



The maturity premium[☆]

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ABSTRACT

We show that firms with longer debt maturities earn risk premia not explained by unconditional factors. Embedding dynamic capital structure choices in an asset-pricing framework where the market price of risk evolves with the business cycle, we find that firms with long-term debt exhibit more countercyclical leverage. The induced covariance between betas and the market price of risk generates a maturity premium similar in size to our empirical estimate of 0.21% per month. We also provide direct evidence for the model mechanism and confirm that the maturity premium is consistent with observed leverage dynamics of long- and short-maturity firms.

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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 of whether these dynamics are affected by debt maturity and how they are related to equity risk premiums. 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 premiums, 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 \(2021\)](#) and [DeMarzo and He \(2020\)](#), we show that long-term financing makes leverage more countercyclical. Firms that are 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,

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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, the 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](#)), based on 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 in the Internet Appendix confirm our results.

To explain the empirical findings, we propose a theoretical conditional CAPM with a dynamic corporate finance foundation. Extending the framework of [Dangl and Zechner \(2021\)](#) and [DeMarzo and He \(2020\)](#), we develop a partial equilibrium dynamic trade-off model and study its implications for the cyclicity of leverage and stock returns. As in [Admati et al. \(2018\)](#), [Dangl and Zechner \(2021\)](#), and [DeMarzo and He \(2020\)](#), 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 roll over part of the maturing debt, thereby reducing leverage. Shorter maturity strengthens this effect, since it implies a higher rollover rate. Shareholders of firms that are financed with short-term credit suffer less from the misalignment 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. The debt level of these firms decreases very slowly after a negative profitability shock, 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 the CAPM. This is the case because 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 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 empirical evidence for the predictions of our model. First, we conduct a direct test of the mechanism driving the maturity premium. We exploit the arguably exogenous variation in the debt maturity of firms at the onset of the financial crisis in 2008. The idea is that two firms that optimally choose the same maturity when they issue debt may have different effective maturities at a given point in time, since the issue dates of their debt components will differ across firms. For example, a firm that issued its seven-year bond five years ago will need to roll it over in two years, whereas a firm that issued a similar bond one year ago has a six-year remaining maturity. We exploit 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 employ debt instruments with a 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 and 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, a 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.

Next, we provide evidence, from the entire sample period, that leverage of long-maturity financed firms is sticky, as suggested by our theoretical model. We find that short-term financed firms adjust their outstanding debt more quickly towards past average leverage levels, while long-term financed firms only show limited adjustments. Moreover, we also compute excess leverage following [Frank and Shen \(2019\)](#) and see that short-term financed firms are quicker in adjusting towards their target leverage. In both cases, the findings are consistent with the theoretical mechanism driving the maturity premium.

Finally, we investigate whether conditional beta estimates vary with the market price of risk and whether a conditional CAPM can explain the alpha in the unconditional specification. To this end, we follow [Boguth et al. \(2011\)](#) to obtain conditional beta estimates. To study their business-cycle properties, we additionally estimate the market price of risk, using a vector of macro variables. We find that the beta of the long-short maturity portfolio co-moves positively with the market price of risk. This finding provides direct empirical support for the model prediction that long-term financed firms have more prolonged exposure to systematic risk in downturns. Moreover, the intercept in a conditional CAPM is insignificant, as predicted by our theoretical model.

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. This assumption contradicts empirical evi-

dence 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 premiums, we develop a model where leverage dynamics are chosen optimally by firms. We demonstrate that optimal leverage adjustments and thus equity risk premiums depend on debt maturity. Therefore, the extent to which financial leverage 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., 2021](#) show that short-term leverage entails a positive equity premium due to an increase in rollover risk, which is in fact consistent with our hypothesis that short-maturity financed firms are risky over short holding horizons. [Friewald et al., 2021](#) 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 riskier than firms that borrow predominantly from banks, because they have more difficulty re-negotiating their debt, and this risk is priced by equityholders. [Berk et al. \(1999\)](#), [Gomes and Schmid \(2010\)](#), [Kuehn and Schmid \(2014\)](#), [Babenko et al. \(2016\)](#), and [Gu et al. \(2017\)](#), 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 et al., 2020](#) 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 underperformance of distressed firms. In contrast to their paper, we focus on the role of finite debt maturity instead of 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 underperform 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 (see, e.g., Julio, 2013). 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 (2021) investigate the business-cycle implications of the sticky leverage caused by long maturity of debt, arguing that the failure to delever in downturns 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. (2021) show that maturity is pro-cyclical. They argue that this is due to liquidity shocks to bondholders, which become more pronounced in crises and affect long-term bondholders more severely. In our setting, we abstract from optimal maturity adjustments.² 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., 2020) have been shown to be related to equity risk premiums. We contribute to this literature by demonstrating that the maturity choices 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 (2021) and DeMarzo and He (2020) by explicitly modeling time-varying market risk premiums and analyzing the asset-pricing implications of leverage dynamics in such a setting.

2. Empirical results

We first document a positive relation between debt maturity and equity returns. We establish this result by analyzing a portfolio that is long long-maturity financed firms and short short-maturity financed firms

while 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 Center for Research in Security Prices (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. A firm is included when all items for computing its debt maturity are available.³ 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).⁴ 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 three years.⁵ Given recent empirical evidence on the use of credit lines (Korteweg et al., 2021), we believe that the cut-off of three 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.

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 three 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.

³ 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.

⁴ For detailed definitions on all variables (including the exact items used), we refer to Appendix A.

⁵ 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.

² Recent papers that tackle the question of maturity dynamics include Brunnermeier and Oehmke (2013), He and Milbradt (2016), and Chaderina (2018), among others.

Table 1

Summary statistics. We compute the mean and the 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 is 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

Table 2

Firm characteristics across debt maturity. We compute average characteristics across five debt maturity buckets. We sort firms into quintiles for every year in our sample. 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 is 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
Cash	18.03	11.19	9.53	9.35	12.03
β^U	0.84	0.70	0.68	0.68	0.76
CAPEX	0.19	0.16	0.14	0.13	0.16

[Table 2](#) summarizes the characteristics of firms across five debt maturity buckets. We notice that there is 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 smaller than firms in the longest maturity bucket. However, the two groups' 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. They also have higher cash balances, lowering their net leverage even more in comparison to firms with longer debt maturities. Asset betas and CAPEX rates do not appear to be related to debt maturities.

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.⁶

⁶ 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.

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 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 alongside the beta estimates from the five-factor model.

The 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. The double-sorted long-minus-short portfolios also have statistically significant CAPM alphas, except for the two largest size quintiles. In the smallest size-bucket, the long-maturity firms outperform the short-maturity firms by 0.44% per month. We also show, in [Tables IA-3](#) and [IA-4](#) in the Internet Appendix, that the LMS portfolio results are robust to excluding the bottom size quintile and to using NYSE breakpoints.⁷

The positive and statistically highly significant factor loading β^{HML} indicates that the LMS portfolio has an expo-

⁷ Our results also hold for equal-weighted portfolio sorts, as shown in [Table IA-5](#) in the Internet Appendix. Moreover, we find that the maturity premium is most pronounced among more highly levered firms (see [Table IA-6](#)) and is robust to sorts with idiosyncratic volatility (see [Table IA-7](#)).

Table 3

Debt maturity-sorted portfolios. Panel A shows the average excess return of the value-weighted portfolios. The last row represents the long-maturity minus short-maturity portfolios (LMS). The portfolios are formed by double sorts on size (five buckets at the 20%, 40%, 60%, and 80% percentiles) and debt maturity (five buckets at the 20%, 40%, 60%, and 80% percentiles) 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 their alpha estimates from CAPM-regressions (α^{CAPM}), the three-factor model by Fama and French (1993) (α^{FF3}), and the five-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
α^{CAPM}	0.44*** (2.98)	0.32** (2.03)	0.22* (1.82)	0.04 (0.41)	0.03 (0.26)	0.21*** (2.93)
α^{FF3}	0.35*** (2.69)	0.20 (1.44)	0.09 (0.82)	0.00 (0.04)	0.11 (0.94)	0.15** (2.31)
α^{FF5}	0.30** (2.27)	0.10 (0.59)	-0.06 (-0.60)	-0.11 (-1.22)	0.25** (2.57)	0.10* (1.67)
β^M	-0.08** (-1.99)	-0.04 (-1.17)	0.02 (0.75)	0.08*** (3.62)	-0.13*** (-4.45)	-0.03* (-1.78)
β^{SMB}	-0.17*** (-3.09)	-0.23*** (-3.53)	-0.12*** (-2.76)	-0.01 (-0.28)	0.07 (1.41)	-0.09*** (-2.97)
β^{HML}	0.36*** (5.44)	0.33*** (3.80)	0.33*** (5.25)	0.00 (0.08)	-0.13 (-1.32)	0.18*** (3.92)
β^{RMW}	0.20*** (2.73)	0.22 (1.51)	0.36*** (5.18)	0.18** (2.50)	-0.26*** (-3.55)	0.14*** (2.65)
β^{CMA}	-0.21* (-1.89)	0.05 (0.46)	0.01 (0.07)	0.20** (2.21)	-0.16 (-1.41)	-0.02 (-0.45)

*** $p < .01$, ** $p < .05$, * $p < .1$

sure 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 also 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.

3. Model

In this section, we present a theoretical framework that captures the effects of debt maturity on the dynamics of firms' leverage and allows us to analyze the resulting asset-pricing implications. A key feature of our model is that firms must refinance their maturing debt at every instant in time, but they can freely adjust their capital structure when doing so. That is, firms may decide to hold the face value of debt constant by issuing new debt with a face value equal to that of the expiring debt, but they may also decide to increase or decrease the face value of their debt. They may also repurchase non-expiring debt at any time. Following Dangi and Zechner (2021) and DeMarzo and He (2020), we assume that equityholders cannot credibly commit to future leverage adjustments via contractual

obligations.⁸ Specifically, we embed the model developed by DeMarzo and He (2020) in a partial equilibrium asset-pricing framework, where the market price of risk evolves countercyclically and firms are subject to both systematic and idiosyncratic cash-flow shocks. This framework generates a tractable link between debt maturity and leverage dynamics and allows us to analyze how maturity affects the counter-cyclicality of leverage and the co-movement of betas with the market price of risk.

While our model lacks some realistic features, such as transaction costs and different debt seniority, it allows us to analyze the effect of debt maturity on equity risk premiums in a parsimonious way.⁹

⁸ Contractual commitments to leverage adjustments 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), and Goncharenko (2021). Thus, the absence of commitment to leverage adjustments may be motivated by contracting frictions firms face.

⁹ The link between maturity and the dynamics of leverage is robust to incorporating transaction costs into the framework, as shown by

3.1. Cash flow

We consider a market comprising 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 :

$$dX_t = \mu(X_t, t)X_t dt + \sigma_X X_t dW_{X,t}^P, \quad (1)$$

$$\mu(X_t, t) = \mu_0 - k[\log(X_t) - (\mu_0 - \sigma_X^2/2)t]. \quad (2)$$

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 .¹⁰ 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 cyclicity to the productivity growth, i.e., a business cycle.¹¹ An alternative way to model cyclicity would be via a time-varying intensity of a rare disaster risk (see, e.g., Wachter, 2013; Seo and Wachter, 2018). As in our model, the time-varying rare disaster risk implies stochastic discount factors (SDFs) that attach higher prices to output shocks when the economy is doing poorly.

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:

$$dI_{i,t} = \sigma_i I_{i,t} dW_{i,t}^P. \quad (3)$$

Given the multiplicative combination of the variables, the resulting cash flow $Y_{i,t}$ also follows a geometric Brownian motion

$$dY_{i,t} = \mu(X_t, t)Y_{i,t} dt + \sigma_Y Y_{i,t} dW_{Y,t}^P, \quad (4)$$

$$\text{where } \sigma_Y = \sqrt{\sigma_X^2 + \sigma_i^2} \quad \text{and} \quad dW_{Y,t}^P = (\sigma_X dW_{X,t}^P + \sigma_i dW_{i,t}^P) / \sigma_Y.$$

3.2. Stochastic discount factor

Following Berk et al. (1999) and in line with more recent literature (see, e.g., Kuehn et al., 2017), we take the

Dangl and Zechner (2021) for proportional issuance costs of debt, and by Benzoni et al., 2020 for fixed debt issuance costs.

¹⁰ 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, $\mathbb{E}_0[X_t] < X_0 e^{\mu_0 t}$, since the covariance between μ_t and X_t is negative: $\mathbb{E}_0[X_t e^{\mu_t t}] = \text{Cov}(X_t, e^{\mu_t t}) + \mathbb{E}_0[X_t] \mathbb{E}_0[e^{\mu_t t}] < \mathbb{E}_0[X_t] e^{\mu_0 t}$. Also, $\mathbb{E}_0[e^{\mu_t t}] < e^{\mu_0 t}$ due to Jensen's inequality.

¹¹ The current specification for the drift process admits low values for the growth rate of the productivity process. Some of them are low enough that the market price of risk, which is related to the drift, can turn negative. While it might seem counterintuitive, 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. We provide details in the Internet Appendix.

consumption process of the representative consumer in the economy as given, so under our assumptions the financing decisions of a firm do not impact the market price of risk.

We assume the following evolution of the stochastic discount factor (SDF)

$$\frac{d\Lambda_t}{\Lambda_t} = -r dt - \frac{\mu(X_t, t) + \delta - r}{\sigma_X} dW_{X,t}^P, \quad (5)$$

where the market price of risk is

$$\lambda_t = \frac{\mu(X_t, t) + \delta - r}{\sigma_X}, \quad (6)$$

where $\delta > 0$ represents aggregate dividends. The market price of risk is time-varying due to the variation in $\mu(X_t, t)$, as specified in Eq. (2). Furthermore, we denote by η_t the risk premium for bearing systematic risk, which equals $\eta_t = \sigma_X \lambda_t$.

In our model, the market price of risk λ_t is governed by shocks to the aggregate productivity process X_t . The higher the aggregate productivity, the smaller the market price of risk. Such a countercyclical price of risk is a standard feature of many asset-pricing models (see, e.g., Mehra and Prescott, 1985; Campbell and Cochrane, 1999). A countercyclical price of risk is also supported by micro-evidence (see, e.g., Guiso et al., 2018) and is crucial in explaining many asset-pricing phenomena, not only in equity but also in bond markets (Bekaert et al., 2021).¹² This setting is very similar to other papers at the intersection of dynamic corporate finance and asset pricing (see, e.g., Zhang, 2005; Kuehn and Schmid, 2014).

3.3. Debt and equity valuation

To model a firm's financing options, we utilize the setting of DeMarzo and He (2020). A firm issues debt with face (book) value $F_{i,t}$. The bond pays a fixed coupon rate c that is tax-deductible at the marginal tax rate τ . A constant fraction m_i of outstanding debt 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 and issuance of new claims are given by the coupon payments and the retirement of maturing debt $(c + m_i)F_{i,t} dt$. 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 life. The 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 (2021) and following DeMarzo and

¹² Dividends in our model are positively related to the cash-flow shocks, so they are negatively related to the market price of risk, consistent with the empirical evidence (Van Binsbergen and Kojien, 2010). 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 reduce this link but complicate the model substantially.

He (2020), firms are also allowed to increase debt smoothly by issuing more than the maturing fraction of debt, i.e., by choosing $G_{i,t} > m_i F_{i,t}$. Consequently, the dynamics of the outstanding face value of debt are $dF_{i,t} = (G_{i,t} - m_i F_{i,t}) dt$.

We abstract from transaction costs of issuing either debt or equity. The residual cash flows net of debt-related payments and taxes

$$\Pi_{i,t} dt = \{Y_{i,t}(1 - \tau) + \tau c F_{i,t} - (c + m_i) F_{i,t} + G_{i,t} v_{i,t}^D\} dt, \quad (7)$$

are 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 terms 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 $v_{i,t}^D$.

The market value of equity is the expected value of future dividends, i.e.,

$$V_{i,t}^E(Y_{i,0}, F_{i,0}) \Lambda_0 = \mathbb{E}_0^P \left[\int_0^{t_b} \Lambda_s \Pi_{i,s} ds \right]. \quad (8)$$

We restrict the solution space to policy functions $G_{i,t}$ that 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 (2020), we find closed-form solutions for the scaled value of equity $v_i^E(y_{i,t})$ and debt $v_i^D(y_{i,t})$. For a detailed model solution see Appendix B.

3.4. Debt issuance policy and leverage dynamics

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

$$g_{i,t}(y_{i,t}) = m_i \left(\frac{y_{i,t}}{y_{m,i}} \right)^{\gamma_i}, \quad (9)$$

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

$$y_{m,i} = y_{b,i} \left(\gamma_i \frac{c(1 - \tau) + m_i}{(r + m_i)\tau c} m_i \right)^{1/\gamma_i} \quad (10)$$

and $y_{b,i}$ denotes the endogenously chosen scaled cash flow at which the equityholders default. 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. Firms in our model roll over only a fraction of the maturing debt when cash flows are low ($y_{i,t} < y_{m,i}$) and issue more than the maturing debt when cash flows are high ($y_{i,t} \geq y_{m,i}$).

As in Dangi and Zechner (2021) and DeMarzo and He (2020), the issuance policy in our model is crucially different from Leland and Toft (1996). When the firm's cash flow in our model decreases, shareholders roll over a smaller fraction of debt, thereby reducing outstanding debt and the default risk. In Leland and Toft (1996), irrespective of the distance to default, shareholders must always fully roll over all expiring debt. Along a decreasing cash-flow path, the firm's leverage increases in Leland and Toft (1996), while in our model its increase is dampened by the reduction in the outstanding debt. A policy of always fully rolling over expiring debt is suboptimal ex post.

Eq. (9) 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. Fig. 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 in both increasing the leverage after positive cash-flow shocks and decreasing the leverage after negative cash-flow shocks.

3.5. 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 section, 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 are 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

$$L_{i,t} = \frac{v_{i,t}^D}{v_{i,t}^E + v_{i,t}^D}, \quad (11)$$

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 and at other times 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:

$$F_{i,t} = \left(\int_0^t \gamma_i m_i \left(\frac{Y_{i,s}}{y_{m,i}} \right)^{\gamma_i} e^{\gamma_i m_i (s-t)} ds \right)^{1/\gamma_i}. \quad (12)$$

Following Admati et al. (2018), we define the ratchet effect of leverage as shareholders' unwillingness to actively

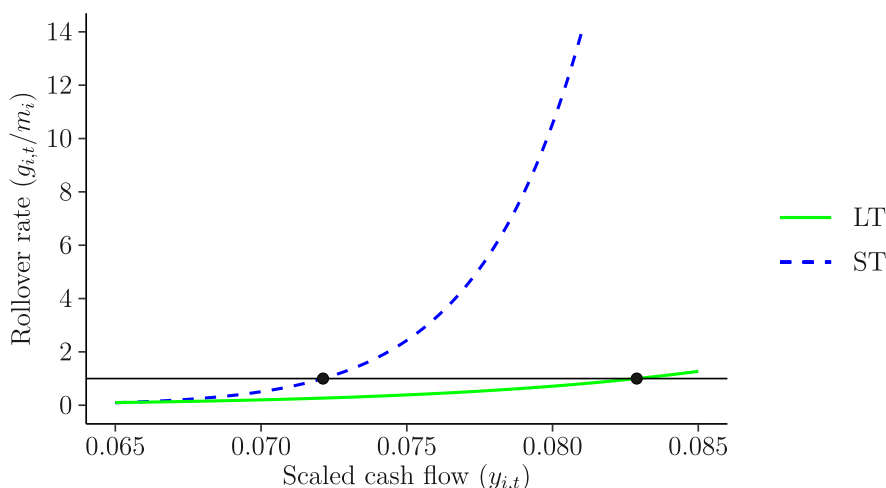


Fig. 1. Optimal rollover rate. This graph shows the optimal rollover rate of debt, which is given by the issuance policy $g_{i,t}$ scaled by the maturity rate m_i . It is plotted against the scaled cash-flow shock $y_{i,t}$. This ratio equals one when the firm's net issuance is zero. The short- and long-maturity financed firms are characterized by $m_i = 0.5$ and $m_i = 0.2$, i.e., a debt maturity of two (ST) and five (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.

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 to do 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 Dangi and Zechner (2021) and DeMarzo and He (2020), 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 Fig. 2.

The graph in Fig. 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 the ups and downs of the cash-flow 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.¹³ These dynamics are due to the leverage 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 choose 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 the leverage 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 derive the asset-pricing implications of different debt maturities. To this end, we develop a partial equilibrium model, where the market price of risk is determined by the aggregate productivity level of the economy, as defined by Eq. (6) in Section 3.2. While our partial equilibrium setup may miss some potentially interesting general equilibrium feedback effects, it keeps the model simple and tractable while still incorporating a countercyclical market price of risk, as observed in the data.

4.1. 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

¹³ While we plot the policy functions for a random cash-flow path, we would see similar differences in the leverage dynamics of short- and long-term financed firms for other cash-flow paths. Along paths that are generally decreasing, long-term financed firms would delever more slowly. Along paths that are increasing, long-term financed firms would increase outstanding debt more slowly.

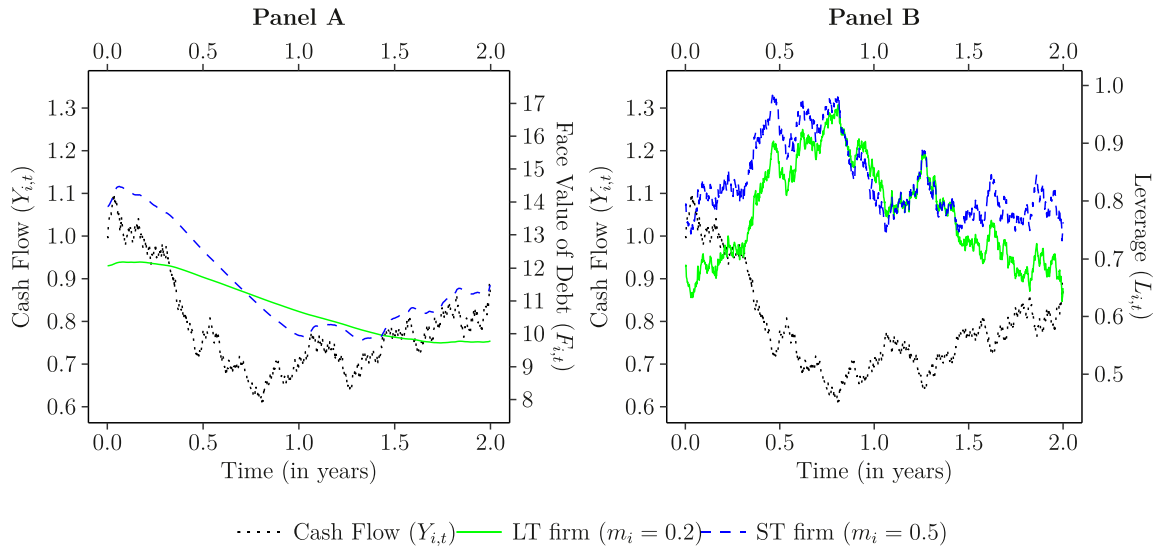


Fig. 2. Debt maturity and the leverage ratchet effect. This figure illustrates the differences in leverage dynamics for a short- (dashed lines) and long-maturity (solid lines) financed firm (referred to as ST and LT, respectively). Panel A (Panel B) shows the face value of debt $F_{i,t}$ (leverage $L_{i,t}$)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

can be computed as

$$r_{i,t}^E dt = \frac{dV_{i,t}^E + \Pi_{i,t} dt}{V_{i,t}^E}. \quad (13)$$

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

$$r_{i,t}^E dt = r dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \eta_t dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \sigma_{Y_i} dW_{Y_{i,t}}^P, \quad (14)$$

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 .¹⁴ Under the physical measure it is:

$$\begin{aligned} \mathbb{E}_t^P[r_{i,t}^E dt] &= \mathbb{E}_t^P\left[r dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \eta_t dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \sigma_{Y_i} dW_{Y_{i,t}}^P\right] \\ &= r dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \eta_t dt. \end{aligned} \quad (15)$$

This expression illustrates that the conditional CAPM holds in our setting. The asset beta is normalized to one, and the equity beta is then one plus debt over equity, i.e., $\beta_{i,t} = 1 + \frac{v_{i,t}^D}{v_{i,t}^E}$, while η_t represents the time-varying market risk premium.¹⁵

¹⁴ $\mathbb{E}_t^Q[r_{i,t}^E dt] = \mathbb{E}_t^Q[r dt + (1 + \frac{v_{i,t}^D}{v_{i,t}^E}) \sigma_{Y_i} dW_{Y_{i,t}}^Q] = r dt$.

¹⁵ Assuming that the value of the market portfolio $M(X_t)$ is determined by the stochastic aggregate productivity X_t , we obtain the same result if we define beta by $\beta_{i,t} = \frac{\text{Cov}(r_{i,t}^E dt, r_{i,t}^M dt)}{\text{Var}(r_{i,t}^M dt)}$. See Appendix C for the definition of a market return in our setting. See Appendix E for the details on deriving beta through the covariance with the market return.

Eq. (15) implies that levered returns increase linearly with leverage, which is reminiscent of a Modigliani-Miller setting. The lack of an option-like term (found, e.g., in Bhamra et al., 2010) driven by default is a direct consequence of the lack of commitment to a debt issuance policy. As in DeMarzo and He (2020), firms in our model lever up to the point where the tax benefits of leverage exactly offset the expected default costs and leverage at the optimum has a neutral effect on the equity value (see Appendix B for the HJB). While it simplifies the analytical solution, the link between debt maturity and the dynamics of beta we identify does not rely on the linearity of levered equity returns.

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.

4.2. 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

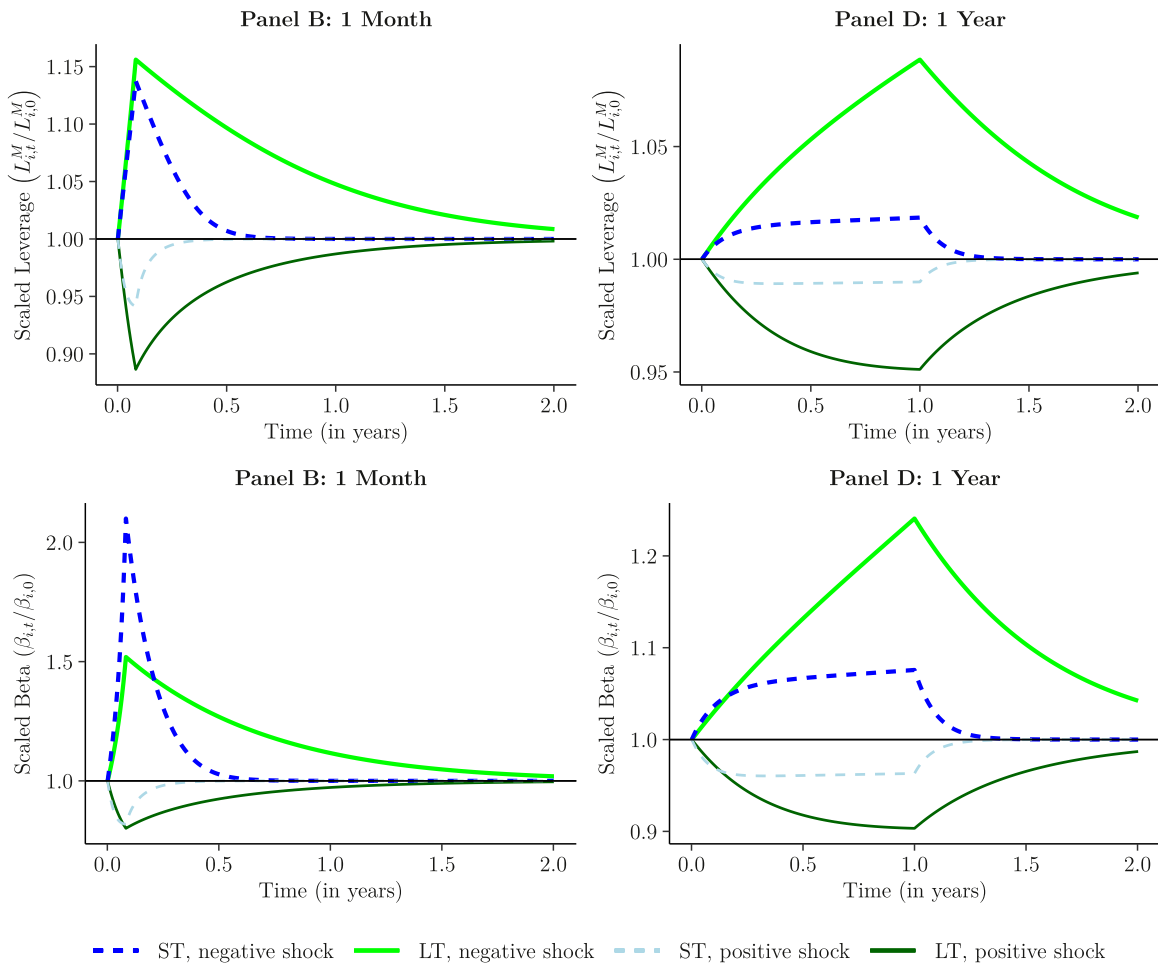


Fig. 3. Evolution of leverage and beta following cash-flow shocks. This figure shows leverage ($L_{i,t}^M$) and beta ($\beta_{i,t}$) responses to linear cash-flow increases and decreases of 15% over different time intervals. After the cash flow changes, the cash-flow level is held constant but the firms continue rolling over debt. In the two top panels, leverage dynamics are based on shocks over one month (Panel A) and one year (Panel B). The two lower panels show the dynamics of betas to shocks over one month (Panel C) and one year (Panel D). All variables are scaled by the starting values before the introduction of a shock. The initial values of $y_{i,t}$ are chosen such that the firms roll over the amount of debt that matures. The solid (dashed) lines represent a firm with $m_i = 0.2$ ($m_i = 0.5$), i.e., a debt maturity of five (LT) and two (ST) years. For both firms $\sigma_i = 0.15$. The underlying parameters are as in the benchmark case, i.e., $\mu_0 = 0.05$, $k = 0.25$, $\sigma_X = 0.15$, $\delta = 0.04$, $r = 0.05$, and $\tau = 0.3$.

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% for a single firm that starts at the full rollover debt level (i.e., $y_{i,t} = y_{m,i}$). We assume that these shocks occur linearly without any noise over one month or twelve months, respectively.¹⁶ We first consider the sharp shocks over one month, which are illustrated by Panels A and C of Fig. 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 those betas remain elevated for longer. A few months after the shock, the betas of long-term financed firms exceed the betas 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

¹⁶ 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.

that leverage affects beta of equity in a nonlinear way

$$\beta_{i,t} = \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \beta^{\text{Assets}} = \frac{1}{1 - \frac{v_{i,t}^D}{v_{i,t}^E + v_{i,t}^D}} \beta^{\text{Assets}}. \quad (16)$$

Hence, beta is more sensitive to a drop in equity values than leverage.¹⁷

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 Fig. 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.

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.¹⁸

4.3. Unconditional CAPM and alpha

In our model, the conditional version of the CAPM holds, period by period. We can rewrite the expression for the conditional expected equity return in Eq. (15) using $\beta_{i,t}$ to arrive at a notation similar to the CAPM

$$\mathbb{E}_t[r_{i,t}^E dt] = r dt + \left(1 + \frac{v_{i,t}^D}{v_{i,t}^E}\right) \sigma_X \lambda_t dt = r dt + \beta_{i,t} \eta_t dt, \quad (17)$$

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:

$$\alpha_i = \left[1 - \frac{\eta^2}{\sigma_M^2}\right] \text{Cov}(\beta_{i,t}, \eta_t) - \frac{\eta}{\sigma_M^2} \text{Cov}(\beta_{i,t}, (\eta_t - \eta)^2), \quad (18)$$

where $\eta = \mathbb{E}[\eta_t]$ is the unconditional mean of the market risk premium, and $\sigma_M^2 = \sigma_X^2 + \sigma_\eta^2$ 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.¹⁹

In our setting, $\text{Cov}(\beta_{i,t}, \eta_t)$ 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 relation 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 Eq. (18), 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 (e.g., data from Prof. French's home page estimates the market's annual Sharpe ratio at 0.52), this condition will hold under plausible market conditions.

The second term in Eq. (18) 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 is close to zero. In our numerical simulations 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.

4.4. The maturity premium

As shown in the previous section, 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 affect 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 $\text{Cov}(\beta_{i,t}, \eta_t)$. 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

¹⁷ Recall that we assume $\beta^{\text{Assets}} = 1$. Formally, $\left|\frac{\partial \beta}{\partial E}\right| = \frac{D}{(D+E)^2} > \left|\frac{\partial \beta}{\partial E}\right| = \frac{D}{E^2}$.

¹⁸ In the Internet Appendix 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.

¹⁹ The formula in Eq. (18) is for an annual alpha with $dt = 1$. Generally speaking, alpha over increments of time dt is

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

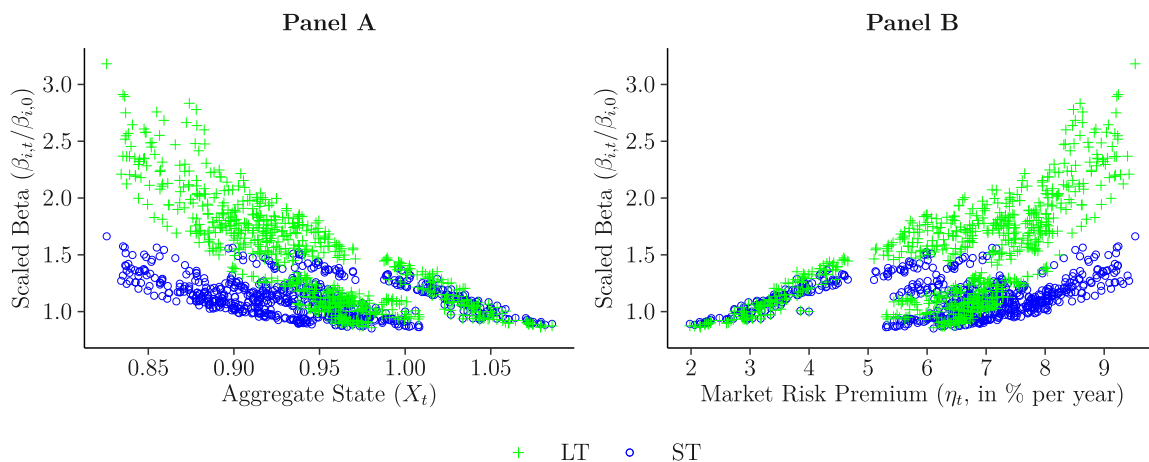


Fig. 4. Beta, aggregate state, and market risk premium. This figure shows the endogenous development of scaled beta ($\beta_{i,t}/\beta_{i,0}$) against the aggregate state variable X_t in Panel A and against the market risk premium η_t in Panel B. The crosses (circles) represent $\beta_{i,t}/\beta_{i,0}$ 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 five (LT) and two (ST) years, respectively. The underlying parameters are as in the benchmark case, i.e., $\mu_0 = 0.05$, $k = 0.25$, $\sigma_X = 0.15$, $\delta = 0.04$, $r = 0.05$, and $\tau = 0.3$.

firms with higher idiosyncratic 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, 2021). 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 Fig. 4 we see a simulated scatter-plot of beta over the aggregate state X_t for firms financed with long- and short-term debt.²⁰ When the aggregate productivity process is low, long-term financed firms exhibit larger betas than short-maturity firms, despite the fact that during high-productivity states, the 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 .

To assess whether our model can account for the observed magnitude of the maturity 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

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., $\mu_0 = 0.05$, $k = 0.25$, $\sigma_X = 0.15$, $\delta = 0.04$, and $r = 0.05$. 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%	
CAPM- α	0.06%	0.25%	
Maturity Premium			0.19%

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).

4.5. 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 5000 economies of 1000 firms for ten 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 and provide results in Fig. 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. Maturity increases beyond six years have a

²⁰ We allow for a “burn-in” period of ten years of constant cash flows in all simulations. Hence, we exclude the firms’ initial leveraging process when computing the maturity premium.

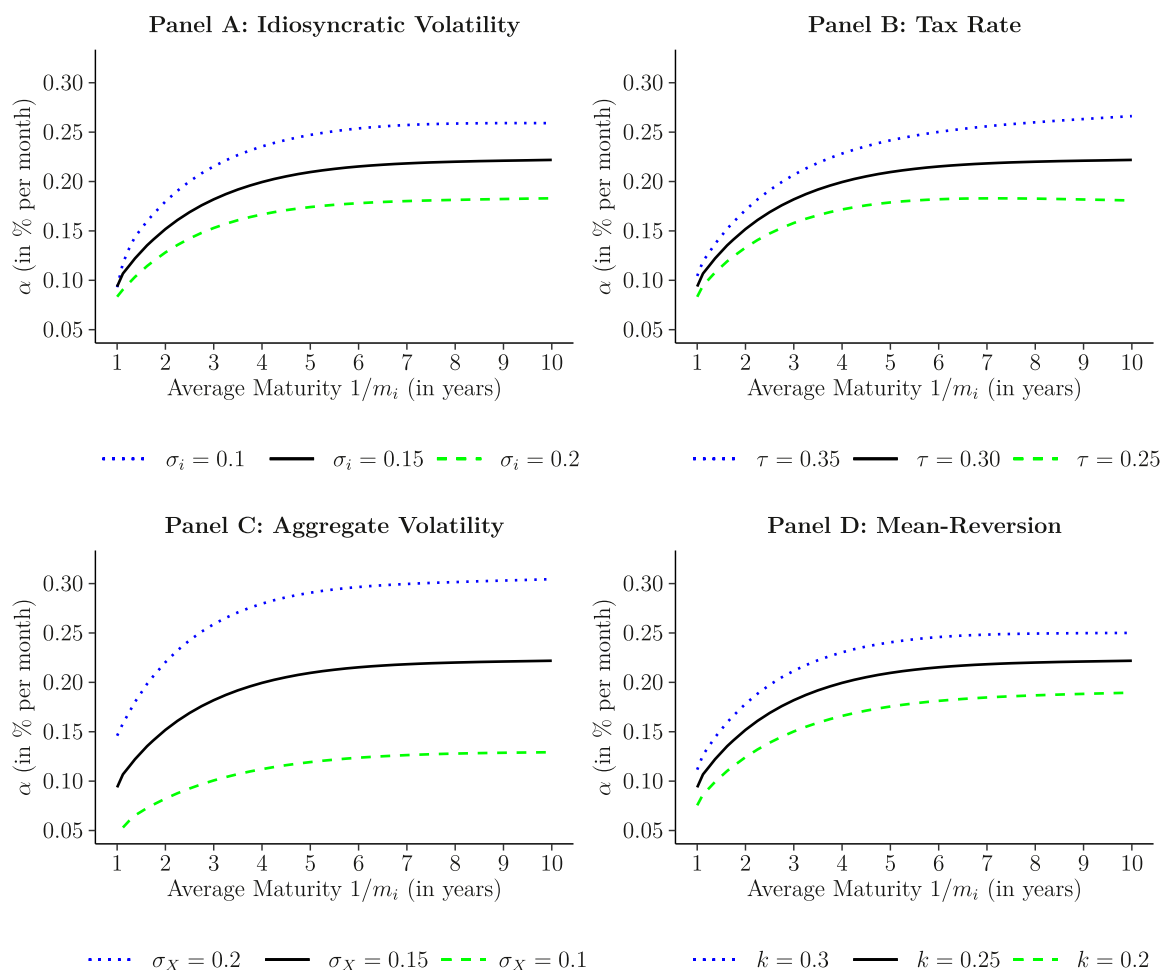


Fig. 5. Maturity premium and parameters. In this figure we present the resulting alpha from unconditional CAPM regressions of simulations for different values of key parameters (over 10,000 economies of 2500 firms each). Alphas are represented in % per month. All parameters underlying this simulation are detailed in Table 5.

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 0.05	k 0.25	σ_X 0.15	σ_i 0.15	μ_Y 0.01
Rates & Debt	r 0.05	δ 0.04	τ 0.30	$1/m$ [1, 10]	c 0.07
Simulation	economies 10,000	firms 2500	years 10	Δt 1/1200	

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 bankruptcy

risk. Thus, as we move to very long maturities, the additional covariance between beta and the market price of risk for given leverage is offset by 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 Fig. 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 ten 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 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 premiums.

Next, we investigate the effects of the productivity process parameters on the maturity premium levels. The bottom left-hand diagram in Fig. 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; therefore, there is no maturity premium. The larger the k , the more variation in the market price of risk and the more pronounced the maturity premium. We set $k = 0.25$, which 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 Fig. 5 quantifies the effect of the mean reversion k in the drift process. The larger the k , the larger the maturity premium, but quantitatively the effect is moderate.

We conclude this section with a brief discussion of the robustness of our numerical analysis when debt maturity would be allowed to change over time. Chen et al. (2021) 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 (see also Bruche and Segura, 2017). Chaderina (2018) argues that firms shorten maturity to accommodate severe cash shortfalls. Firms temporarily borrow above their long-term target and use shorter maturity as a commitment to delever in the near future. That is, firms deviate from their long-term optimal financial structure to weather the crisis.

In our model, as in DeMarzo and He (2020), 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: Suppose that, 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 in a crisis subsequently have lower incentives to delever. Consequently, allowing firms to shorten maturity in crises is unlikely to qualitatively change our

prediction that firms with initially longer maturities will have higher systematic risk exposures during a crisis.

5. Empirical evidence of the model mechanism

In this section, we provide empirical evidence for the model mechanism and confirm that the maturity premium is consistent with observed differences in leverage dynamics of long- and short-maturity financed firms. In the first part, we analyze a quasi-natural experiment of exogenous variation in debt maturity at the onset of the financial crisis in 2008–2009. We hereby document the effect of debt maturity on the leverage and beta dynamics triggered by aggregate cash-flow shocks. In the second part, considering the full time series, we study how firms with different maturities adjust their debt levels. In particular, we investigate how firms adjust their debt levels given a mismatch between current and target leverage at the level of individual firms, as well as aggregated into maturity-sorted portfolios. The third part focuses on the cyclicity of the systematic risk loadings of the long-short portfolio. To this end, we estimate conditional betas and evaluate their comovement with the estimated market price of risk. Then, we present the results of a conditional CAPM and discuss how they are related to the alpha of the LMS portfolio in the standard CAPM.

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 differs 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 issued its bond five years ago and thus has a remaining time to maturity of only two years, whereas firm B issued its bond last year and thus has a remaining debt maturity of six years. If they both optimally roll over their seven-year bonds when they expire, firm A and firm B 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 et al. (2012).

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 select 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	Long
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

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*** (0.01)	0.03*** (0.01)
Post	0.14*** (0.01)	
FE	Firm	Firm, Time
Observations	1,490	1,490
Adjusted R ²	0.851	0.872

*** $p < .01$, ** $p < .05$, * $p < .1$

We select firms that have an average maturity of debt at origination between five and seven years.²¹ 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 are 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. 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 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 roll over debt maturing in

2008.²² As a consequence, we expect firms with relatively shorter remaining maturity to delever faster than firms with relatively longer remaining maturity. Fig. 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, but the increase was larger for the long-term 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 early 2009, the leverage increase of long-maturity financed firms was significantly higher than that of short-maturity financed firms. Thus, the dynamics in Fig. 6 are in full accordance with the model results (see Section 4.2 and Fig. 3 for a detailed discussion).

The increase in the difference between the average 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 while 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, 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 period.²³ 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 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 the 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 Fig. 7. Before 2008, the beta of the portfolio was not statistically different from zero, meaning that the average betas of the long- and short-maturity financed firms were close. In the second half of 2008, the beta of the long-

²² Bao et al. (2011) report that the secondary market of corporate bonds became more illiquid following the collapse of the Bear Stearns in March 2008 and 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 roll over maturing 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.

²³ Our results are robust to including the first two quarters of 2008 to either the pre-treatment or post-treatment periods.

²¹ This range is approximately centered around the median of average bond maturities at origination.

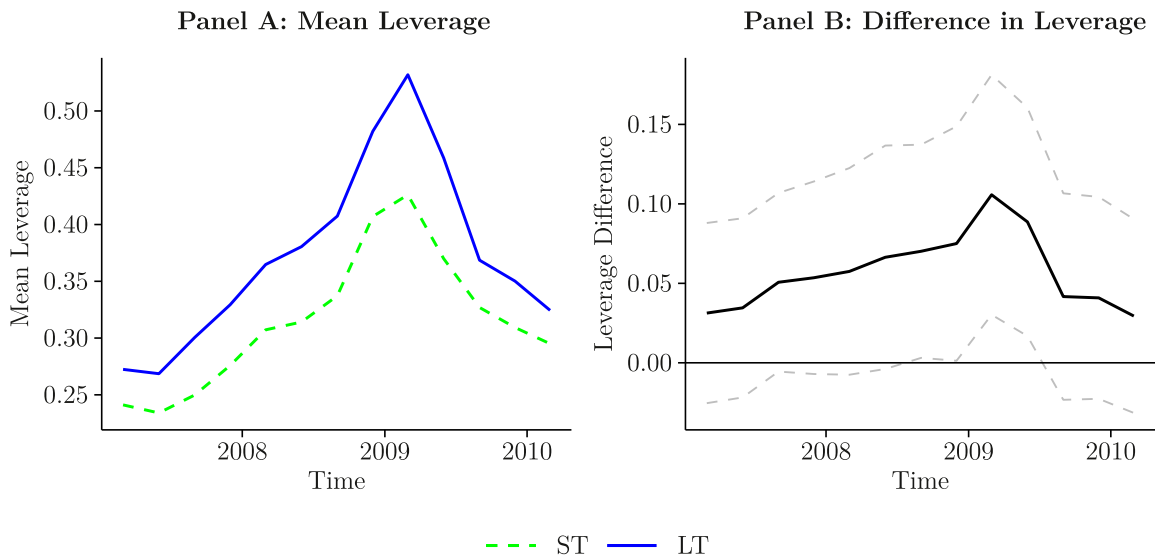


Fig. 6. Quarterly leverage during the financial crisis. This graph shows the development of quarterly leverage around the financial crisis. We select firms with average maturities at issuance between five and seven years for instruments outstanding in December 2007. We sort firms into short (ST) and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

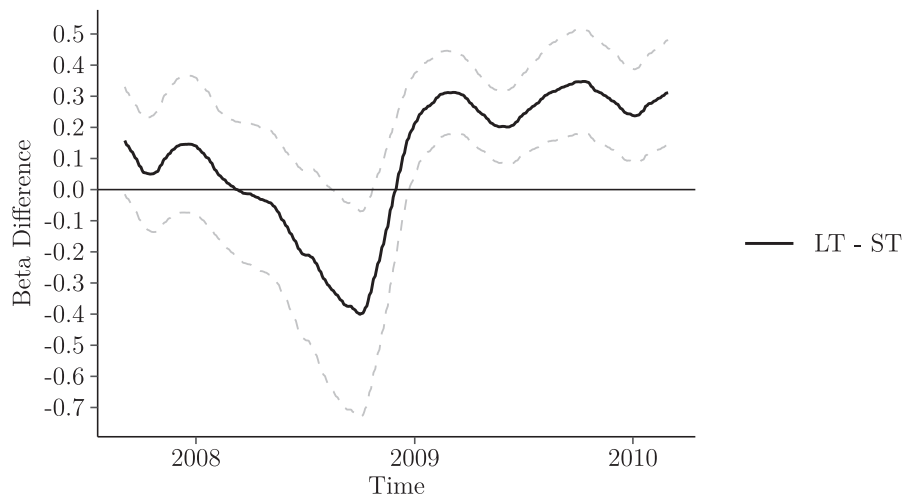


Fig. 7. Beta during the financial crisis. We show the evolution of betas estimated in rolling windows over the past 60 days on daily returns. We select firms with average maturities at issuance between five and seven years for instruments outstanding in December 2007. We sort firms into short (ST) and long (LT) maturity buckets based on the remaining debt maturity in the fiscal year 2007 at the 40% and 60% percentiles, respectively. We plot the difference between the beta of LT-financed firms and the beta of ST-financed firms. We take rolling means over 60 observations and plot 95% confidence intervals around the point estimates.

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 Fig. 7, this is not the case for leverage (see Panel B in Fig. 6). Both of these results are in accordance with our simulation results in Section 4.2.

Overall, the findings of the quasi-natural experiment lend support to our model predictions. Firms that prefer to issue debt of similar maturities respond very differently to the crisis shock depending on the remaining maturity at

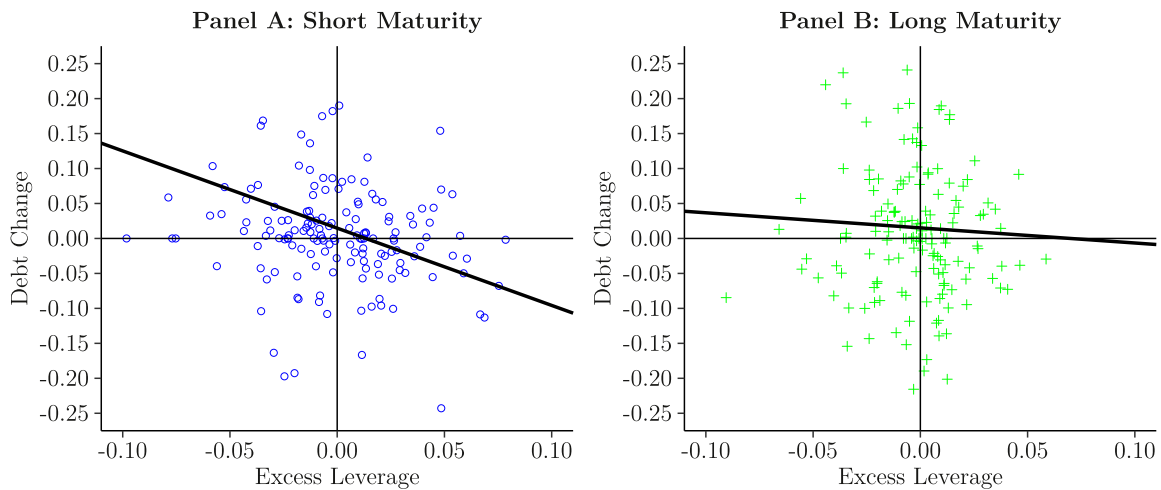


Fig. 8. Excess leverage and subsequent debt changes. This figure shows excess leverage and subsequent relative quarterly changes in the face value of debt. In Panel A (Panel B), we show the results for firms within the shortest (longest) debt maturity quintile. We define excess leverage as the difference of current leverage to each portfolio's average leverage over the past four quarters. Debt changes are relative to the next quarter. The solid line represents the estimated linear relation between debt changes and excess leverage. The sample period is from January 1976 until December 2017.

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.

5.2. Leverage dynamics

We next provide evidence on the interaction between debt maturity and leverage dynamics, based on the entire time series. Our model mechanism is based on the fact that debt levels of long-term financed firms are more sticky than those of short-term financed firms. Several recent papers provide empirical support for this. [Dangl and Zechner \(2021\)](#) find that highly levered shorter-term financed firms are more likely to delever next period than firms of similar leverage that are long-term financed. [Jungherr and Schott \(2021\)](#) document that debt adjustments of longer-term financed firms exhibit a longer lag with GDP growth, while debt levels of short-term financed firms mostly co-move with GDP innovations contemporaneously. Below, we investigate whether similar patterns hold in our data. To this end, we present the results from two simple empirical analyses that accord well with the theoretical channel for the maturity premium that we identify.

In our model, firms' incentives to either increase or decrease debt do not depend on the absolute magnitude of the cash-flow shock, but on its size relative to the threshold level $y_{m,i}$, at which firms have no incentive to adjust leverage. Our model predicts that firms with long-term debt adjust more slowly than those with short-term debt.

In the first empirical analysis, shown in [Fig. 8](#), we define excess leverage by comparing a portfolio's current leverage with its average leverage over the past four quarters.²⁴ Then we calculate the change in debt levels over the

subsequent quarter. [Fig. 8](#) shows the relation between excess leverage and subsequent changes. We find that firms with short debt maturities adjust their debt levels much faster than firms with long debt maturities. When regressing debt changes on lagged excess leverage ratios, the slope coefficient is -1.1 and statistically significant for firms with short debt maturities, whereas it is only -0.22 and statistically insignificant for firms with long debt maturities. Hence, relative to firms financed with short-term debt, long-term financed firms exhibit more persistent debt levels, as our mechanism requires.

Our second set of results is based on a more structural measure of excess leverage, based on [Frank and Shen \(2019\)](#).²⁵ We now estimate excess leverage at an annual frequency from firm-level predictive regressions using the logarithm of assets and market-to-book ratios as predictors. Then we double-sort firms on debt maturity and excess leverage into nine buckets. Within each bucket, we then measure the average leverage response in the next period relative to the current year. [Table 8](#) shows that short-maturity financed firms with high excess leverage experience a larger reduction in leverage than any other group of firms. In contrast, long-term financed firms with excess leverage are less likely to decrease leverage, consistent with our model predictions. Similarly, firms with short-maturity debt are more aggressive in leveraging up when they are below the target leverage level.

5.3. Market price of risk and beta dynamics

The maturity premium stems from long-maturity financed firms experiencing a more prolonged increase in their exposure to systematic risk in downturns when the

²⁴ The insights on the speed of debt adjustments also hold if we consider longer time windows for computing excess leverage. Specifically, Internet Appendix Section E shows the results using eight and 12 quarters.

²⁵ [Frank and Shen \(2019\)](#) show that excess leverage, defined from firm-level predictive regressions for leverage using the logarithm of assets and market-to-book, predict firms' leverage adjustments.

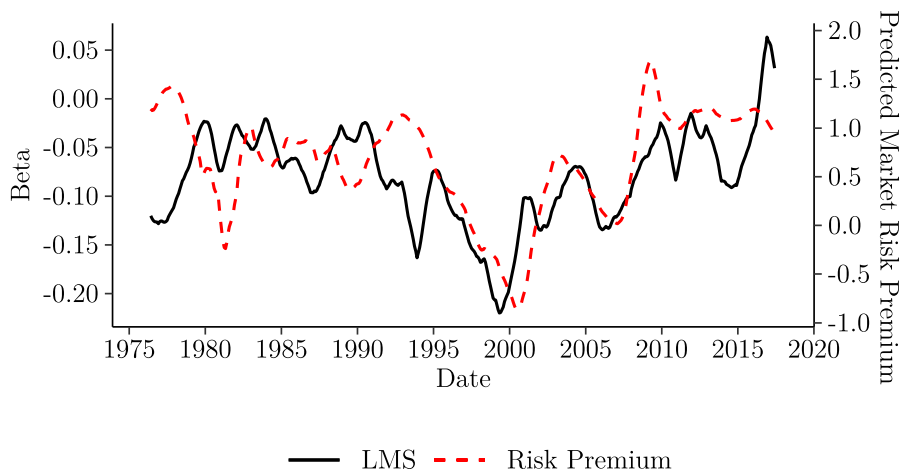


Fig. 9. Time dynamics of conditional betas and the market price of Risk. This figure shows the dynamics of conditional betas of the LMS portfolio estimated from the conditional CAPM following [Boguth et al. \(2011\)](#) (solid line on the left axis). We overlay the dynamics of the market risk premium (dashed line on the right axis). Both variables are described in more detail in [Appendix F](#), and the beta line is smoothed using 12-month rolling means. The sample period is from January 1976 until December 2017.

Table 8

Leverage changes across excess leverage and debt maturity. This table shows relative leverage changes on an annual frequency in percent. We follow [Frank and Shen \(2019\)](#) and define excess leverage from firm-level regressions using the logarithm of firm assets and book-to-market ratios as predictors. We double-sort firms independently every year into buckets at the 33% and 66% breakpoints based on their excess leverage and debt maturity. Within the resulting groups, we take averages of the relative changes in leverage over the next year. The sample period is from January 1976 until December 2017.

		Excess Leverage		
		High	Medium	Low
Debt Maturity	Short	-14.88	13.44	46.65
	Medium	-7.74	6.59	28.78
	Long	-7.24	7.73	35.44

market price of risk is high. In this section, we provide direct empirical evidence that the beta of long-term financed firms is indeed more procyclical than the beta of short-maturity financed firms. Furthermore, a conditional CAPM demonstrates that this variation explains the unconditional alpha that we document for the LMS portfolio empirically.

First, we focus our attention on the co-movement between the market price of risk and the LMS betas. Recall that in our model 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. To this end, we estimate time-varying betas of the LMS portfolio using the conditional CAPM specification of [Boguth et al. \(2011\)](#), which was also employed in a similar context by [Kuehn et al. \(2017\)](#).²⁶ Next, we use macro-

variables to estimate the dynamics of the market price of risk following [Choi \(2013\)](#), using the dividend yield and Treasury bill rates. Details on the estimation procedures are provided in [Appendix F](#).

The resulting dynamics of the estimated market price of risk and beta of the LMS portfolio are illustrated in [Fig. 9](#). Over the entire sample, the estimated beta of the LMS portfolio co-moves with our estimate of the market price of risk. In fact, the two time-series exhibit a statistically-significant positive correlation of 0.48 at the quarterly frequency. This represents direct evidence that the exposure to systematic risk of the long-short maturity portfolio is countercyclical and accords well with our results in [Section 5.1](#) above.

While for some return “anomalies,” such as the size or the value premium, there seems to be too little time-variation in conditional beta estimates to be explained by a conditional CAPM ([Lewellen and Nagel, 2006](#)), this is not the case for the maturity premium. To see this, we note that [Eq. \(18\)](#) implies that the empirically observed alpha should be close to the product $\sigma(\beta_{i,t})\sigma(\eta_t)$.²⁷ Our beta estimates show substantial time variation, despite the fact that the conditional beta estimates are unlikely to capture the full variation of the forward-looking conditional betas ([Lettau and Ludvigson, 2001](#)). The standard deviation of our LMS monthly beta estimates is 0.56. A plausible estimate for the standard deviation of the market price of risk, based on [Cochrane \(2011\)](#), is 0.50% at a monthly frequency.²⁸ Taken together, these numbers therefore imply an alpha due to the time-variation in beta of 0.277%, which

²⁷ This is because empirical estimates for η^2/σ_M^2 and for the last term in [Eq. \(18\)](#) are close to zero and $\rho(\beta_{i,t}, \eta_t)$ in our model is one.

²⁸ We take the estimate of the standard deviation of the estimated market risk premium from Table I in [Cochrane \(2011\)](#) 5.45%, and scale it by 11 to account for the possible persistence of the market price of risk.

²⁶ We present time-varying betas estimated by rolling CAPM regressions from daily returns without conditioning variables in Internet Appendix Section D. These supplementary findings confirm the results shown here.

Table 9

Debt maturity-sorted portfolios – conditional CAPM. The portfolios are formed by double sorts on size (five buckets at the 20%, 40%, 60%, and 80% percentiles) and debt maturity (five buckets at the 20%, 40%, 60%, and 80% percentiles) conditional within each size group. This table displays results for the five maturity portfolios by averaging across the size buckets (MAT1 for short-maturity to MAT5 for long-maturity financed firms) and the long-short portfolio of the difference between long-maturity and short-maturity financed firms (LMS). In the first row, we show CAPM intercept estimates for each portfolio. In the rows below, we show the alpha alongside other coefficients from the conditional CAPM following [Boguth et al. \(2011\)](#). 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.

	MAT1	MAT2	MAT3	MAT4	MAT5	LMS
α^{CAPM}	-0.06 (-0.41)	0.09 (0.64)	0.16 (1.25)	0.21 (1.56)	0.15 (1.24)	0.21*** (2.93)
α^{COND}	0.04 (0.27)	0.12 (0.89)	0.16 (1.35)	0.20* (1.66)	0.15 (1.25)	0.11 (1.52)
β^M	1.29*** (4.22)	0.85*** (3.37)	0.92*** (4.00)	0.78*** (3.95)	1.14*** (4.54)	-0.04*** (-2.64)
Dividend Yield	0.03 (0.20)	0.17 (1.02)	0.32** (2.12)	0.28** (2.11)	0.12 (1.02)	0.07* (1.71)
Term Spread	-3.40 (-0.83)	-0.76 (-0.18)	-1.16 (-0.27)	-1.71 (-0.44)	-2.53 (-0.59)	-0.69 (-0.86)
T-Bill Rate	-1.73 (-0.67)	-0.50 (-0.21)	-1.69 (-0.76)	-2.06 (-0.96)	-1.20 (-0.56)	-0.81* (-1.90)
Default Spread	6.17 (0.87)	0.44 (0.05)	-1.78 (-0.23)	2.14 (0.34)	0.75 (0.11)	-3.79 (-1.49)
Beta LC36	-0.44 (-1.32)	-0.24 (-0.75)	-0.26 (-0.77)	-0.27 (-0.75)	-0.69* (-1.89)	-0.07 (-0.21)
Beta LC6	0.44 (1.00)	0.59* (1.76)	0.44 (1.30)	0.64 (1.60)	0.87** (2.23)	0.98** (2.44)
M36	-0.00* (-1.79)	-0.00 (-0.98)	-0.00 (-0.52)	-0.00 (-0.77)	-0.00** (-2.00)	-0.00 (-1.27)
M6	0.01*** (2.72)	0.01** (2.35)	0.01** (2.21)	0.01* (1.95)	0.01*** (2.74)	-0.00 (-0.46)

*** $p < .01$; ** $p < .05$; * $p < .1$

is in the ballpark with our estimates of the maturity premium of 0.1%–0.21%, as reported in [Table 3](#).

Finally, according to our model, the maturity premium arises in the unconditional CAPM because of omitted co-movement between the market price of risk and the conditional beta of the LMS portfolio. We therefore also estimate the alpha of a LMS portfolio accounting for time-variation in beta based on a conditional CAPM, as in [Boguth et al. \(2011\)](#). The results for this conditional specification are summarized in [Table 9](#). It can be seen that indeed the estimated alpha is now insignificant. That is, once the variation in conditional beta is taken into account, there seems to be no more statistically significant difference in excess returns between long- and short-maturity financed firms. This suggests that the underlying mechanics of our theoretical predictions are indeed present, i.e., the co-movement of the LMS beta with the market price of risk drives the maturity premium.

6. Conclusion

Firms' dynamic capital structure strategies clearly affect the risk characteristics and thus the equilibrium risk premiums 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: 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 that is 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 earn a premium, i.e., a positive alpha.

We also report empirical evidence on leverage and beta dynamics that is 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 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. 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 A-1.

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

$$L := \frac{DLC + DLTT}{DLC + DLTT + PRCC_F * CSHO} \quad (A-1)$$

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

$$DM := \frac{DLTT - DD2 - DD3}{DLC + DLTT} \quad (A-2)$$

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

$$ME := \frac{alt\,prc * shROUT}{1000} \quad (A-3)$$

Table A-1

Compustat and 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
AT	Assets - Total
CAPX	Capital Expenditures
CHE	Cash and Short-Term Investments
CSHO	Common Shares Outstanding
DD1	DD1 – Long-Term Debt Due in One Year
DD2	DD2 – Debt Due in 2nd Year
DD3	DD3 – Debt Due in 3rd Year
DLC	Debt in Current Liabilities - Total
DLTT	Long-Term Debt - Total
PPEGT	Property, Plant and Equipment - Total (Gross)
PRCC_F	Price Close - Annual - Fiscal
PSTKRV	Preferred Stock Redemption Value
PSTKL	Preferred Stock Liquidating Value
PSTK	Preferred/Preference Stock (Capital) - Total
SEQ	Stockholders' Equity - Total
TXDITC	Deferred Taxes and Investment Tax Credit
alt prc	Price Alternate
shROUT	Number of Shares Outstanding

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.

$$BE := SEQ + TXDITC - [BVPS] \quad (A-4)$$

The book-to-market (*BM*) 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*.

$$BM := \frac{BE}{ME} \quad (A-5)$$

The CAPEX measure we use is defined as

$$CAPEX := \frac{CAPX}{PPEGT} \quad (A-6)$$

We define cash as *CHE* scaled by total assets (i.e., *AT*). Finally, we define unlevered beta β^U by unlevering our equity beta using

$$\beta^U = \beta * \frac{PRCC_F * CSHO}{DLC + DLTT + PRCC_F * CSHO} \quad (A-7)$$

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 (one-month T-bill rates) are taken from the Kenneth French web page.²⁹

For the conditional version of the CAPM, we take data on the macro-economic variables that we use as predictors from Amit Goyal's home page. 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:

$$c_t = \alpha + \beta_a a_t + \beta_y y_t + \sum_{i=-8}^8 b_{a,i} \Delta a_{t-i} + \sum_{i=-8}^8 b_{y,i} \Delta y_{t-i} + \epsilon_t, \quad (A-8)$$

$$CAY_t := c_t - \hat{\beta}_a a_t - \hat{\beta}_y y_t, \quad (A-9)$$

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 fourth quarter of 2018.

Appendix B. Model solution

Equityholders' objective function is:

$$V^E(Y_{i,t}, F_{i,t}) = V_{i,t}^E = \mathbb{E}_t^P \left[\int_t^{t_b} \frac{\Lambda_s}{\Lambda_t} \Pi_{i,s} ds \right]. \quad (B-1)$$

²⁹ See

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

Recall that the SDF is

$$\frac{d\Lambda_t}{\Lambda_t} = -r dt - \frac{\mu(X_t, t) + \delta - r}{\sigma_X} dW_{X,t}^P \quad \text{and} \quad (B-2)$$

λ_t denotes the market price of risk, with $\lambda_t = \frac{\mu(X_t, t) + \delta - r}{\sigma_X}$. Then,

$$\Lambda_t = \Lambda_0 e^{-rt - \int_0^t \frac{\lambda_s^2}{2} ds - \int_0^t \lambda_s dW_{X,s}^P} \quad (B-3)$$

We change the measure to Q using a Radon-Nikodym derivative $\frac{dQ}{dP} = e^{-\int_0^t \lambda_s dW_{X,s}^P - \frac{1}{2} \int_0^t \lambda_s^2 ds}$ and

$$V_{i,t}^E = \mathbb{E}_t^P \left[\int_t^{t_b} \frac{\Lambda_s}{\Lambda_t} \Pi_{i,s} ds \right] = \mathbb{E}_t^Q \left[\int_t^{t_b} e^{-r(s-t)} \Pi_{i,s} ds \right]. \quad (B-4)$$

Under the risk-neutral measure, a firm's cash flows are given by

$$dY_{i,t} = \mu_Y Y_{i,t} dt + \sigma_Y Y_{i,t} dW_{Y,t}^Q, \quad (B-5)$$

where $\mu_Y = r - \delta < r$.

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

Consider the following the Hamilton-Jacobi-Bellman equation (HJB) for the optimal $G_{i,t}$:³⁰

$$\begin{aligned} rV_{i,t}^E = & \max_{G_{i,t}} \{ Y_{i,t}(1 - \tau) + \tau c F_{i,t} - (c + m_i) F_{i,t} \\ & + G_{i,t} v_{i,t}^D + (G_{i,t} - m_i F_{i,t}) V_F^E(Y_{i,t}, F_{i,t}) \} \\ & + \mu_Y V_Y^E(Y_{i,t}, F_{i,t}) + 1/2 \sigma_Y^2 V_{YY}^E(Y_{i,t}, F_{i,t}). \end{aligned} \quad (B-6)$$

Issuing a marginal unit of debt generates benefits of $v_{i,t}^D$ to equityholders and costs of $V_F^E(Y_{i,t}, F_{i,t})$ for future payments to debtholders. 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)

$$v_{i,t}^D + V_F^E(Y_{i,t}, F_{i,t}) = 0. \quad (B-7)$$

DeMarzo and He (2020) lay out optimality conditions for the debt issuance policy, which are met in our setup. Using the FOC from Eq. (B-7) in the HJB shown in Eq. (B-6) yields the following HJB that does not depend on $G_{i,t}$

$$\begin{aligned} rV_{i,t}^E = & Y_{i,t}(1 - \tau) + \tau c F_{i,t} - (c + m_i) F_{i,t} - m_i F_{i,t} V_F^E(Y_{i,t}, F_{i,t}) \\ & + \mu_Y V_Y^E(Y_{i,t}, F_{i,t}) + 1/2 \sigma_Y^2 V_{YY}^E(Y_{i,t}, F_{i,t}). \end{aligned} \quad (B-8)$$

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 Eq. (B-5) are given by

$$dy_{i,t} = (\mu_Y + m_i - g_{i,t}) y_{i,t} dt + \sigma_Y y_{i,t} dW_{Y,t}^Q, \quad (B-9)$$

which also changes the HJB from Eq. (B-8) to

$$(r + m_i) v_{i,t}^E = y_{i,t}(1 - \tau) + c\tau - (c + m_i)$$

³⁰ 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.

$$+ (\mu_Y + m_i) y_{i,t} v_Y^E(y_{i,t}) + 1/2 \sigma_Y^2 y_{i,t}^2 v_{YY}^E(y_{i,t}). \quad (B-10)$$

To solve Eq. (B-10) we impose the boundary condition for $y_{i,t} \rightarrow \infty$, 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

$$v_{i,t}^E = \frac{1 - \tau}{r - \mu_Y} y_{i,t} - \frac{c(1 - \tau) + m_i}{r + m_i} \left(1 - \frac{1}{1 + \gamma_i} \left(\frac{y_{i,t}}{y_{b,i}} \right)^{-\gamma_i} \right), \quad \text{with} \quad (B-11)$$

$$\gamma_i = \frac{(\mu_Y + m_i - \sigma_Y^2/2) + \sqrt{(\mu_Y + m_i - \sigma_Y^2/2)^2 + 2\sigma_Y^2(r + m_i)}}{\sigma_Y^2} > 0, \quad \text{and} \quad (B-12)$$

$$y_{b,i} = \frac{\gamma_i}{1 + \gamma_i} \frac{r - \mu_Y}{r + m_i} \left(c + \frac{m_i}{1 - \tau} \right). \quad (B-13)$$

The scaled value of debt, i.e., the price per unit of face value, follows from the FOC in Eq. (B-7)

$$v_{i,t}^D = \frac{c(1 - \tau) + m_i}{r + m_i} \left(1 - \left(\frac{y_{i,t}}{y_{b,i}} \right)^{-\gamma_i} \right). \quad (B-14)$$

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,

$$\begin{aligned} rv_{i,t}^D = & c + m_i(1 - v_{i,t}^D) + (G_{i,t} - m_i F_{i,t}) v_F^D(Y_{i,t}, F_{i,t}) \\ & + \mu_Y v_Y^D(Y_{i,t}, F_{i,t}) + 1/2 \sigma_Y^2 v_{YY}^D(Y_{i,t}, F_{i,t}). \end{aligned} \quad (B-15)$$

Next, we impose the FOC from Eq. (B-7) on the derivative with respect to the debt level $F_{i,t}$ of the HJB for equity in Eq. (B-8) to find another HJB for the price of debt, which is equal to

$$\begin{aligned} -rv_{i,t}^D = & \tau c - (c + m_i) + m_i v_{i,t}^D + m_i F_{i,t} v_F^D(Y_{i,t}, F_{i,t}) \\ & - \mu_Y v_Y^D(Y_{i,t}, F_{i,t}) - 1/2 \sigma_Y^2 v_{YY}^D(Y_{i,t}, F_{i,t}). \end{aligned} \quad (B-16)$$

Adding Eqs. (B-15) and (B-16) results in the expression for the optimal debt issuance policy

$$g_{i,t} = \frac{(r + m_i) \tau c}{c(1 - \tau) + m_i} \frac{1}{\gamma_i} \left(\frac{y_{i,t}}{y_{b,i}} \right)^{\gamma_i}. \quad (B-17)$$

We can see that there is a cash flow level, which we denote by $y_{m,i}$, 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

$$y_{m,i} = y_{b,i} \left(\frac{c(1 - \tau) + m_i}{(r + m_i) \tau c} \right)^{1/\gamma_i} \quad (B-18)$$

and can be used to restate Eq. (B-17) from above to the version in Eq. (9).

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

$$dF_{i,t} = \left(m_i \frac{Y_{i,t}^{\gamma_i}}{y_{m,i}^{\gamma_i}} F_{i,t}^{1-\gamma_i} - m_i F_{i,t} \right) dt. \quad (B-19)$$

Appendix C. The market portfolio and stochastic discount factor

We consider an economy 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. Moreover, we assume that the market portfolio $M(X_t)$ includes not only levered equity but also other assets, such as corporate debt, and represents an unlevered exposure to the priced risk of the stochastic aggregate productivity X_t , defined in Eq. (1).³¹ Its return over a time increment is therefore given by

$$r_t^M dt = (\mu(X_t, t) + \delta) dt + \sigma_X dW_{X,t}^P. \quad (C-1)$$

To see that the market portfolio dynamic is consistent with our SDF, note that the SDF must satisfy

$$r dt = -\mathbb{E}_t \left[\frac{d\Lambda_t}{\Lambda_t} \right] \text{ and} \quad (C-2)$$

$$\mathbb{E}_t \left[\frac{dV_t^M}{V_t^M} \right] + \delta dt = r dt - \mathbb{E}_t \left[\frac{d\Lambda_t}{\Lambda_t} \frac{dV_t^M}{V_t^M} \right]. \quad (C-3)$$

where V_t^M denotes the value of the market portfolio at time t .

Since the SDF satisfies

$$\mathbb{E}_t \left[\frac{d\Lambda_t}{\Lambda_t} \right] = \mathbb{E}_t \left[-r dt - \frac{\mu_t + \delta - r}{\sigma_X} dW_{X,t}^P \right] = -r dt, \quad (C-4)$$

we get

$$\mathbb{E}_t \left[\frac{dV_t^M}{V_t^M} \right] + \delta dt = (\mu_t + \delta) dt \quad (C-5)$$

and

$$\begin{aligned} \mathbb{E}_t \left[\frac{d\Lambda_t}{\Lambda_t} \frac{dV_t^M}{V_t^M} \right] \\ = \mathbb{E}_t \left[\left(-r dt - \frac{\mu_t + \delta - r}{\sigma_X} dW_{X,t}^P \right) (\mu_t dt + \sigma_X dW_{X,t}^P) \right] \end{aligned} \quad (C-6)$$

$$= (\mu_t + \delta - r) dt, \quad (C-7)$$

where the last expression follows from Ito's lemma.

Appendix D. Return on equity

In this part, 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 financial leverage $v_{i,t}^D/v_{i,t}^E$.

³¹ Alternatively, we could consider a traded asset that offers a levered exposure to the risk of X_t (levered market portfolio), with leverage equal to the aggregate leverage that firms in our model generate. A weighted average of equity returns of our firms would then add up to the levered market portfolio return, and individual firms' instantaneous betas could be calculated with respect to this levered market portfolio. However, the resulting covariance between these betas and the risk compensation for the levered market portfolio would be identical to the one obtained for the market portfolio we consider in our model.

We start by looking at the return on equity, i.e.,

$$\begin{aligned} r_{i,t}^E dt &= \frac{dV_{i,t}^E + \Pi_{i,t} dt}{V_{i,t}^E} \\ &= \frac{V_F^E dF_{i,t} + V_Y^E \mu_Y Y_t dt + V_Y^E \sigma_Y Y_{i,t} dW_{Y,t}^Q + \frac{1}{2} V_{YY}^E \sigma_Y^2 Y_{i,t}^2 dt + \Pi_{i,t} dt}{V_{i,t}^E}, \end{aligned} \quad (D-1)$$

where

$$\begin{aligned} \frac{\partial V^E(Y, F)}{\partial F} &= \frac{\partial}{\partial F} \left(V^E \left(\frac{Y}{F}, 1 \right) F \right) \\ &= -\frac{Y}{F^2} \frac{\partial V^E \left(\frac{Y}{F}, 1 \right)}{\partial \frac{Y}{F}} F + V^E \left(\frac{Y}{F}, 1 \right) \\ V_F^E &= -Y V_Y^E + V^E. \end{aligned} \quad (D-2)$$

Then,

$$\begin{aligned} rV^E(Y_{i,t}, F_{i,t}) &= \max_{G_{i,t}} \left\{ \Pi_{i,t} dt + V_F^E dF_{i,t} + V_Y^E \mu_Y Y_{i,t} dt + \frac{1}{2} V_{YY}^E \sigma_Y^2 Y_{i,t}^2 dt \right\} \text{ and} \\ r_{i,t}^E dt &= \frac{1}{V_{i,t}^E} (rV_{i,t}^E dt + V_Y^E \sigma_Y Y_{i,t} dW_{Y,t}^Q) \\ &= r dt + \frac{V_Y^E Y_{i,t}}{V_{i,t}^E} \sigma_Y dW_{Y,t}^Q; \text{ divide and multiply by } F_{i,t} \\ &= r dt + \frac{V_Y^E Y_{i,t}}{V_{i,t}^E} \sigma_Y dW_{Y,t}^Q; \text{ and using Eq. (D-2) we arrive at} \\ &= r dt + \frac{V_F^E - V^E}{V_{i,t}^E} \sigma_Y dW_{Y,t}^Q; \text{ using FOC from Eq. (B-7)} \\ &= r dt + \frac{V_{i,t}^D + V_{i,t}^E}{V_{i,t}^E} \sigma_Y dW_{Y,t}^Q = r dt + \left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \sigma_Y dW_{Y,t}^Q. \end{aligned} \quad (D-3)$$

Under the physical measure we find:

$$r_{i,t}^E dt = r dt + \left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \eta_t dt + \left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \sigma_Y dW_{Y,t}^P. \quad (D-4)$$

Appendix E. Detailed beta derivation

$$\beta_{i,t} = \frac{\text{Cov}_t(r_{i,t}^E dt, r_t^M dt)}{\text{Var}_t(r_t^M dt)} \quad (E-1)$$

$$= \frac{1}{\text{Var}_t(r_t^M dt)} \text{Cov}_t \left(\left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \sigma_Y dW_{Y,t}^P; \sigma_X dW_{X,t}^P \right) \quad (E-2)$$

$$= \frac{1}{\sigma_X^2} \sigma_Y \sigma_X \left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \text{Cov}_t(dW_{Y,t}^P, dW_{X,t}^P) \quad (E-3)$$

$$= \frac{1}{\sigma_X} \sigma_Y \left(1 + \frac{V_{i,t}^D}{V_{i,t}^E} \right) \text{Cov}_t \left(\frac{1}{\sigma_Y} (\sigma_X dW_{X,t}^P + \sigma_i dW_{i,t}^P), dW_{X,t}^P \right) \quad (E-4)$$

$$= 1 + \frac{V_{i,t}^D}{V_{i,t}^E}. \quad (E-5)$$

Appendix F. Conditional CAPM and market price of risk estimation

First, we provide details on the estimation of the conditional CAPM following [Boguth et al. \(2011\)](#). We estimate the LMS portfolio's beta dynamics by estimating the following model on a monthly frequency:

$$r_t^{\text{LMS}} = \alpha^{\text{COND}} + \beta_0 r_t^M + \beta_1 \text{DY}_{t-1} r_t^M + \beta_2 \text{DS}_{t-1} r_t^M + \beta_3 \text{TS}_{t-1} r_t^M + \beta_4 \text{TB}_{t-1} r_t^M + \beta_5 \text{LC6}_{t-1} r_t^M + \beta_6 \text{LC36}_{t-1} r_t^M + \beta_7 \text{RM6}_{t-1} v + \beta_8 \text{RM36}_{t-1} r_t^M + \epsilon^{\text{LMS}}_t, \quad (\text{F-1})$$

where the variables abbreviated above are the dividend yield (DY), the default spread (DS), the term spread (TS), the T-bill rate (TB), the average lagged 6- (LC6) and 36-month (LC36) portfolio betas from standard CAPM regressions,³² and the 6- (RM6) and 36-month (RM36) market return. Then we compute the time-series of conditional betas from the coefficients of [Eq. \(F-1\)](#) estimated over the entire sample period, i.e., we sum

$$\beta_t^{\text{COND}} = \beta_0 + \beta_1 \text{DY}_{t-1} + \beta_2 \text{DS}_{t-1} + \beta_3 \text{TS}_{t-1} + \beta_4 \text{TB}_{t-1} + \beta_5 \text{LC6}_{t-1} + \beta_6 \text{LC36}_{t-1} + \beta_7 \text{RM6}_{t-1} + \beta_8 \text{RM36}_{t-1}. \quad (\text{F-2})$$

Second, to estimate the dynamics of the market price, we start with the following list of macro variables as potential predictors: 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 home page, and the detailed description of their construction is available in [Welch and Goyal \(2007\)](#).³³

We fit a one-month-ahead predictive regression to span the observed market return by the predictors mentioned above, i.e.,

$$r_t^M = \delta_0 + \delta_1 \text{DY}_{t-1} + \delta_2 \text{DS}_{t-1} + \delta_3 \text{TS}_{t-1} + \delta_4 \text{TB}_{t-1} + \delta_5 \text{CAY}_{t-1} + \epsilon_t^M = \eta(Z_{t-1}) + \epsilon_t^M. \quad (\text{F-3})$$

Results of the fitting estimation are presented in [Table F-1](#). 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 macro-models in explaining the dynamics of expected equity returns ([Cochrane, 2011](#)).

³² We control for the inherent portfolio recomposition by estimating individual component betas and aggregating those using the time-varying value-weights.

³³ 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 F-1

Predictive variable. This table shows the regression of the market excess return on lagged predictors at monthly frequency. 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*** (2.91)	1.60** (2.43)
DS	-7.10 (-0.08)	
TS	-34.47 (-1.34)	
TB	-36.15** (-2.16)	-18.99** (-2.37)
CAY	16.75 (1.30)	
Intercept	11.77*** (3.05)	7.40*** (2.74)
R ²	0.02	0.02
Adj. R ²	0.01	0.01

*** $p < .01$, ** $p < .05$, * $p < .1$

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.jfineco.2021.07.008](https://doi.org/10.1016/j.jfineco.2021.07.008)

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