bucket the long-maturity firms outperform short maturity firms by 0.44% per month.[8]

The positive and statistically highly significant factor loading β^{HML} indicates that the LMS portfolio has an exposure to the value factor. However, the value premium does not subsume the maturity premium. Even after controlling for the value factor, the alpha on the LMS portfolio remains positive and statistically significant. The maturity portfolio aslo has marginally negative exposure to systematic risk, indicating that the average beta of long-maturity financed firms is smaller than that of the short-maturity financed firms.

[8] While value-weighted portfolios alleviate the concern of a small-cap bias, the LMS portfolio results are robust to excluding the bottom size quintile, as shown in Table IA-3 in the Internet Appendix. Our results are also robust to equal-weighted portfolio sorts as shown in Table IA-4. Moreover, the maturity premium in the LMS is most pronounced among more highly levered firms, see Table IA-5 the Internet Appendix.

Table 3: Debt Maturity-Sorted Portfolios. Panel A shows the average excess return of the individual value-weighted portfolios. The last row represents the long-maturity minus short-maturity portfolios (LMS). The portfolios are formed by double sorts on size (5 buckets at 20%, 40%, 60%, and 80%-percentile) and debt maturity (5 buckets at 20%, 40%, 60%, and 80%-percentile) conditional within each size group. Panel B displays results for the LMS portfolios within each size bucket (LMS1 for small to LMS5 for large firms) and the average return of these five portfolios in the last column (LMS itself). The long-short portfolios are characterized by excess returns (r^e) as well as alpha estimates from CAPM-regressions (α^{CAPM}), the 3-factor model by Fama and French (1993) (α^{FF3}) and the 5-factor model by Fama and French (2015) (α^{FF5}). Moreover, factor loadings for FF5 are shown. We report t-statistics based on standard errors following Newey and West (1987, 1994) in parentheses. The underlying data set comprises matched observations from CRSP and COMPUSTAT from January 1976 until December 2017.

Panel A: Portfolio Sorts

		Size				
		Small	·	Medium	·	Large
Debt Maturity	Short	0.59	0.71	0.72	0.81	0.62
	·	0.66	0.82	0.86	0.89	0.68
	Medium	0.75	0.82	0.92	0.89	0.66
	·	0.86	0.89	0.99	0.93	0.60
	Long	0.92	0.91	0.86	0.86	0.64
LMS		0.33	0.20	0.14	0.05	0.01

Panel B: Long-Short Portfolios (long-minus-short debt maturity, LMS)

	LMS1	**LMS2**	**LMS3**	**LMS4**	**LMS5**	**LMS**
r^e	0.33**	0.20	0.14	0.05	0.01	0.15*
	(2.01)	(1.25)	(1.21)	(0.59)	(0.09)	(1.93)
α^{CAPM}	0.44***	0.32**	0.22*	0.04	0.03	0.21***
	(2.98)	(2.03)	(1.82)	(0.41)	(0.26)	(2.93)
α^{FF3}	0.35***	0.20	0.09	0.00	0.11	0.15**
	(2.69)	(1.44)	(0.82)	(0.04)	(0.94)	(2.31)
α^{FF5}	0.30**	0.10	−0.06	−0.11	0.25**	0.10*
	(2.27)	(0.59)	(−0.60)	(−1.22)	(2.57)	(1.67)
β^{M}	−0.08**	−0.04	0.02	0.08***	−0.13***	−0.03*
	(−1.99)	(−1.17)	(0.75)	(3.62)	(−4.45)	(−1.78)
β^{SMB}	−0.17***	−0.23***	−0.12***	−0.01	0.07	−0.09***
	(−3.09)	(−3.53)	(−2.76)	(−0.28)	(1.41)	(−2.97)
β^{HML}	0.36***	0.33***	0.33***	0.00	−0.13	0.18***
	(5.44)	(3.80)	(5.25)	(0.08)	(−1.32)	(3.92)
β^{RMW}	0.20***	0.22	0.36***	0.18**	−0.26***	0.14***
	(2.73)	(1.51)	(5.18)	(2.50)	(−3.55)	(2.65)
β^{CMA}	−0.21*	0.05	0.01	0.20**	−0.16	−0.02
	(−1.89)	(0.46)	(0.07)	(2.21)	(−1.41)	(−0.45)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3 Model

In this section, we analyze the implications of different debt maturities for the dynamics of firms' leverage. The key feature of our model is that equityholders at every instant without prior commitment decide what fraction of their maturing debt to re-finance. Following Dangl and Zechner (2016) and DeMarzo and He (2019), we assume that equityholders cannot credibly commit to future leverage reductions via contractual obligations.[9] This setup allows for a tractable link between debt maturity and leverage dynamics. While our model lacks some realistic features such as transactions costs or different debt seniority, it allows us to analyze the effect of debt maturity on equity risk premia in a parsimonious way.[10]

3.1 Cash Flow

We consider a market comprised of heterogeneous firms. An individual firm's cash flow before paying interest and taxes, $Y_{i,t}$, is the product of two components, namely $Y_{i,t} = X_t \cdot I_{i,t}$. First, cash flows of all firms are driven by an aggregate productivity factor, X_t, which follows a geometric mean-reverting process with a drift $\mu(X_t,t)$ and volatility σ_X:

$$dX_t = \mu(X_t,t)X_t\,dt + \sigma_X X_t\,dW^P_{X,t}, \tag{1}$$

$$\mu(X_t,t) = \mu_0 - k\left[log(X_t) - \left(\mu_0 - \sigma_X^2/2\right)t\right]. \tag{2}$$

The growth rate of the aggregate process $\mu(X_t,t)$ is mean-reverting with a speed of k to its time-average of μ_0.[11] The drift's deviations from μ_0 are due to X_t diverging from its expected growth path. During periods where X_t is above the expected trajectory, expected growth rates are reduced. Thus, the drift component introduces cyclicality to the productivity growth, i.e. a business cycle.[12]

[9] Contractual commitments to leverage reductions are not trivial, as can be seen from the work on contingent convertible bonds (CoCos), which are granted an equity-like treatment in the regulatory framework of Basel III. CoCos feature a trigger that leads to automatic recapitalization. Several papers show that such automatic recapitalizations can create agency conflicts, potentially leading to earnings management, underinvestment and risk shifting. See, for example, McDonald (2013), Flannery (2014), Sundaresan and Wang (2015) or Goncharenko (2019). Thus, our assumption of no commitment to leverage reductions may be motivated by contracting frictions firms face.

[10] The link between maturity and the dynamics of leverage is robust to incorporating transactions costs into the framework, as shown by Dangl and Zechner (2016) for proportional issuance costs of debt or by Benzoni et al. (2019) for fixed debt issuance costs.

[11] Note that while $\mathbb{E}_0[\mu(t,X_t)] = \mu_0$, it is not true that $\mathbb{E}_0[X_t] = X_0 e^{\mu_0 t}$. In fact, $\mathbb{E}_0[X_t] < X_0 e^{\mu_0 t}$, and the reason the aggregate process grows at a smaller rate than it would if the drift-process was not mean-reverting is in the negative covariance between μ_t and X_t. $\mathbb{E}_0[X_t e^{\mu_t t}] = Cov(X_t, e^{\mu_t t}) + \mathbb{E}_0[X_t]\,\mathbb{E}_0[e^{\mu_t t}] < \mathbb{E}_0[X_t]\,e^{\mu_0 t}$. It is also true that $\mathbb{E}_0[e^{\mu_t t}] < e^{\mu_0 t}$ due to Jensen's inequality.

[12] The current specification for the drift process admits low values for the growth rate of the productivity process. Some of them are low enough so that the market price of risk, which is related to the drift, can turn negative. While

The firm-specific cash-flow shocks are orthogonal to the aggregate state variable, and are determined by a firm-specific idiosyncratic factor $I_{i,t}$, which is independent across firms. It follows a geometric Brownian motion without drift:

$$dI_{i,t} = \sigma_i I_{i,t}\, dW^P_{i,t}. \tag{3}$$

Given the multiplicative combination of the variables, the resulting cash flow $Y_{i,t}$ of a firm i also follows a geometric Brownian motion (under the physical measure)

$$dY_{i,t} = \mu(X_t,t) Y_{i,t}\, dt + \sigma_Y Y_{i,t}\, dW^P_{Y_i,t}, \tag{4}$$

where $\sigma_Y = \sqrt{\sigma_X^2 + \sigma_i^2}$ and $dW^P_{Y_i,t} = (\sigma_X\, dW^P_{X,t} + \sigma_i\, dW^P_{i,t})/\sigma_Y$. Moreover, under the risk-neutral measure, a firm's cash flows are

$$dY_{i,t} = \mu_Y Y_{i,t}\, dt + \sigma_Y Y_{i,t}\, dW^Q_{Y_i,t}, \tag{5}$$

where $\mu_Y < r$. In Section 4.1, we further specify the Girsanov kernel associated with this measure change from no-arbitrage conditions for the market portfolio, and characterize μ_Y. We take the consumption process of the representative consumer in the economy as given, so under our assumptions the financing decisions of a firm impact neither the change of measure nor the market price of risk.

3.2 Debt and Equity Valuation

Consider a firm that issues debt with face (book) value $F_{i,t}$. The bond pays a fixed coupon rate c that is tax-deductible. The marginal tax rate is denoted by τ. In the spirit of finite-maturity debt models (e.g., Leland (1994) and Leland (1998), among others), we consider a debt structure in which a constant fraction m_i of outstanding bonds matures every period. The average maturity of outstanding debt is $1/m_i$, which is constant even if the firm stops rolling over maturing debt. Hence, cash flows to debt holders in the absence of default are given by the coupon payments and the retirement of debt $(c + m_i)F_t\, dt$. In default we assume a zero recovery for simplicity. When the firm is founded, it chooses a debt maturity, which is then held constant throughout the firm's

it might seem counter-intuitive, empirical estimates for the market price of risk do turn negative (Cochrane, 2011). Moreover, for robustness we also solve and simulate the model with an alternative specification for the drift that is bounded from below, ensuring that the market price of risk is always non-negative. All the main results remain qualitatively the same, and the maturity premium is only slightly smaller quantitatively. See Internet Appendix B for details.

life. As in DeMarzo and He (2019), founders of firms are indifferent between alternative debt maturities.

At any point in time, the firm can issue new debt with a face value $G_{i,t}$. Negative values of $G_{i,t}$ represent voluntary retirements. As long as $G_{i,t}$ is less than or equal to the maturing debt, $m_i F_{i,t}$, the firm's total face value of debt is either reduced or stays constant. In contrast to Dangl and Zechner (2016) and following DeMarzo and He (2019), firms in our model are also allowed to increase debt smoothly by issuing more than the maturing fraction of debt, i.e. choosing $G_{i,t} > m_i F_{i,t}$. Consequently, the dynamics of the outstanding face value of debt is:

$$dF_{i,t} = (G_{i,t} - m_i F_{i,t})\, dt\,. \tag{6}$$

Next, we specify the cash distributions to equity owners. We abstract from transaction costs of issuing either debt or equity. Hence, the residual cash flow net of debt-related payments and taxes,

$$\Pi^i_{t,t+dt} = \left\{ Y_{i,t}(1-\tau) + \tau c F_{i,t} - (c+m_i)F_{i,t} + G_{i,t} v^D_{i,t} \right\} dt, \tag{7}$$

is distributed to equityholders. The first term represents the operating cash flows before interest. The second term captures the tax benefits of debt coupons. The third and fourth term are related to leverage adjustments: The currently outstanding debt $F_{i,t}$ has to be serviced by paying coupons and retiring the maturing portion and new debt is issued (or bought back if $G_{i,t}$ is negative) at market prices $v^D_{i,t}$.

The market values of equity and debt claims, $V^E_{i,t}$ and $V^D_{i,t}$, can be computed as the conditional expectations of their respective future cash flows under the risk-neutral measure Q:

$$V^E_i(Y_{i,t}, F_{i,t}) = \mathbb{E}^Q_t \left[\int_t^{t_b} e^{-r(s-t)} \Pi^i_{t,s}\, ds \right], \text{ and} \tag{8}$$

$$V^D_i(Y_{i,t}, F_{i,t}) = \mathbb{E}^Q_t \left[\int_t^{t_b} e^{-(r+m_i)(s-t)} (c+m_i)\, ds \right] F_{i,t}, \tag{9}$$

where t_b denotes the time when the equity owners endogenously declare default.

Following DeMarzo and He (2019), we restrict the solution space to policy functions $G_{i,t}$ which are continuous in the state variables, i.e. the debt issuance policy is smooth. The equity maximization problem involves solving the Hamilton-Jacobi-Bellman equation, which is homogeneous in the face value of debt $F_{i,t}$. Therefore, we scale every variable by $1/F_{i,t}$, and use lower case letters to indicate the scaled version, e.g., $y_{i,t} = Y_{i,t}/F_{i,t}$ throughout.

Using the valuation principles from DeMarzo and He (2019), we find the closed-form solutions for the scaled value of equity[13]:

$$v_i^E(y_{i,t}) = \frac{1-\tau}{r-\mu_Y} y_{i,t} - \frac{c(1-\tau)+m_i}{r+m_i}\left(1 - \frac{1}{1+\gamma_i}\left(\frac{y_{i,t}}{y_{bi}}\right)^{-\gamma_i}\right), \tag{10}$$

$$\gamma_i = \frac{(\mu_Y + m_i - \sigma_Y^2/2) + \sqrt{(\mu_Y + m_i - \sigma_Y^2/2)^2 + 2\sigma_Y^2(r+m_i)}}{\sigma_Y^2} > 0,$$
$$y_{b,i} = \frac{\gamma_i}{1+\gamma_i}\frac{r-\mu_Y}{r+m_i}\left(c + \frac{m_i}{1-\tau}\right),$$

where $y_{b,i}$ denotes the endogenously chosen scaled cash flow at which the equityholders default.

Moreover, from the solution to the equity-maximization problem we can derive the value of debt. Given that equityholders can adjust the outstanding amount of debt freely, the equilibrium price of debt $v_i^D(y_{i,t})$, i.e. the marginal benefit from debt issuance, will equal the marginal cost of future obligations, $-\partial V^E(Y,F)/\partial F$. Hence, the price of debt per unit of face value equals

$$v_i^D(y_{i,t}) = \frac{c(1-\tau)+m_i}{r+m_i}\left(1 - \left(\frac{y_{i,t}}{y_{b,i}}\right)^{-\gamma_i}\right). \tag{11}$$

3.3 Debt Issuance Policy and Leverage Dynamics

The optimal debt issuance policy function $g_{i,t}$ is a key driver of leverage dynamics. As we show in Appendix A, the debt issuance policy function is given by

$$g_i(y_{i,t}) = m_i\left(\frac{y_{i,t}}{y_{m,i}}\right)^{\gamma_i}, \tag{12}$$

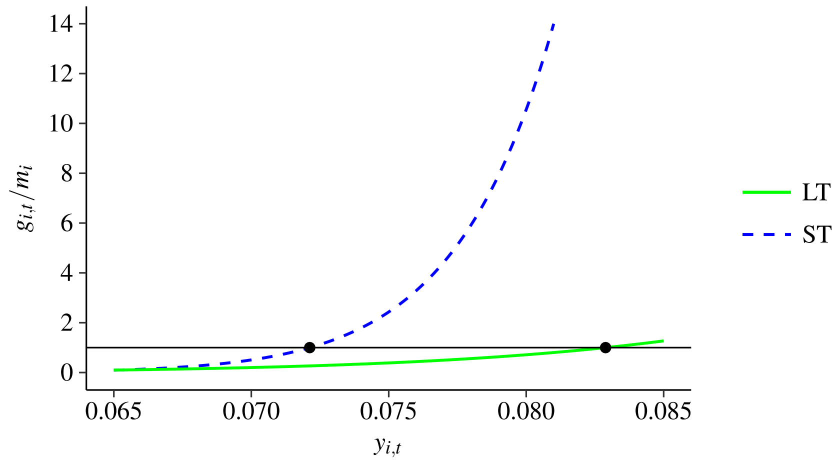
where $y_{m,i}$ denotes the scaled cash flow level at which the firm's issuance rate is exactly equal to the maturity rate m_i:

$$y_{m,i} = y_{b,i}\left(\gamma_i \frac{c(1-\tau)+m_i}{(r+m_i)\tau c} m_i\right)^{1/\gamma_i}. \tag{13}$$

At the scaled cash flow level $y_{m,i}$ the firm keeps the outstanding amount of debt constant. For a level of cash flows $Y_{i,t}$, we refer to the face value of debt that results in the scaled level of cash flows of $y_{m,i}$, i.e. $F_{m,i,t} = Y_{i,t}/y_{m,i}$, as the target face value of debt.

[13] For a detailed model solution see Appendix A.

Figure 1: Optimal Rollover Rate. This graph shows the optimal rollover rate of debt, which is given by the issuance policy $g_{i,t}$ scaled by the maturity rate m_i. This ratio equals one when the firm's net issuance is zero. The short- and long-maturity financed firms are characterized by $m_i = 0.5$ and $m_i = 0.2$, i.e. a debt maturity of 2 (ST) and 5 (LT) years, respectively. The volatility of the cash flows is $\sigma_X = 0.15$ and $\sigma_i = 0.15$. The solid (dashed) line represents the rollover rate of the LT (ST) firm.



Equation (12) implies that the net debt issuance is non-negative. This means that shareholders never actively repurchase debt, even though there are no associated transaction costs. This illustrates the leverage ratchet effect of Admati et al. (2018) and the debt-overhang problem that existing debt creates. Second, the rollover rate positively depends on cash flow shocks, meaning that firms with higher cash flows per unit of face value issue more debt. Figure 1 illustrates the optimal debt issuance policy functions for different levels of cash flow shocks and different maturities of debt. Long and short-term financed firms have different levels of optimal leverage. As short-term financed firms have higher target leverage levels, there are cash flow values $y_{i,t}$ for which short-term financed firms issue debt, while long-term financed firms reduce leverage through partial rollover, everything else equal. However, short-term financed firms respond more aggressively to changes in cash flows than long-term financed firms. They are relatively more aggressive at both increasing the leverage after positive cash flow shocks, and decreasing leverage after negative cash flow shocks.

3.4 The Leverage Ratchet Effect and Maturity

The goal of our theoretical model is to establish the effect of different debt maturities on the dynamics of leverage over a profitability cycle. In this subsection, we look at the evolution of market leverage of two firms — one financed with long-term debt (low m_i) and one financed with short-term debt (high m_i) — that were hit with the same sequence of cash flow realizations. Our focus is on the difference in leverage responses between the two firms.

The market leverage in our model is:

$$L_{i,t} = \frac{v^D_{i,t}}{v^E_{i,t} + v^D_{i,t}}\ , \tag{14}$$

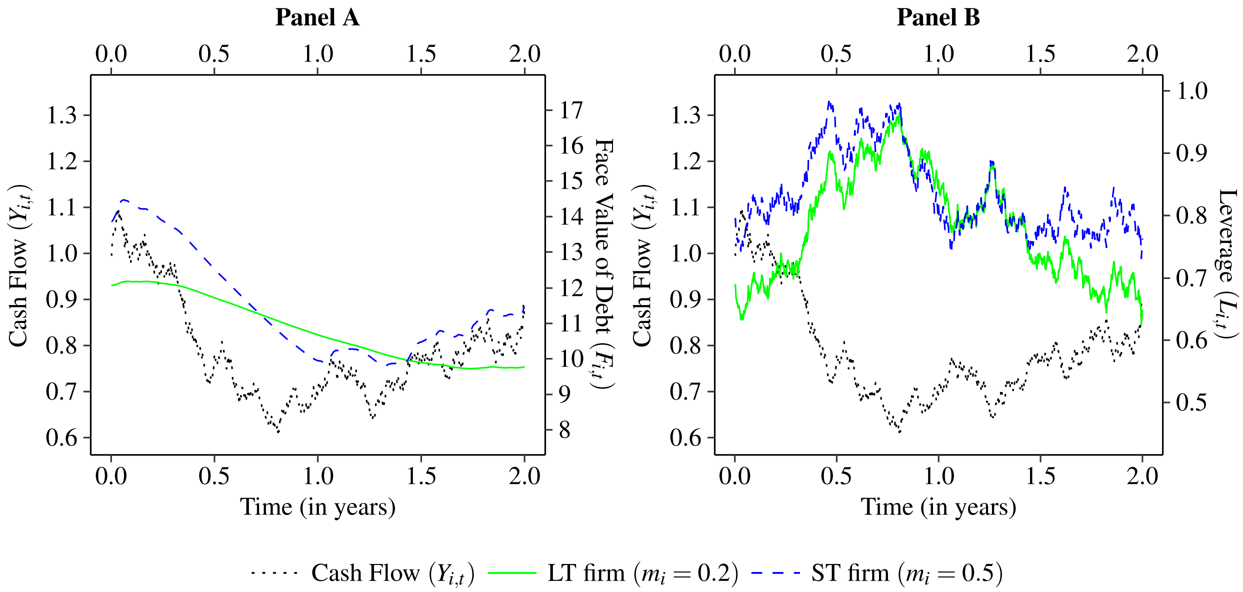
and it changes over time for two reasons — the firm actively manages the face value of debt outstanding $F_{i,t}$, and the value of the firm's assets changes. The face value of debt can increase or decrease over time, as the firm sometimes decides to issue additional debt, while at other times it optimally lets the debt mature and does not roll it over completely. The dynamics of $F_{i,t}$ depend on the realized path of the cash flow process:

$$F_{i,t} = \left(\int_0^t \gamma_i m_i \left(\frac{Y_{i,s}}{y_{m,i}} \right)^{\gamma_i} e^{\gamma_i m_i (s-t)}\, ds \right)^{1/\gamma_i}. \tag{15}$$

Following Admati et al. (2018), we define the ratchet effect of leverage as shareholders' unwillingness to actively repurchase debt following a deterioration of market conditions. In the notation of our model, we see that $g_{i,t} > 0$, which means that firms never actively repurchase debt, even though it is frictionless doing so (no transaction costs on repurchasing of debt). The reason for this lies in the debt overhang that existing debt imposes on shareholders. However, as pointed out by Dangl and Zechner (2016) and by DeMarzo and He (2019), this intuition does not apply one-to-one to the refinancing of maturing debt. Shareholders sometimes find it optimal to roll over only a fraction of maturing debt, effectively reducing their leverage. Therefore, the amount of maturing bonds is the maximum by which the firm reduces its outstanding debt. Long-term financed firms are slow to decrease debt, while short-term financed firms respond relatively fast to negative profitability shocks. We illustrate this intuition in Figure 2.

The graph in Figure 2 Panel A illustrates the different adjustments of the face value of debt between a short-term and a long-term financed firm, where both firms experience the same cash flow trajectory. The face value of debt for the short-term financed firm follows ups and downs of the cash flows process very closely. This is not the case for the long-term financed firm. Its face value responds less to cash flow fluctuations, which is most noticeable when cash flows decrease — the face value of debt also decreases, but much more slowly. As a result, we see in Panel B that the leverage of the long-term financed firm increases much more than the leverage of the short-term financed firm due to the deterioration of cash flows. These dynamics are due to the leverage

Figure 2: Debt Maturity and the Leverage Ratchet Effect. This figure illustrates the differences in leverage dynamics for a short- (dashed lines) and long-maturity (solid lines) financed firm (referred to ST and LT, respectively). Panel A (Panel B) shows the face value of debt $F_{i,t}$ (leverage $L_{i,t}$) for two firms facing the the same cash flow process $Y_{i,t}$. The parameters for this simulation are: $\mu_0 = 5\%$, $k = 0.25$, $\sigma_X = 15\%$, $\sigma_i = 15\%$, $r = 5\%$, $\delta = 4\%$, $c = r/(1-\tau)$, $\tau = 30\%$. The LT firm has an average maturity rate of $m_i = 0.2$ (5 years), while the ST firm has $m = 0.5$ (2 years).



ratchet effect, which manifests itself in the slow deleveraging process for the long-term financed firm.

Moreover, as in classical models of Leland (1994), firms with shorter debt maturity chose to have a higher average leverage. Following a negative cash flow shock, the leverage of short-term financed firms goes up, then quickly down, but remains on average higher than that of the long-term financed firms. Short-term financed firms take advantage of their flexibility with leverage changes and have a smaller default risk for a given level of leverage than long-term financed firms. They optimally lever up to a higher level than long-term financed firms, taking advantage of the extra tax shield.

Overall, we see that the leverage of longer-term financed firms decreases more slowly following a negative cash-flow shock than that of shorter-term financed firms. Next, we turn to the asset-pricing implications of the leverage ratchet effect.

4 Asset Pricing Implications of Debt Maturity

In this section, we explore the asset-pricing implications of different maturities of debt. The focus of our analysis is on the effect of the different leverage dynamics on the evolution of equity betas, and the resulting perceived alphas.

4.1 Market Return and the Market Price of Risk

We consider the market to be populated by a large number of firms so that an individual firm's capital structure decision does not affect the dynamics of the market portfolio in our analysis, in accordance with our assumptions that firms' financing decisions do not affect the market price of risk. The market portfolio $M(X_t)$ is driven by the aggregate productivity level X_t, which is defined in Equation (1). This market portfolio is traded and its return over a time increment is:

$$r^M_{t,t+dt} = (\mu(X_t,t) + \delta)\,dt + \sigma_X\,dW^P_{X,t}\,, \tag{16}$$

where $\delta > 0$ represents aggregate dividends. Assuming no-arbitrage and complete markets, we change to the risk neutral measure. Given that the market portfolio is traded, its risk neutral drift equals the risk-free rate r. Therefore, by Girsanov's theorem, the market price of risk is:

$$\lambda_t = \frac{(\mu(X_t,t) + \delta - r)}{\sigma_X}. \tag{17}$$

It is time-varying due to the variation in $\mu(X_t,t)$, as specified in Equation (2). Furthermore, we denote by η_t the market risk premium for bearing systematic risk, which equals $\eta_t = \sigma_X \lambda_t$. The risk-neutral drift of a firm's cash flows, μ_Y, consistent with the no-arbitrage condition is given by $\mu_Y = r - \delta$.

In our model, the market price of risk λ_t is driven by shocks to the aggregate productivity process X_t. The higher the aggregate productivity is, the smaller the market price of risk is, reflecting the countercyclical nature of the representative investor's risk-aversion or the appetite for risk in the economy (Guiso et al., 2018). Moreover, since dividends in our model are positively related to the cash-flow shocks, they are negatively related to the market price of risk, consistent with the empirical evidence (Van Binsbergen and Koijen, 2010).[14]

[14] In our model dividends are essentially a pass-through process, except for the leverage adjustments. So the link between the market price of risk and dividends is stronger than what we observe in the data. Investments or cash-saving motives would dampen the strength of the link, but complicate the model substantially.

4.2 Equity Returns and Equity Beta

Next, we turn our attention to the analysis of the link between leverage and the systematic risk exposure of the firm, i.e. its beta. Instantaneous returns to equityholders can be computed as:

$$r^E_{t,t+dt} = \frac{dV^E_t + \Pi_{t,t+dt}}{V^E_t}\,. \tag{18}$$

Utilizing the equity-pricing equation (see details in Appendix B):

$$r^E_{t,t+dt} \;=\; r\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\eta_t\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\sigma_Y\,dW^P_{Y_i,t}, \tag{19}$$

we arrive at a decomposition of equity returns that consists of three components: the risk-free rate, the market price of risk times the exposure to the systematic risk, and a random component.

Under the risk-neutral measure the expected value of equity returns is just the risk-free rate r.[15] Under the physical measure it is:

$$\begin{aligned}\mathbb{E}^P_t\left[r^E_{t,t+dt}\right] &= \mathbb{E}^P_t\left[r\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\eta_t\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\sigma_Y\,dW^P_{Y_i,t}\right] \\ &= r\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\eta_t\,dt\,. \end{aligned} \tag{20}$$

This expression illustrates that the conditional CAPM holds in our setting. The asset beta is normalized to one in our setting, and the equity beta is then one plus debt over equity, i.e. $\beta_{i,t} = 1 + \frac{v^D_{i,t}}{v^E_{i,t}}$, while η_t represents the time-varying market risk premium.[16]

In our model $\beta_{i,t}$ is the amplification of the firm's asset beta by financial leverage, where we have normalized the latter to one. In reality, firms differ substantially in the systematic exposure of their physical assets. The variations in beta that we analyze are on top of any differences in asset betas. While betas in our setting are by construction larger than one, they should be interpreted as scaling the asset beta of each firm. For example, a beta of 1.3 in our setting corresponds to an equity beta of a real firm that is 30% larger than its asset beta, which is due to financial leverage. Therefore, while all betas in our model are above one, our model can be easily calibrated to empirical beta distributions, once heterogeneity in asset betas is taken into account.

[15] $\mathbb{E}^Q_t\left[r^E_{t,t+dt}\right] = \mathbb{E}^Q_t\left[r\,dt + \left(1+\frac{v^D_{i,t}}{v^E_{i,t}}\right)\sigma_Y\,dW^Q_{Y_i,t}\right] = r\,dt.$

[16] We obtain the same result if we derive beta from $\beta_{i,t} = \frac{Cov_t(r^E_{t,t+dt}, r^M_{t,t+dt})}{Var_t(r^M_{t,t+dt})}$. Details can be found in Appendix C.

4.3 Shocks, Leverage and Beta

The dynamics of financial leverage in our setting determine the dynamics of beta. We have already established that due to the ratchet leverage effect, long-term financed firms exhibit larger increases in leverage following negative cash flow shocks. Therefore, we expect the beta of long-term financed firms to increase more in bad times.

To visualize the different responses of short- and long-term financed firms to cash flow shocks, we analyze positive and negative cash-flow shocks of 15%. We assume that these shocks occur linearly over one month or twelve months, respectively.[17] We first consider the sharp shocks over one month, which are illustrated by Panels A and C of Figure 3. Firms' initial leverage ratios are chosen so that they are at their targets, i.e. each firm rolls over exactly 100% of its expiring debt. While Panel A shows the reaction of leverage, Panel C shows the response of betas. For a sudden negative shock, both short- and long-term financed firms experience similar increases in leverage. Yet short-term financed firms experience a significantly larger spike in beta, which subsequently falls because firms do not roll over the entire maturing debt. Their beta falls quickly within a year after the negative cash flow shock. The opposite is true for long-term financed firms. They experience a similar initial spike in leverage, but they take substantially longer, more than three years, to reduce leverage back to the target level. Long-term financed firms show a smaller initial spike in their betas, but they remain elevated for longer, so that a few months after the shock, the betas of long-term financed firms exceed those of firms financed with short-term debt.

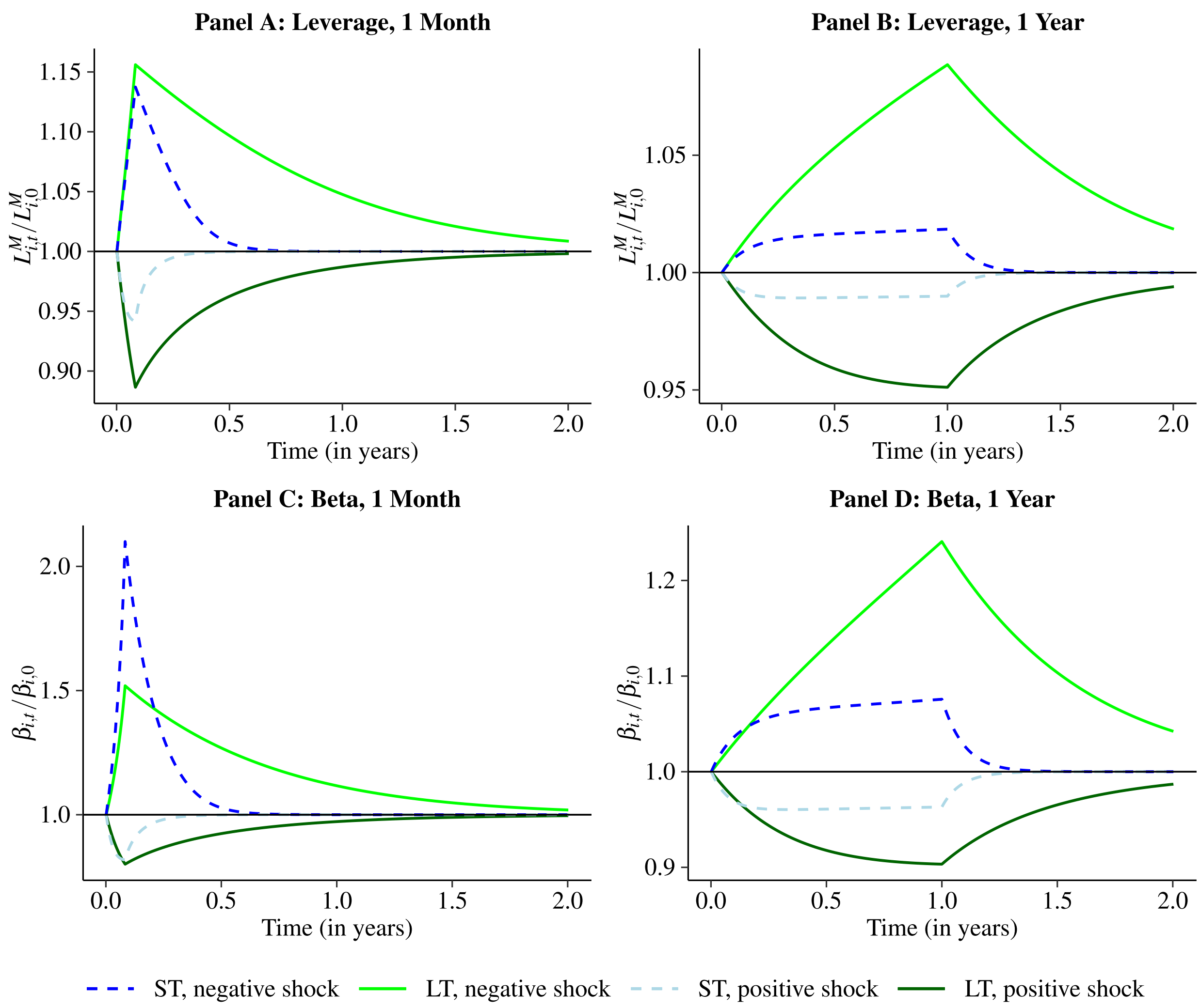
The more limited response of leverage compared to that of betas to the cash flow shocks is due to the fact that debt enters their definitions differently. Leverage is calculated as the ratio of the value of debt to the sum of debt and equity values. Thus, it is bounded by one. Beta, however, is proportional to the ratio of the value of debt over the value of equity. Hence, beta is more sensitive to a drop in equity values than leverage.[18]

Next we investigate how leverage and beta respond to more gradual cash flow shocks with a linear impact over a year. After that period, cash flows are held constant again, while firms adjust their leverage by issuing or retiring maturing debt. Panels B and D of Figure 3 show that short-term financed firms delever by not rolling over their maturing debt, so that their leverage never increases as much as that of long-term financed firms. Moreover, the leverage of long-term financed firms stays elevated for more than two years after the shock, while the leverage of short-term financed firms goes back to previous levels much faster. Betas show similar dynamics.

[17] Note that this is the cash flow path that we consider in our simulation but, of course, the firms in our simulations do not anticipate that the cash flows will remain constant as they move through time.

[18] Formally, $\left|\frac{\partial L}{\partial E}\right| = \frac{D}{(D+E)^2} > \left|\frac{\partial \beta}{\partial E}\right| = \frac{D}{E^2}$.

Figure 3: Evolution of Leverage and Beta Following Cash Flow Shocks. This figure shows leverage (as defined in Equation (14)) and beta (as defined in Equation (20)) responses to a linear cash flow increases and decreases of 15% over different time intervals. After the cash flow changes it is held constant, but the firms continue rolling over debt. In the two top panels leverage dynamics are based on shocks over 1 month (Panel A) and 1 year (Panel B), respectively. The two lower panels show the dynamics of betas to shocks over 1 month (Panel C) and 1 year (Panel D), respectively. All variables are scaled by the starting values before the introduction of a shock. The initial values are chosen such that the firms roll over the amount of debt that matures. The solid (dashed) lines represent a firm with $\sigma_i = 0.15$ (while $\sigma_X = 0.15$) and $m_i = 0.2$ ($m_i = 0.5$) — i.e. a debt maturity of 5 (LT) and 2 (ST) years. The lines featuring initial spikes (drops) represent reactions to cash flow decreases (increases).



To summarize, a fast deterioration of cash flows initially affects short-term financed firms more severely, raising their equity betas more sharply. While long-term financed firms' initial equity beta spike is more modest, their leverage and betas remain elevated for a long time. If the cash flow deteriorates over a year, then short-term financed firms' leverage and equity betas never rise that much, since these firms reduce debt levels quickly. By contrast, long-term financed firms' leverage and betas rise more, as their debt reductions are slower. They exhibit elevated levels of leverage and equity betas for a long period of time.[19]

4.4 Unconditional CAPM and Alpha

In our model, the conditional version of the CAPM holds, period by period. We can re-write the expression for the conditional expected equity return stated in Equation (20) using $\beta_{i,t}$ to arrive at a notation similar to the CAPM:

$$\mathbb{E}_t\left[r^E_{t,t+dt}\right] = r\,dt + \left(1 + \frac{v^D_{i,t}}{v^E_{i,t}}\right)\sigma_X \lambda_t\,dt = r\,dt + \beta_{i,t}\eta_t\,dt, \tag{21}$$

where $\eta_t = \sigma_X \lambda_t = \mu(X_t,t) + \delta - r$ is the time-varying market risk premium.

However, an unconditional CAPM does not hold because $\beta_{i,t}$ and η_t are related through the evolution of the aggregate state X_t. Unconditional alpha, according to Lewellen and Nagel (2006), can be calculated as:

$$\alpha_i = \quad \left[1 - \frac{\eta^2}{\sigma^2_M}\right] Cov(\beta_{i,t},\eta_t) - \frac{\eta}{\sigma^2_M} Cov(\beta_{i,t},(\eta_t-\eta)^2), \tag{22}$$

where $\eta = \mathbb{E}[\eta_t]$ is the unconditional mean of the market risk premium, and $\sigma^2_M = \sigma^2_X + \sigma^2_\eta$ is the unconditional variance of the market return. Note that in our model $\sigma_{t,M} = \sigma_X$, that is, the conditional market volatility is constant in time.[20]

[19] In the Internet Appendix in Section C we analyze the term-structure of equity returns implied by our model. While over short holding horizons short-term financed firms are more risky and command a higher equity premium, over longer holding horizons longer-term financed firms earn higher expected returns.

[20] The formula in 22 is for an annual alpha with $dt = 1$. Generally speaking, alpha over increments of time dt is

$$\alpha_{i,dt}\,dt = \quad \left[1 - \frac{(\eta\,dt)^2}{\sigma^2_M\,dt}\right] Cov(\beta_{i,t},\eta_t\,dt) - \frac{\eta\,dt}{\sigma^2_M\,dt} Cov(\beta_{i,t},(\eta_t\,dt - \eta\,dt)^2),$$

and its annualized version is:

$$\alpha_{i,dt} = \quad \left[1 - \frac{\eta^2}{\sigma^2_M}\,dt\right] Cov(\beta_{i,t},\eta_t) - \frac{\eta}{\sigma^2_M} Cov(\beta_{i,t},(\eta_t-\eta)^2)\,dt\,.$$

In our setting, $Cov(\beta_{i,t}, \eta_t)$ is non-zero because of the time-varying market price of risk λ_t. In the downturns, when the market risk premium η_t is high because of low aggregate productivity X_t, the firm's leverage is high, and correspondingly its systematic risk exposure $\beta_{i,t}$ is high. Therefore, there is a positive relationship between the market risk premium η_t and the firm's exposure to risk $\beta_{i,t}$. This co-movement is not captured by the unconditional CAPM and appears as α in CAPM regressions.

As can be seen from the expression in squared brackets in Equation (22), whether the covariance between beta and the market risk premium translates into an increase or a decrease of alpha depends on the market's squared Sharpe ratio. If the Sharpe ratio is below one, then the covariance between beta and the market price of risk leads to an increase in alpha. Since empirical estimates for Sharpe ratios are normally well below one,[21] this condition will hold under plausible market conditions.

The second term in Equation (22) denotes the covariance between beta and the squared deviation of the market price of risk from its mean. If η_t is distributed symmetrically around its mean, as is the case in our model, this term will be close zero. In our numerical simulations below the second term is quantitatively very small. Summarizing, the observed α_i is a scaled version of the beta's covariance with the market risk premium.

4.5 The Maturity Premium

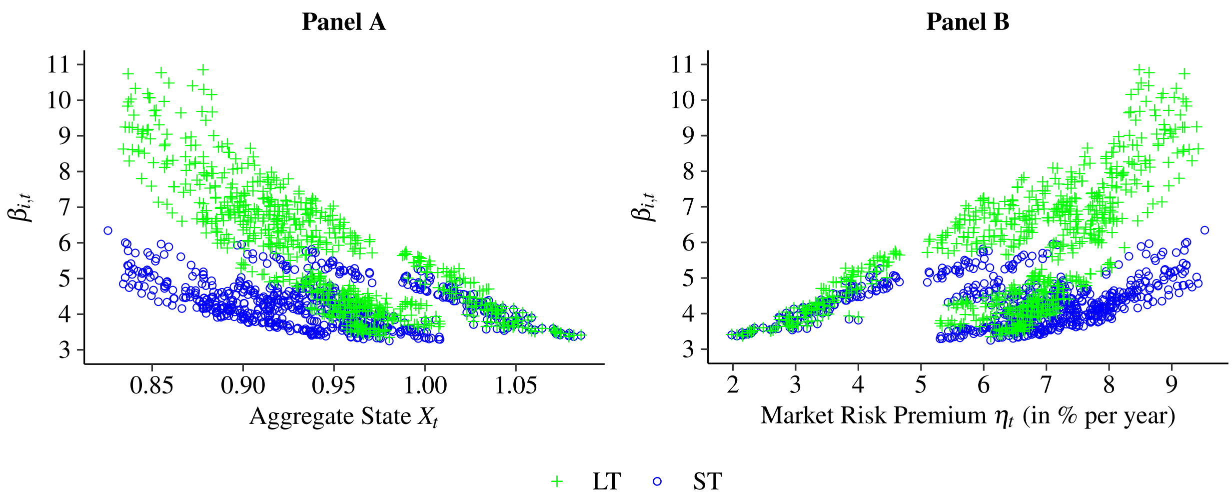
As shown in the previous subsection, short- and long-maturity firms have different dynamics of leverage and, therefore, different dynamics in their exposure to systematic risk. In particular, long-maturity firms experience larger increases in leverage, and the leverage remains elevated longer during recessions. This implies that, ceteris paribus, there is more co-movement between betas and the market price of risk for long-maturity firms than for short-maturity firms.

To isolate the effect of debt maturity, it is important to control for the differences in the average leverage levels between long-term and short-term financed firms because they affects the covariance between betas and market price of risk above and beyond the leverage ratchet effect. More levered firms will have higher average levels of beta, and therefore, ceteris paribus, higher levels of $Cov(\beta_{i,t}, \eta_t)$. We therefore isolate the effect of the leverage ratchet effect on equity returns by comparing firms with different maturities but the same average leverage levels.

To remove the effect of different average leverage levels of short-term versus long-term debt firms in our numerical simulations, we build on the fact that empirically firms with higher idiosyn-

[21] Using the market excess return from Prof. French's homepage, the market's annual Sharpe ratio for our time interval equals 0.52.

Figure 4: Beta, Aggregate State, and Market Risk Premium. This figure shows the endogenous development of $\beta_{i,t}$ against the aggregate state variable X_t in Panel A and against the market risk premium η_t in Panel B. The crosses (circles) represent $\beta_{i,t}$ for a firm with $\sigma_i = 0.10$ ($\sigma_i = 0.20$) and $m_i = 0.2$ ($m_i = 0.5$) — i.e. a debt maturity of 5 (LT) and 2 (ST) years, respectively. The underlying parameters are as in the benchmark case, i.e. $\mu_0 = 0.05$, $k = 0.25$, $\sigma_X = 0.15$, $\delta = 0.04$, $r = 0.05$, $\tau = 0.3$.



cratic risk tend to be financed with shorter maturity debt (e.g., Custódio et al., 2013). While in our simple model debt maturity does not affect firm value, this stylized empirical fact is consistent with theoretical predictions from a more realistic model with transaction costs for new debt issues (see Dangl and Zechner, 2016). Firms with higher idiosyncratic volatility, everything else equal, choose lower levels of leverage, as their default probability is higher. Therefore, to achieve the same level of average leverage for short- and long-term financed firms, we compare long-term financed firms with lower idiosyncratic volatility to short-term financed firms with higher idiosyncratic volatility. Hence, in what follows we will compare firms that differ in their maturity, but their average leverage level is the same.

In Panel A of Figure 4 we see a simulated scatter-plot of beta over the aggregate state X_t for firms financed with long- and short-term debt. When the aggregate productivity process is low, long-financed firms exhibit larger betas than short-maturity firms, despite the fact that during high-productivity states, betas of these firms are very similar. Panel B depicts the same relation in a scatter plot of beta on market risk premium. Long-term financed firms have more co-movement between beta $\beta_{i,t}$ and the market risk premium η_t.

Next, in order to assess if our model can account for the observed magnitude of the maturity

Table 4: Maturity Premium. This table presents the simulation results for a panel of short-maturity and long-maturity financed firms that replicate the maturity premium observed in the data. The main parameters for this simulation are as in the benchmark specification, i.e. $\mu_0 = 0.05$, $k = 0.25$, $\sigma_X = 0.15$, $\delta = 0.04$, $r = 0.05$, $\tau = 0.3$. The parameters for the short- and long-maturity financed firms are chosen to reflect the characteristics of the firms in the lowest and highest maturity buckets, see Table 2.

	Short	Long	LMS
Debt Maturity (years)	1	5	
σ_i	20%	10%	
τ	20%	30%	
α	0.06%	0.25%	
Maturity Premium			0.19%

premium, we simulate two panels of firms. The results are summarized in Table 4. The characteristics of the short- and long-maturity financed firms match those in the data (see Table 2). The short-maturity financed firms have higher levels of idiosyncratic volatility and lower levels of the marginal tax rates. The longer-maturity financed firms exhibit higher alpha relative to the CAPM than short-maturity financed firms, and the resulting maturity premium is 0.19% per month, comparable to the 0.21% maturity premium that we estimated in the data (see Table 3).

4.6 Comparative Statics

Finally, we conduct a simulation study of the maturity effect on CAPM alphas. We simulate the capital structure model introduced in Section 3. In total, we simulate 5,000 economies of 1,000 firms for 10 years. At origination of the analysis all firms start at their target leverage levels. Then, we average the quantities of interest over firms in every economy and then over economies. All parameters are as in the benchmark specification, see Table 5.

We simulate the model for various combinations of key parameters to illustrate the effects on the maturity premium. See Figure 5. We start with idiosyncratic volatility. Moving along each line from left to right and holding idiosyncratic volatility constant, we see that as the average maturity of debt increases, the unconditional alpha also increases. However, the largest effects of debt maturity on alpha occur for maturity increases from one to six years. Additional maturity increases beyond six years have a relatively moderate additional effect. The reason for this result is the inverse relation between debt maturity and target leverage. Firms with long-term debt optimally lever less. They rationally anticipate that they will not delever when profitability decreases, thereby creating

Table 5: Benchmark Simulation Parameters. This table details the parameters of the simulation study. We group them into three categories. First, we present cash flow parameters associated with $Y_{i,t}$ under both probability measures. Second, we show parameters used for three rates and debt related parameters. The bottom line presents details on the simulation setting.

Cash Flow	μ_0	k	σ_X	σ_i	μ_Y
	0.05	0.25	0.15	0.15	0.01
Rates & Debt	r	δ	τ	$1/m$	c
	0.05	0.04	0.30	[1, 10]	0.07
Simulation	economies		firms	years	Δt
	10,000		2,500	10	1/1200

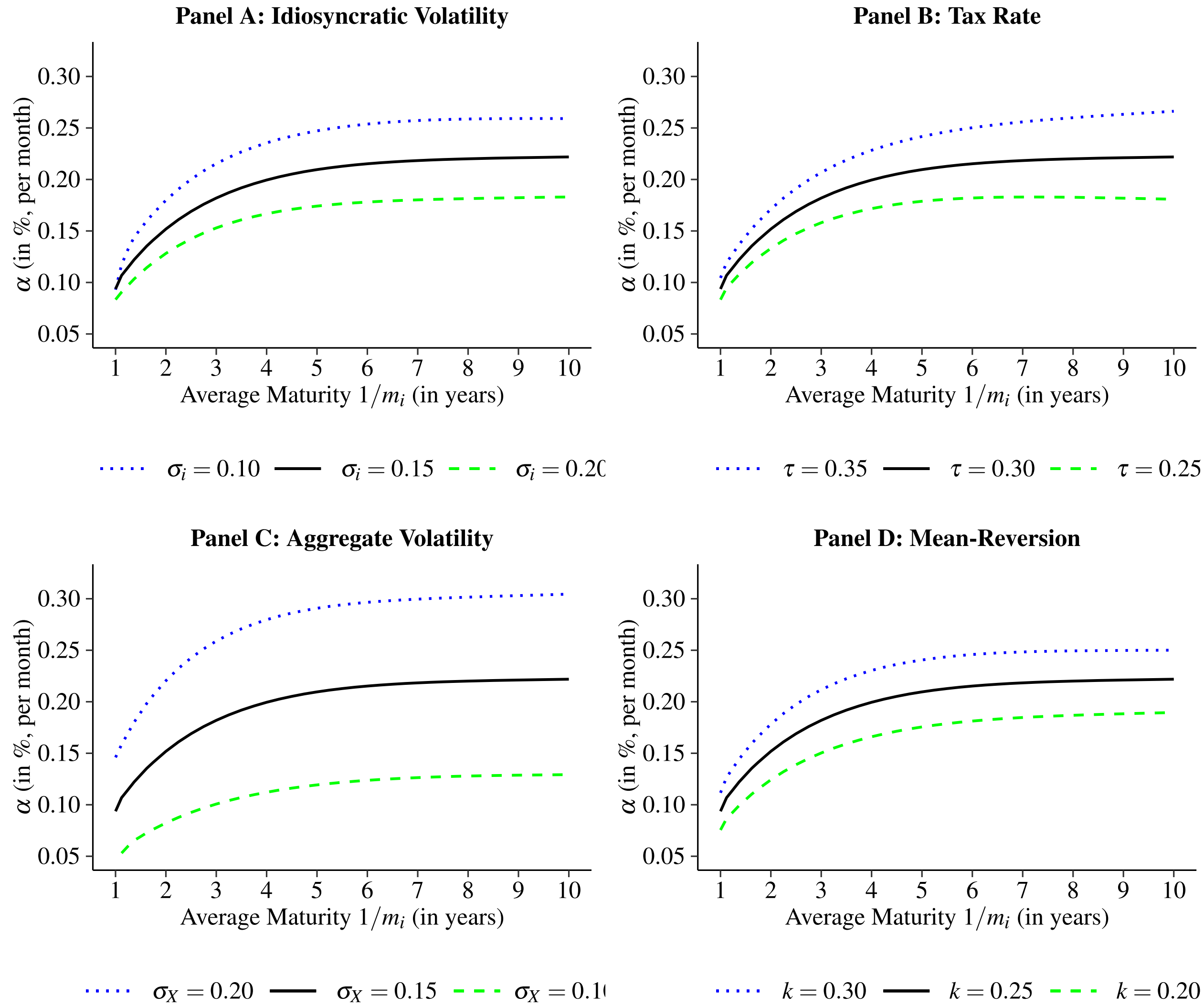
bankruptcy risk. Thus, as we move to very long maturities, the additional covariance between beta and the market price of risk for given leverage tends to be offset by the lower target leverage ratios. Overall, firms with more idiosyncratic risk exhibit a smaller maturity premium.

Next we look at the marginal tax rates. The higher the tax benefits of debt, the higher the target debt level. We therefore vary the tax rate τ in the simulations displayed in the top right-hand diagram in Figure 5. The higher the tax rate, the higher the alpha. Moreover, for all tax levels we find that unconditional alphas increase substantially as we increase a firm's average debt maturity. The increase is much more pronounced for firms with larger tax rates. For example, for a tax rate of 0.35, the monthly alpha increases from less than 10 basis points per month to over 24 basis points as we move from a one year debt maturity to a six year debt maturity. If the tax benefit of debt is only 0.25, then the alpha increases to only slightly just above 18 basis points as we move to a six year debt maturity. Thus, firms with a significant tax benefit of debt, and therefore higher leverage ratios, exhibit larger maturity premia.

Next we investigate the effects of the productivity process parameters on the maturity premium levels. The bottom left-hand diagram in Figure 5 illustrates the positive effect of the volatility of the productivity process σ_X on the maturity premium. This is the opposite reaction to an increase in the idiosyncratic volatility σ_i, as shown in the top left-hand diagram. As the volatility of the productivity process increases, the market price of risk becomes more volatile. Hence, it co-moves more with betas of long-maturity financed firms, which we capture as higher unconditional alphas.

One of the key parameters in our model is k, which governs the speed of mean-reversion in the market price of risk process. If $k = 0$, there is no time-variation in the market price of risk, and therefore, there is no maturity premium. The larger the k, the more variation in the market price of risk, and therefore, the more pronounced the maturity premium. We set $k = 0.25$, which

Figure 5: Maturity Premium and Parameters. In this figure we present the resulting alpha from unconditional CAPM regressions of simulations for different values of key parameters (over 10,000 economies of 2,500 firms each). Alphas are represented in % per month. All parameters underlying this simulation are detailed in Table 5.



results in the market price of risk in our model being on average 3.4% per year, with a two-standard deviation interval around it from approximately −5% to 13%. This is similar to the estimates of the discount rate shocks in Campbell et al. (2013) between −4% and 6%. The top right-hand diagram in Figure 5 quantifies the effect of the mean reversion k in the drift process. While the larger k, the larger the maturity premium, quantitatively the effect is moderate.

We conclude this subsection with a brief discussion of the robustness of our numerical analysis when debt maturity would be allowed to change over time. Chen, Xu and Yang (2019) document countercyclical dynamics of average maturity. They argue that the liquidity premium that long-term bondholders require goes up during downturns, making short-term debt more attractive.[22] Another reason why firms might choose to shorten maturity in crises is that they use short-maturity bonds as a commitment to delever in the near future, as argued by Chaderina (2018).

In our model, as in DeMarzo and He (2019), the choice of maturity of any future debt issuance does not affect shareholder value. However, it might be a concern to the mechanism of our model if firms, for reasons outside of our model, were to shorten their debt maturity once they enter a crisis.

However, it is plausible that the effect of debt maturity on beta dynamics would be strengthened if long-term debt firms were allowed to reduce maturities during crises. Consider the following thought experiment: right after a negative shock to productivity, long-maturity financed firms reduce their debt maturities. First, ceteris paribus, shortening debt maturities in our framework leads to a beta increase. Second, firms financed with shorter-maturity bonds have higher optimal leverage. So, while shortening maturity reduces debt overhang, it increases optimal leverage. Therefore, firms that experience a reduction in maturity will not delever after a negative shock due to higher optimal leverage levels. Therefore, allowing firms to shorten maturity in crises is unlikely to weaken or eliminate our prediction that firms with longer maturity before a crisis will have higher systematic exposure in crises.

5 Empirical Evidence of the Model Mechanism

In this section we provide specific empirical evidence for the model mechanism and confirm empirically that the maturity premium can, at least partially, be explained by the difference in leverage dynamics of long- and short-maturity financed firms. In the first part of this section, we analyze exogenous variations in debt maturity at the onset of the recent financial crisis. We document the effect of debt maturity on the dynamics of leverage and betas triggered by the subsequent cash flow shocks. Next, we study the cyclicality of the systematic risk loadings of our long-short portfolio. We estimate a conditional version of the CAPM and investigate the co-movement between betas and the market price of risk.

[22] See also Bruche and Segura (2017).

5.1 Crisis Experiment

To provide direct evidence that longer debt maturities contribute directly to the countercyclical dynamics of firms' systematic risk exposure, we conduct the following quasi-natural experiment.

The general idea is that the remaining time to maturity of firms' bonds differ between otherwise similar firms according to arguably exogenous past issue dates. For example, consider two firms that both optimally choose a maturity of seven years for their bonds at issuance. Firm A may have issued its bond five years ago, and thus has a remaining time to maturity of only two years, whereas firm B may have issued its bond last year, thus currently exhibiting a remaining debt maturity of six years. If they both optimally roll over their seven-year bonds when they expire, they have the same target average bond maturity, but at any given point in time the effective bond maturity will differ. We use this presumably exogenous variation in maturity dates between firms before the onset of the financial crisis of 2008. Using data from Capital IQ on debt instruments, including bank loans and corporate bonds, we select firms with similar preferences for debt maturity. In particular, we calculate a value-weighted average maturity at origination using debt instruments that were outstanding as of December 2007.

We argue that the drivers of the timing decisions of debt issuances are likely unrelated to the onset of the financial crisis. This assumption allows us to attribute the differential effect of the crisis on short- and long-maturity financed firms to the maturity differences and not to any other underlying firm characteristics. Our approach is similar to the use of heterogeneity in the fraction of remaining long-term debt at the onset of the financial crisis among otherwise similar firms by Almeida, Campello, Laranjeira and Weisbenner (2012).

We select firms that have an average maturity of debt at origination between 5 and 7 years. Then, we use information from Compustat on the fraction of debt maturing in four years or more (*DM*) to sort firms into buckets of those with shorter (40% of the sample), medium (20%), and longer (40%) remaining maturity of debt. We hereby use *DM* as of the fiscal year 2007, which means that for the majority of firms the information is as of the end of the calendar year 2007. Summary statistics for these firms are in Table 6. The table shows that firms in different maturity buckets exhibit fairly similar characteristics. None of the differences in the reported characteristics between firms in different maturity buckets is statistically significant, except for the debt maturity itself. After forming short- and long-maturity buckets, we analyze their dynamics through the financial crisis of 2008 and the subsequent recovery thereafter. We focus on the evolution of their market leverage and unconditional beta estimated using daily equity returns over quarter-long rolling windows.

In 2008 the S&P 500 showed a record negative return of approximately 37%, a reflection of

Table 6: Summary Statistics for Firms in Quasi-Natural Experiment. This table summarizes characteristics of firms in the quasi-natural experiment as reported for the fiscal year 2007. We consider firms with average maturities at issuance between five and seven years for instruments outstanding in December 2007. We sort firms into short (ST) and long (LT) maturity buckets based on the remaining debt maturity of the fiscal year 2007 at the 40% and 60% percentiles, respectively.

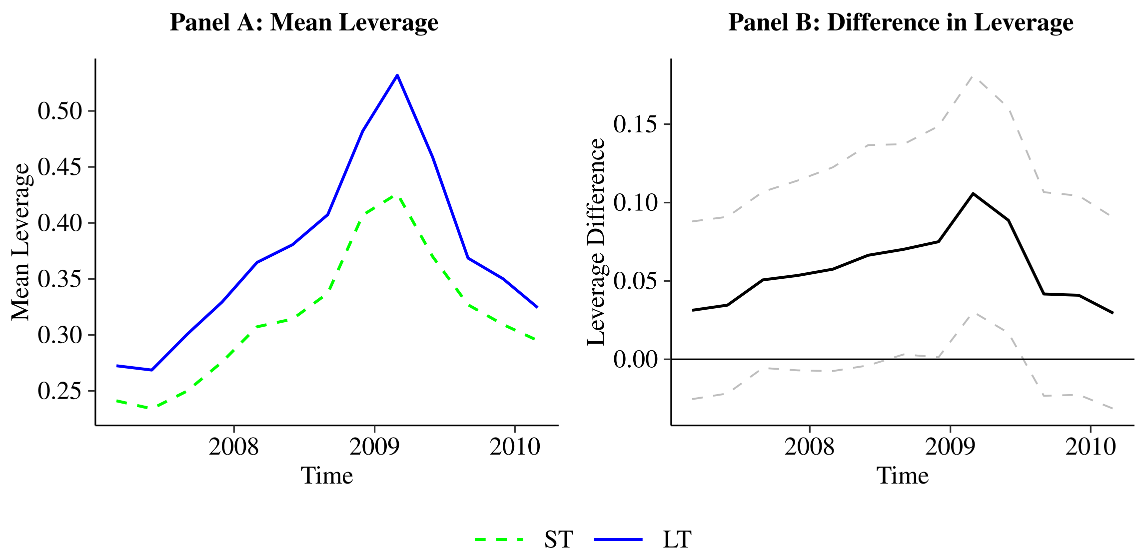
Debt Maturity	Short	Medium	High
Number of firms	108	54	108
Debt Maturity (%)	45.43	84.64	97.28
Market Equity	4,906.24	4,910.58	3,279.48
Book-To-Market	0.62	0.87	0.72
Leverage (%)	26.69	38.02	32.04
IVOL (%)	8.99	9.51	9.59

the struggling economy, constituting a negative cash flow shock to the vast majority of firms. Following the intuition of our model, we would expect firms not to fully rollover debt maturing in 2008.[23] As a consequence, we expect firms with relatively shorter remaining maturity to delever faster than firms with relatively longer remaining maturity. Figure 6 illustrates our findings. In Panel A we plot the equal-weighted average of the leverage ratios for long- and short-maturity financed firms. We see that the leverage of both long- and short-maturity financed firms increased during the crisis. However, the long-term financed firms experienced a larger increase in leverage than the short-maturity financed firms. In Panel B we plot the difference between the mean leverage levels of long- and short-maturity financed firms. At the peak of the leverage increase, in the early 2009, the leverage increase of long-maturity financed firms was significantly higher than that of short-maturity financed firms. Thus, the dynamics in Figure 6 are in full accordance with the model results (see Section 4.3 and Figure 3 for a detailed discussion).

The increase in the difference between the mean leverage of long- and short-maturity firms we see in data is statistically significant even after we account for potential unobserved differences between firms. We conduct a difference-in-difference estimation, using firms in the long-maturity bucket as treated, and short-maturity financed firms as a control group and controlling for firm fixed effects. While the market conditions started worsening at the beginning of 2008, it was in the second half of 2008 when the liquidity in debt markets dried up (Bao et al., 2011). Hence,

[23] Bao et al. (2011) report that the secondary market of corporate bonds became more illiquid following the collapse of the Bear Sterns in March of 2008, the collapse of Lehman Brothers and the bailout of AIG in September 2008. Illiquidity of the secondary market likely had an adverse effect on the primary market, making it expensive for firms to rollover maturity debt. This is perfectly consistent with the mechanism at work in our theoretical model, namely that issuing new bonds to roll over expiring ones can only be done at very unfavorable terms in a negative cash-flow scenario.

Figure 6: Quarterly Leverage During the Financial Crisis. This graph shows the development of quarterly leverage around the financial crisis. We consider firms with average maturities at issuance between five and seven years for instruments outstanding in December 2007. We sort firms into short (ST) and long (LT) maturity buckets based on the remaining debt maturity in September 2008 at the 40% and 60% percentiles, respectively. Panel A considers the equally-weighted mean leverage for ST-firms (green, dashed line) and LT-firms (blue, solid line). Panel B depicts the difference in value-weighted leverage between the firms and a 95% confidence region.



we set four quarters in 2007 as the pre-treatment period, and quarters 3 and 4 of 2008, as well as the first two quarters in 2009 as the post-treatment periods.[24] We see that the leverage of short-term financed firms increased in the post-treatment period by 14%, while the leverage of long-term financed firms increased by an additional 3%. The difference is statistically significant even after we control for firm and time fixed effects. Hence, firms that had relatively longer remaining maturities of debt at the onset of the crisis experienced a larger increase in leverage during the crisis, as predicted by our theory.

Next we investigate how the crisis affected the systematic exposure of firms in long- and short-maturity buckets. We form a long-short portfolio using the firms in the two buckets, similar to the LMS portfolio that we analyzed in Section 2. Then, we estimate rolling-window CAPM regressions, using daily stock returns, shifting the window each time by one day. We report a moving-average of the last 60 observations of beta estimates in Figure 7. Before 2008 the beta of the portfolio was not statistically different from zero, meaning that the average betas of the long- and

[24] Our results are robust to including the first two quarters of 2008 to either the pre-treatment or post-treatment periods.

Table 7: Quarterly Leverage Difference-in-Differences Estimation. We regress quarterly leverage from the pre-period (the year 2007) and the post-period (2008 Q3 and Q4 as well as 2009 Q1 and Q2) on an interaction term for long-maturity financed firms at the onset of the financial crisis. In both models firm fixed-effects are included. Model (2) adds fixed effects in the time dimension, which requires excluding the post-crisis dummy which is included in Model (1).

	Model (1)	Model (2)
Post × LT	0.03^{***}	0.03^{***}
	(0.01)	(0.01)
Post	0.14^{***}	
	(0.01)	
FE	Firm	Firm, Time
Observations	1,490	1,490
Adjusted R^2	0.851	0.872

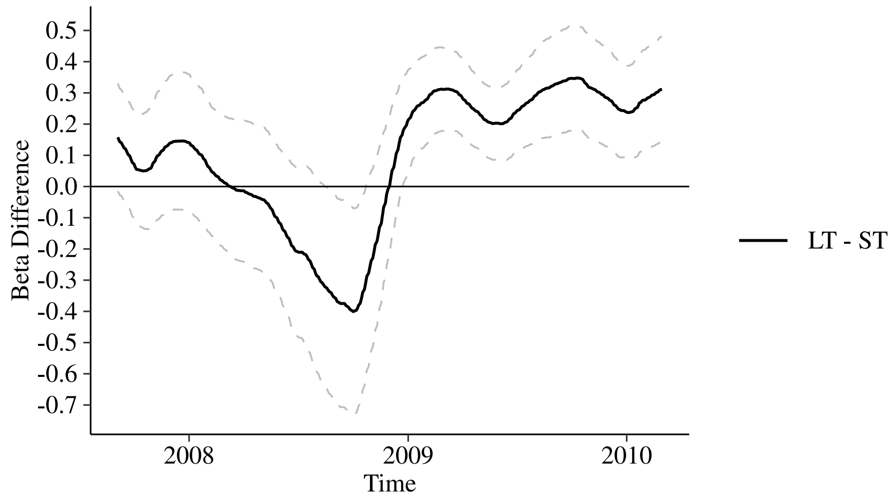
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

short-maturity financed firms were close to each other. In the second half of 2008 the beta of the long-short portfolio became negative, reflecting that the short-financed firms were more severely affected by the cash flow shock initially. However, starting with 2009 the beta of the long-short portfolio becomes positive and statistically significant, implying that later in the crisis and in the recovery afterwards, when the market price of risk was high, the longer-maturity financed firms co-moved more strongly with the market.

The peak of the difference in leverage between long- and short-maturity financed firms coincides in timing with the beta increase of the long-short portfolio, consistent with our model predictions. Moreover, while we observe an initial dip in the long-short portfolio's beta in Figure 7, this is not the case for leverage (see Panel B in Figure 6). Both of these results are in accordance with our simulation results in Section 4.3.

Overall, the findings of the quasi-natural experiment lend support to our model predictions. Firms which prefer to issue debt of similar maturities respond very differently to the crisis shock depending on the remaining maturity at the onset of the crisis. Both the difference between their leverage dynamics as well as the difference in their beta dynamics align well with our theory.

Figure 7: Beta During the Financial Crisis. We show the evolution of betas estimated in rolling windows over the past sixty days on daily returns. We consider firms with average maturities at issuance between five and seven years for instruments outstanding in December 2007. We sort firms into short (ST) and long (LT) maturity buckets based on the remaining debt maturity in the fiscal year 2007 at the 40% and 60% percentiles, respectively. We take rolling means over sixty observations to smooth the graph. 95% confidence intervals are plotted around the point estimates.



5.2 Conditional CAPM and Beta Dynamics

The existence of a maturity premium in our model relies on the fact that long-maturity financed firms experience a larger and more prolonged increase in their exposure to systematic risk in downturns than short-maturity financed firms. In this subsection we estimate a conditional CAPM to provide the direct empirical evidence that the beta of long-term financed firms increases in crises and that this increase is larger than that experienced by short-term financed firms.

While it might be most intuitive to study whether the variation of short-window realized betas can directly explain the observed maturity premium, this leads to over-conditioning bias in the alpha estimation, as argued by Boguth et al. (2011). To avoid this problem, we follow a 2-step instrumental variable approach as in Choi (2013). We restrict the conditioning space to a linear combination of lagged macro variables that best predicts the contemporaneous market price of risk.[25]

To estimate the dynamics of the LMS-portfolio's beta we consider the following conditional

[25] Our approach is similar to that of Jagannathan and Wang (1996). While they use credit spread as a conditioning variable, we additionally use information in treasury bill rate and the dividend yield.

version of the CAPM:

$$r_t^{LMS} = \alpha + \beta_0 r_t^M + \beta_1 \eta_t r_t^M + \varepsilon_t. \tag{23}$$

where η_t is the market price of risk. The average exposure to systematic risk of the portfolio is captured by the value β_0, as in the classical CAPM. Moreover, the time-variation in beta is captured by the third coefficient, i.e. β_1. Therefore, the time-varying conditional beta is $\beta_0 + \beta_1 \eta_t$.

Using the market price of risk as a conditioning variable is a natural choice in our setting. Recall that X_t, the aggregate productivity process, drives both the evolution of the firm's beta and the market price of risk. Therefore, the only variation in a firm's beta that is relevant for the maturity premium is the one that is projected on the variation in the market price of risk.

Since we do not directly observe the market price of risk, we use a vector of lagged controls, Z_{t-1}, to estimate it. In particular, using a 2-stage IV approach we estimate the following conditional CAPM:

$$r_t^{LMS} = \alpha + \beta_0 r_t^M + \beta_1 \eta(Z_{t-1}) r_t^M + \varepsilon_t, \tag{24}$$

Our instruments Z consist of variables that are likely to drive the countercyclical market risk premium. As predictors we use the dividend yield (DY), the default spread (DS), the term spread (TS), the T-Bill rate (TB) and the consumption-wealth ratio (CAY) (see Lettau and Ludvigson, 2001). We obtain their estimates from Amit Goyal's homepage, and the detailed description of their construction is available in Welch and Goyal (2007).[26]

The first step in the IV approach is to fit a one-month ahead predictive regression to span the observed market return by the predictors mentioned above, i.e.

$$r_t^M = \delta_0 + \delta_1 \mathrm{DY}_{t-1} + \delta_2 \mathrm{DS}_{t-1} + \delta_3 \mathrm{TS}_{t-1} + \delta_4 \mathrm{TB}_{t-1} + \delta_5 \mathrm{CAY}_{t-1} + \varepsilon_t^M = \eta(Z_{t-1}) + \varepsilon_t^M. \tag{25}$$

Results of the fitting estimation are presented in Table 8. In the first column, we use all five macro-variables to forecast the market return. As we see, only two out of five variables are significant. Hence, we re-estimate the model using only the dividend yield and t-bill rate as explanatory variables. Model (2) of the same table contains the estimates of this specification.

Although the two regression coefficients reported for model (2) are highly statistically significant, the overall predictive power of the regression is small. It explains only approximately 2% of the overall variation in the market risk premium. This is in line with the low power of the

[26] We use quarterly CAY estimates in our monthly predictive regressions. We lag CAY observations by one month and hold them constant for the subsequent two months.

Table 8: Predictive Variable. This table shows the predictive regression of the market excess return on lagged predictors. The lagged explanatory variables are the dividend yield (DY), the default spread (DS), the term spread (TS), the T-Bill rate (TB), and the consumption-wealth ratio (CAY). In Model (1) we include all predictors, while in Model (2) only the significant variables from the first test are used. We report t-statistics based on standard errors following Newey and West (1987, 1994) in parentheses. The sample period is from January 1976 until December 2017.

	Model (1)	Model (2)
DY	2.38^{***}	1.60^{**}
	(2.91)	(2.43)
DS	−7.10	
	(−0.08)	
TS	−34.47	
	(−1.34)	
TB	-36.15^{**}	-18.99^{**}
	(−2.16)	(−2.37)
CAY	16.75	
	(1.30)	
Intercept	11.77^{***}	7.40^{***}
	(3.05)	(2.74)
R^2	0.02	0.02
Adj. R^2	0.01	0.01

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

macro-models in explaining the dynamics of expected equity returns (Cochrane, 2011).

In the next step, we use the coefficient estimates reported in Table 8 to calculate the predictor $\hat{\eta}_t = \hat{\eta}(Z_{t-1})$ for the conditional model presented in Equation (24). We note that $\hat{\eta}_t$ is high in times when the dividend yield is high and the t-bill rate is low, consistent with a countercyclical market risk premium. The results of this conditional CAPM are reported in Table 9. The table has three sets of two columns, showing results for the long leg and the short leg of the LMS portfolio as well as for the difference between the long and the short legs, i.e. the LMS portfolio, respectively. The first column in each set contains estimates of a standard unconditional CAPM. We see that the LMS portfolio exhibits a negative unconditional market beta and a positive alpha. This alpha is by construction identical to the alpha reported in Panel B of Table 3.

The second column in each set contains estimates from the conditional CAPM. We interact the market return with our estimated market risk premium to assess the time-variation in beta. The interaction term β_1 is positive and statistically significant at the 5% level for the long leg, meaning

Table 9: Maturity Premium in a Conditional CAPM. This table presents the result of an unconditional and a conditional version of the CAPM, respectively. The dependent variable is the return of the long leg (columns 1 and 2), the short leg (columns 3 and 4), and the long-minus-short portfolio (columns 5 and 6) as constructed in Table 3. The conditional version includes an interaction between the predicted market risk premium of Equation (24) and the market return. The predicted risk premium is constructed using lagged predictors and the coefficient estimates shown in Model (2) of Table 8. While β_0 corresponds to the estimate on a constant market risk premium, β_1 represents the coefficient on the interaction. In the last column we report the difference between the unconditional and conditional intercept from a GMM estimation. The sample period is from January 1976 until December 2017.

	Long-Term		Short-Term		Long-Minus-Short		
	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	$\alpha_u - \alpha_c$
α	0.15	0.11	−0.06	−0.07	0.21***	0.19***	0.02**
	(1.24)	(0.92)	(−0.41)	(−0.52)	(3.39)	(2.77)	(2.10)
β_0	1.04***	0.98***	1.13***	1.11***	−0.09***	−0.13***	
	(33.19)	(24.12)	(36.77)	(23.73)	(−6.51)	(−5.79)	
β_1		0.10**		0.04		0.06***	
		(2.40)		(0.78)		(2.57)	

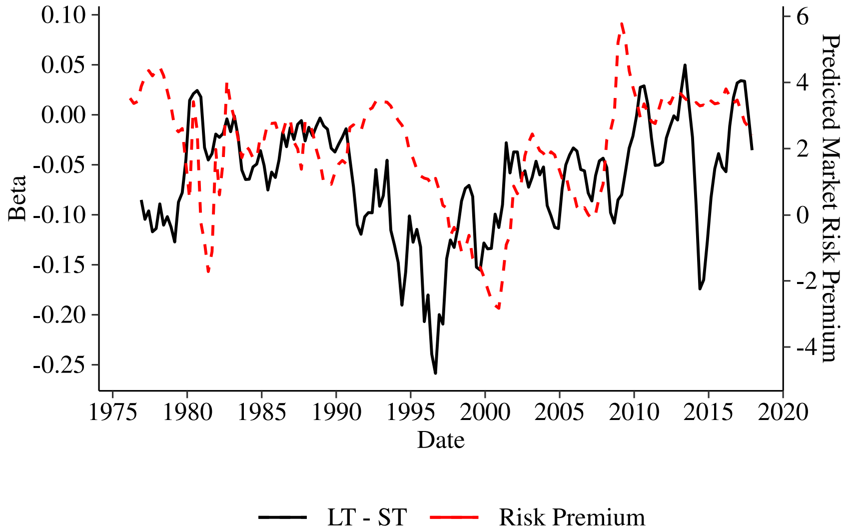
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

that the long-maturity financed firms have higher betas in crises relative to other periods. For the short-maturity financed firms we do not see such a behavior in betas. In the LMS portfolio, the interaction term β_1 is positive and statistically significant at the 1% level. This suggests that the beta of long-maturity financed firms increases in times when the market price of risk is high, i.e. in recessions or crises, more than the beta of short-maturity financed firms. Hence, the overall exposure to market risk of the LMS portfolio increases when the market price of risk increases. This is exactly in line with our theoretical predictions. Long-term financed firms have an increased exposure to systematic risk in times when the market risk premium is particularly high.

Moreover, we also find that the estimated alpha decreases from 0.21 to 0.19 once we introduce our conditioning variable. The reduction in alpha between the unconditional and the conditional CAPM is relatively small, but statistically significant, as we show in our GMM estimation.[27] Thus, the time-variation in beta that we capture via our estimated market price of risk explains part of the maturity premium that we observe in the unconditional CAPM.

[27] The moderate magnitude of the reduction is likely to be due to the fact that the predictive regression for the market excess return is very noisy with with an adjusted R^2 of only 1%.

Figure 8: Time Dynamics of Betas and The Market Price of Risk. This figure shows the dynamics of betas of the LMS portfolio estimated from CAPM regressions using daily returns within each quarter (black, solid line on the left axis). Moreover, it shows the dynamics of the market risk premium, see Equation (25) (red, dashed line on the right axis). For the latter, we use estimates for the first month within a quarter and scale it to a quarterly level. The sample period is from January 1976 until December 2017.



Finally, to provide additional evidence that long-maturity financed firms have higher systematic risk exposure when the market price of risk is high, we estimate the time-varying betas of the LMS portfolio using short-window CAPM regressions.[28] We plot the resulting relationship between the market price of risk estimate and the time-varying LMS beta in Figure 8. The market price of risk is estimated as in Equation (25) based on monthly returns. The LMS beta is the slope estimate from CAPM regressions within quarters using daily returns, averaged over the rolling window of the last four quarters and recorded at the end-date of each estimation window. The two time-series co-move with a correlation coefficient of 0.22, which is statistically significant at the 1% level. This represents further evidence that the exposure to systematic risk of the long-short maturity portfolio is countercyclical. Note that the beta estimates in this analysis do not rely on the choice of conditioning macro-variables, reinforcing the robustness of our observation that long-maturity financed firms have higher systematic risk exposure in downturns.

[28] We do not use these short-window betas to estimate the conditional alpha to avoid the over-conditioning bias, but merely use them to illustrate a co-movement with the market price of risk.

6 Conclusion

Firms' dynamic capital structure strategies clearly affect the risk characteristics and thus the equilibrium risk premia of their equity. Despite this obvious interaction, very little is known about how various features of capital structure affect leverage dynamics and thus asset prices. This paper takes a step towards answering some of these questions by focusing on a specific feature of capital structure, namely debt maturity. We document that, controlling for size, a portfolio long in long-maturity firms and short in short-maturity firms earns an excess risk premium, not explained by unconditional versions of the standard factor models. We call this the maturity premium.

To shed light on this empirical finding, we develop a theoretical model where firms adjust their leverage dynamically over time. The model predicts that long-maturity debt is stickier than short-maturity debt, implying that firms with long debt maturities exhibit more countercyclical leverage dynamics. Because long-term debt is reduced very slowly in a downturn, it leads to higher leverage, whereas short-term debt leads to faster debt reductions in response to decreasing cash flows. Firms with long-term debt therefore experience higher leverage precisely in times when the market price of risk is high. In other words, their leverage covaries more with the market risk premium. Vis-à-vis an unconditional version of the CAPM or a factor model, firms with long debt maturities therefore earn a premium, i.e. a positive alpha.

We also report empirical evidence on leverage and beta dynamics that are consistent with the model predictions. Finally, we exploit arguably random variations in firms' debt maturities at the onset of the recent financial crisis. To this end we define a sample of firms that choose similar debt maturities at the time when they issue bonds or bank loans. However, the lumpiness of the debt issues and their rollover dates implies that at any point in time, there will be arguably exogenous variation in firms' remaining debt maturities. We find that firms with shorter remaining debt maturities at the onset of the crisis experience an initial spike in leverage and betas but that both leverage and betas revert back quickly. By contrast, firms with long remaining debt maturities at the onset of the crisis experience elevated leverage and betas for extended periods of time. These results are consistent with our model predictions.

Our paper also sheds light on the contribution of leverage dynamics to asset pricing patterns that appear as anomalies relative to the unconditional CAPM. As value firms tend to be financed with long-term debt, the book-to-market ratio proxies for maturity choice. We therefore demonstrate that long-term financial leverage contributes to the value premium. However, controlling for the value factor, the portfolio of long-minus-short maturity financed firms still generates an unconditional alpha. This means that the maturity factor is distinct from the value factor and captures the risk of leverage increases in downturns. We believe that a fuller exploration of the effects of dynamic corporate decisions on equity returns is an attractive agenda for future research, as it may shed light on asset-pricing patterns that are not yet well understood.

APPENDIX

A Model Solution

For the valuation of the equity claim, consider the Hamilton-Jacobi-Bellman equation (*HJB* below)[29] associated with the expected future dividends shown in Equation (8). The required return is equal to the risk-free rate r when the firm issues the optimal amount of debt at any point in time, which in turn determines the dynamics of the total face value of debt, $dF_{i,t}$, as defined in Equation (6). Hence, we need to solve the following HJB equation for the optimal $G_{i,t}$

$$rV^E(Y_{i,t},F_{i,t}) = \max_{G_{i,t}} \left\{ Y_{i,t}(1-\tau) + \tau c F_{i,t} - (c+m)F_{i,t} + G_{i,t}v^D_{i,t} + (G_{i,t} - mF_{i,t})V^E_F(Y_{i,t},F_{i,t}) \right\} \tag{A-1}$$

$$+ \mu_Y V^E_Y(Y_{i,t},F_{i,t}) + 1/2\sigma^2_Y V^E_{YY}(Y_{i,t},F_{i,t}).$$

Issuing a marginal unit of debt generates benefits of $v^D_{i,t}$ to equityholders and costs of $V^E_F(Y_{i,t},F_{i,t})$ for future payments to debt holders. Assuming that debt is issued smoothly at the discretion of equityholders, equating marginal benefits and marginal costs results in the following first-order-condition (FOC)

$$v^D_{i,t} + V^E_F(Y_{i,t},F_{i,t}) = 0. \tag{A-2}$$

DeMarzo and He (2019) lay out optimality conditions for the debt issuance policy, which are met in our setup. Using the FOC from Equation (A-2) in the HJB shown in Equation (A-1) yields the following HJB that does not depend on $G_{i,t}$

$$\begin{aligned} rV^E(Y_{i,t},F_{i,t}) =& Y_{i,t}(1-\tau) + \tau c F_{i,t} - (c+m)F_{i,t} - mF_{i,t}V^E_F(Y_{i,t},F_{i,t}) \\ &+ \mu_Y V^E_Y(Y_{i,t},F_{i,t}) + 1/2\,\sigma^2_Y V^E_{YY}(Y_{i,t},F_{i,t}). \end{aligned} \tag{A-3}$$

We divide both state variables by the face value of debt $F_{i,t}$. Lower case letters refer to scaled versions of the upper case variables (e.g., the scaled cash flow level $y_{i,t} = Y_{i,t}/F_{i,t}$). Subsequently, the dynamics of the scaled cash flow process under the risk-neutral measure from Equation (5) are

[29] We use subscripts Y and F for the functions of the market value, where superscripts denote that it is either the equity or debt market value, respectively, to denote partial derivatives with respect to those variables to save on notation.

given by

$$dy_{i,t} = (\mu_Y + m_i - g_{i,t}) y_{i,t}\, dt + \sigma_Y y_{i,t}\, dW^Q_{Y_i,t}, \tag{A-4}$$

which also changes the HJB from Equation (A-3) to

$$(r+m_i) v_i^E(y_{i,t}) = y_{i,t}(1-\tau) + c\tau - (c+m_i) + (\mu_Y + m_i) y_{i,t} v_Y^E(y_{i,t}) + 1/2\sigma_Y^2 y_{i,t}^2 v_{YY}^E(y_{i,t}). \tag{A-5}$$

To solve Equation (A-5) we impose the boundary condition for $y_{i,t} \to \infty$, where the equity value should converge to the perpetuity of the after-tax cash flows plus the coupons tax shield less the bond's perpetuity value. Furthermore, at the cash flow level where equityholders default y_b, equity is worth nothing. Finally, the optimal default boundary is determined by the smooth-pasting condition, i.e. $v_Y^E(y_b) = 0$. Then, the equity value function is given by

$$v_i^E(y_{i,t}) = \frac{1-\tau}{r-\mu_Y} y_{i,t} - \frac{c(1-\tau)+m_i}{r+m_i} \left(1 - \frac{1}{1+\gamma_i} \left(\frac{y_{i,t}}{y_{b,i}}\right)^{-\gamma_i}\right), \text{ with} \tag{A-6}$$

$$\gamma_i = \frac{(\mu_Y + m_i - \sigma_Y^2/2) + \sqrt{(\mu_Y + m_i - \sigma_Y^2/2)^2 + 2\sigma_Y^2 (r+m_i)}}{\sigma_Y^2} > 0, \text{ and} \tag{A-7}$$

$$y_{b,i} = \frac{\gamma_i}{1+\gamma_i} \frac{r-\mu_Y}{r+m_i} \left(c + \frac{m_i}{1-\tau}\right). \tag{A-8}$$

The scaled value of debt, i.e. the price per unit of face value, follows from the FOC in Equation (A-2)

$$v_i^D(y_{i,t}) = \frac{c(1-\tau)+m_i}{r+m_i} \left(1 - \left(\frac{y_{i,t}}{y_{b,i}}\right)^{-\gamma_i}\right). \tag{A-9}$$

We derive the debt issuance policy $G_{i,t}$ by considering the HJB for the value of debt. The value of debt can be based on the expectation of future payments to debtholders as shown in Equation (9),

$$\begin{aligned} rv^D(Y_{i,t}, F_{i,t}) &= \\ &= c + m(1 - v^D(Y_{i,t}, F_{i,t})) + (G_{i,t} - mF_{i,t}) v_F^D(Y_{i,t}, F_{i,t}) + \mu_Y v_Y^D(Y_{i,t}, F_{i,t}) + 1/2\sigma_Y^2 v_{YY}^D(Y_{i,t}, F_{i,t}). \end{aligned} \tag{A-10}$$

Next, we impose the FOC from Equation (A-2) on the derivative with respect to the debt level $F_{i,t}$

of the HJB for equity in Equation (A-3) to find another HJB for the price of debt, which is equal to

$$\begin{aligned} &-rv^D(Y_{i,t},F_{i,t}) = \\ &= \tau c-(c+m)+mv^D(Y_{i,t},F_{i,t})+mF_{i,t}v_F^D(Y_{i,t},F_{i,t})-\mu_Y v_Y^D(Y_{i,t},F_{i,t})-1/2\,\sigma_Y^2 v_{YY}^D(Y_{i,t},F_{i,t}). \end{aligned} \tag{A-11}$$

Adding Equations (A-10) and (A-11) results in the expression for the optimal debt issuance policy

$$g_i(y_{i,t}) = \frac{(r+m_i)\tau c}{c(1-\tau)+m_i}\frac{1}{\gamma_i}\left(\frac{y_{i,t}}{y_{b,i}}\right)^{\gamma_i}. \tag{A-12}$$

We can see that there is a cash flow level, which we denote by $y_{m_i,i}$, at which the firm rolls over exactly the maturing amount of debt m_i, which keeps the face value of debt constant. This cash flow level equals

$$y_{m,i} = y_{b,i}\left(\gamma_i\frac{c(1-\tau)+m_i}{(r+m_i)\tau c}m_i\right)^{1/\gamma_i} \tag{A-13}$$

and can be used to restate Equation (A-12) from above to the version in Equation (12).

The evolution of debt outstanding $F_{i,t}$ is the result of debt issuance and the maturing part of debt,

$$dF_{i,t} = \left(m_i\frac{Y_{i,t}^{\gamma_i}}{y_{m,i}^{\gamma_i}}F_{i,t}^{1-\gamma_i}-mF_{i,t}\right)dt\,. \tag{A-14}$$

B Return on Equity

In this subsection we analyze equity returns in detail and demonstrate that under the risk-neutral measure the expected equity return is r, while innovations to cash flows are amplified by a firm's financial leverage v^D/v^E.

$$r^E_{t,t+dt} = \frac{dV_t^E+\Pi_{t,t+dt}}{V_t^E} \tag{B-1}$$

$$r^E_{t,t+dt} \quad = \quad \frac{V_F^E\,dF_t+V_Y^E\,\mu_Y Y_t\,dt+V_Y^E\,\sigma_Y Y_t\,dW^Q_{Y_i,t}+\frac{1}{2}V_{YY}^E\,\sigma_Y^2 Y_t^2\,dt+\Pi_{t,t+dt}}{V^E(Y_t,F_t)},$$

$$
\begin{aligned}
\frac{\partial V^E(Y,F)}{\partial F} &= \frac{\partial}{\partial F}\left(V^E\left(\frac{Y}{F},1\right)F\right) = -\frac{Y}{F^2}\frac{\partial V^E\left(\frac{Y}{F},1\right)}{\partial \frac{Y}{F}}F + V^E\left(\frac{Y}{F},1\right) \\
V_F^E &= -yv_y^E + v^E && \text{(B-2)} \\
rV^E(Y,F) &= \max_G \Pi_{t,t+dt} + V_F^E\, dF_t + V_Y^E \mu_Y Y_t\, dt + \frac{1}{2}V_{YY}^E \sigma_Y^2 Y_t^2\, dt \\
r_{t,t+dt}^E &= \frac{1}{V^E(Y_t,F_t)}\left(rV^E\, dt + V_Y^E \sigma_Y Y_t\, dW_{Y_i,t}^Q\right) \\
&= r\,dt + \frac{V_Y^E Y_t}{V^E(Y_t,F_t)}\sigma_Y\, dW_{Y_i,t}^Q;\ \text{ divide by } F \\
&= r\,dt + \frac{v_Y^E y_t}{v^E(Y_t,F_t)}\sigma_Y\, dW_{Y_i,t}^Q;\ \text{and using Equation (B-2) we arrive at} \\
&= r\,dt + \frac{v^E - V_F^E}{v^E(Y_t,F_t)}\sigma_Y\, dW_{Y_i,t}^Q;\ \text{using FOC from Equation (A-2)} \\
&= r\,dt + \frac{v^E + v^D}{v^E}\sigma_Y\, dW_{Y_i,t}^Q = r\,dt + \left(1+\frac{v^D}{v^E}\right)\sigma_Y\, dW_{Y_i,t}^Q\,. && \text{(B-3)}
\end{aligned}
$$

Under the physical measure we find:

$$
r_{t,t+dt}^E = r\,dt + \left(1+\frac{v^D}{v^E}\right)\eta_t\, dt + \left(1+\frac{v^D}{v^E}\right)\sigma_Y\, dW_{Y_i,t}^P\,. \qquad \text{(B-4)}
$$

C Detailed Beta Derivation

$$
\begin{aligned}
\beta_{i,t} &= \frac{Cov_t(r_{t,dt}^E, r_{t,dt}^M)}{Var_t(r_{t,dt}^M)} && \text{(C-1)} \\
&= \frac{1}{Var_t(r_{t,dt}^M)}Cov_t\left(\left(1+\frac{v_i^D(y_t)}{v_i^E(y_t)}\right)\sigma_Y dW_{Y,t}^P; \sigma_x dW_{x,t}^P\right) && \text{(C-2)} \\
&= \frac{1}{\sigma_x^2}\sigma_Y\sigma_x\left(1+\frac{v_i^D(y_t)}{v_i^E(y_t)}\right)Cov_t(dW_{Y,t}^P, dW_{x,t}^P) && \text{(C-3)} \\
&= \frac{1}{\sigma_x}\sigma_Y\left(1+\frac{v_i^D(y_t)}{v_i^E(y_t)}\right)Cov_t\left(\frac{1}{\sigma_Y}(\sigma_x dW_{x,t}^P + \sigma_i dW_{i,t}^P), dW_{x,t}^P\right) && \text{(C-4)} \\
&= 1+\frac{v_i^D(y_t)}{v_i^E(y_t)}. && \text{(C-5)}
\end{aligned}
$$

D Definition of Variables

In this section we provide definitions for the variables used in our empirical analysis. Variables from CRSP are indicated in italics. The item abbreviations are matched to variable descriptions in Table D-1.

Table D-1: COMPUSTAT & CRSP Item Description. Items from COMPUSTAT are listed below in capital letters, all variables from CRSP are listed using lower case letters.

Item Name	Variable Description
CSHO	Common Shares Outstanding
*DD*1	DD1 – Long-Term Debt Due in One Year
*DD*2	DD2 – Debt Due in 2nd Year
*DD*3	DD3 – Debt Due in 3rd Year
DLC	Debt in Current Liabilities - Total
DLTT	Long-Term Debt - Total
PRCC_F	Price Close - Annual - Fiscal
PSTKRV	Preferred Stock Redemption Value
PSTKL	Preferred Stock Liquidating Value
PSTK	Preferred/Preference Stock (Capital) - Total
TXDITC	Deferred Taxes and Investment Tax Credit
altprc	Price Alternate
shrout	Number of Shares Outstanding

We define *leverage* as the ratio of book debt to book debt plus market equity, as in Danis et al. (2014).

$$L := \frac{DLC + DLTT}{DLC + DLTT + PRCC\_F * CSHO} \tag{D-1}$$

Next, we define a proxy for *debt maturity* as the share of debt maturing in more than 3 years, as proposed by Barclay and Smith (1995).

$$DM := \frac{DLTT - DD2 - DD3}{DLC + DLTT} \tag{D-2}$$

Market equity is defined as the price per share times shares outstanding scaled by a factor 10^{-3}.

$$ME := \frac{|altprc| * shrout}{1000} \tag{D-3}$$

The *book value of equity* is defined as in Fama and French (1992, 1993) by the book value of stockholder's equity adjusted for the value of tax effects of deferred taxes and investment credit and subtracting the book value of preferred stock. The value of preferred stock (abbreviated $[BVPS]$) is determined by taking redemption, liquidation, or par value (from COMPUSTAT $PSTKRV$, $PSTKL$, or PSK, respectively) depending on availability in the given order.

$$BE := SEQ + TXDITC - [BVPS] \tag{D-4}$$

Finally, the *book-to-market* ratio is calculated as proposed by Fama and French (1992, 1993) by relating book equity of the fiscal year ending in year t to market equity as of December of year t.

$$BM := \frac{BE}{ME} \tag{D-5}$$

We use returns on the ordinary equity of individual firms (CRSP) in excess of the risk-free rate (*excess returns*). The data on risk-free rates (1 month T-bill rates) is taken from the Kenneth French web-page.[30]

For the conditional version of the CAPM, we take data on the macro-economic variables that we use as predictors from Amit Goyal's homepage. The dividend yield (denoted by DY) is the log difference between dividends and lagged prices. Where the dividends are the 12-month moving sum of dividends on the S&P 500. The default spread (denoted by DS) is the difference between the yields on BAA and AAA-rated corporate bonds. The term spread (denoted by TS) is defined as the yield difference between long-term and short-term government bonds. T-bill rate is denoted as TB. CAY is estimated at the quarterly frequency:

$$c_t = \alpha + \beta_a a_t + \beta_y y_t + \sum_{i=-8}^{8} b_{a,i} \Delta a_{t-i} + \sum_{i=-8}^{8} b_{y,i} \Delta y_{t-i} + \varepsilon_t, \tag{D-6}$$

$$CAY_t := c_t - \hat{\beta}_a a_t - \hat{\beta}_y y_t, \tag{D-7}$$

where c_t is aggregate consumption, a_t is aggregate wealth, and y_t is the aggregate income. The sample used for estimating CAY is 1st quarter of 1951 to 4th quarter of 2018.

[30] See http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html#Research.

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