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De Facto Seniority, Credit Risk, and Corporate Bond Prices

Abstract

We study the effect of a bond's place in its issuer's maturity structure on credit risk. Using a structural model as motivation, we argue that bonds due relatively late in their issuers' maturity structure have greater credit risk than do bonds due relatively early. Empirically, we find robust evidence that these later bonds have larger yield spreads and greater comovement with equity and that the magnitude of the effects is consistent with model predictions for investment-grade bonds. Our results highlight the importance of bond-specific credit risk for understanding corporate bond prices.

(*JEL* G12, G13, G14)

Introduction

One of the central issues in the corporate bond literature is about measuring credit risk and its effects on prices and returns. In this paper, we will focus on understanding the empirical implications of de facto seniority, the idea that bonds due relatively late in their issuers' maturity structure are effectively junior even if firms do not have explicit seniority structures. Much of the literature since Merton (1974) has tried to understand the levels and dynamics of corporate bond prices with a focus on more realistic modeling of firms (including bankruptcy costs, endogenizing default decisions, interest rate dynamics, and jumps). Our particular focus is on better understanding how there can be heterogeneity in credit risk for bonds based on de facto seniority, with an emphasis on the impact on bond returns and the cross-section of yield spreads. We control for firm-level credit risk, the actual maturity of a corporate bond, and the average maturity of all of the issuer's corporate bonds, and find that bonds due relatively late in their issuers' maturity structure have higher yield spreads and higher hedge ratios.[1] Thus, we will argue that, in addition to firm-level credit risk, it is important to consider bond-level credit risk based on the place of a bond in its issuer's maturity structure.

The intuition behind our empirical results is that a bond that matures after most of the other bonds issued by the same firm is potentially de facto junior even if all of the firm's bonds have the same explicit seniority.[2] This arises from the fact that a firm in financial trouble may remain solvent long enough to repay bonds due early in its maturity structure, but not bonds due later. The effect is that bond issues that mature later are more sensitive

[1] Hedge ratios are the ratio of corporate bond to equity returns. Schaefer and Strebulaev (2008) argue that hedge ratios are a measure of credit risk less confounded by noncredit components, such as illiquidity.

[2] A de facto junior bond is not explicitly junior. Although it is straightforward to extend the Merton model to allow for *explicitly* junior and senior bonds, it is difficult to empirically examine the effect of explicit seniority on corporate bond prices because most corporate bond issues in the United States are senior unsecured. Furthermore, though bank debt is often senior to corporate bonds, firms with significant amounts of corporate bonds outstanding often do not have significant bank debt. Rauh and Sufi (2010) report that more than 50% of the firms in their sample with significant amounts of corporate bonds have less than 10% of their debt in bank debt. Our sample, which is at the bond-month level, is even more extreme, with a median of approximately 2% of debt in bank debt.

to underlying firm value. We formalize this intuition in an extension of the Merton (1974) model and present both yield spreads and relative hedge ratios in a numerical exercise that shows that, holding the actual maturity constant, bonds due later in their firms' maturity structure have higher yield spreads and hedge ratios.

Empirically, we find that after controlling for various measures of credit risk (including credit ratings), measures of illiquidity, maturity (both of the bond and the average across the issuer's bonds), and firm fixed effects, bonds due latest in their issuer's maturity structure have yield spreads that are 48 basis points higher than bonds due earliest in their issuer's maturity structure. This is larger than an estimated 21-basis-point increase in yield spreads associated with a one-notch deterioration in credit rating.[3] The effect is 47 basis points for investment-grade bonds, compared to 85 basis points for junk-rated bonds. Consistent with model predictions, de facto seniority becomes generally more important as credit quality begins to decline. Our results suggest that the market recognizes the effect of a bond's place in its issuer's maturity structure when pricing bonds and that credit ratings agencies should consider notching bonds based on de facto seniority in addition to the explicit priority structure.[4]

We also test how the magnitudes of our empirical estimates match with the predictions of the extended Merton model. Although the model is largely meant to illustrate intuition and motivate the de facto seniority effect, it is nevertheless useful to understand how well the model fits and identify the types of firms that the model is best able to explain. In our tests, we find that the empirically estimated de facto seniority effect in yield spreads is significantly below the model predicted effect for junk-rated bonds. However, for most specifications, we are unable to reject that model and empirical magnitudes are equal for investment-grade firms. Thus, despite the fact that we find a stronger empirical effect for junk-rated firms,

[3]As another benchmark, consider that Dick-Nielsen, Feldhutter, and Lando (2012) find a 1-4 basis point liquidity effect precrisis and a 5-92 basis point liquidity effect post-crisis for investment-grade bonds. Thus, a 48 basis point effect for a bond's place in its firm's maturity structure is economically large.

[4]Explicit seniority structure is considered by Moody's when rating bonds (Fons et al. 2007), but de facto seniority is not. In our sample, a regression of ratings on proportion due prior (our measure of de facto seniority) and firm fixed effects has a within group R^2 of only 0.0001.

the effects are not as large as the model suggests. Our results are consistent with the fact that junk-rated firms have complex capital structures (Rauh and Sufi (2010)) that are not fully incorporated in the extended Merton model. Investment-grade firms, in contrast, have much simpler debt structures, so our extension of the Merton model provides a reasonable approximation.

In addition to yield spreads, we also consider hedge ratios, the relative returns of corporate bonds and equities. Intuitively, hedge ratios measure how equity-like a corporate bond is, with bonds with greater credit risk behaving in a more equity-like way. Hedge ratios provide not only an alternative setting to test for the de facto seniority effect but one that structural models have performed better on than yield spreads based on previous literature (Schaefer and Strebulaev (2008)). Consistent with the predictions of the extended Merton model, we find that de facto junior bonds have larger hedge ratios than do de facto senior bonds. Hence, our results using hedge ratios confirm our yield spreads results.

Our paper is primarily related to two strands of literature. Empirically, our paper is related to the literature that tries to evaluate the pricing of corporate bonds through the lens of structural models of default. Huang and Huang (2003) is the seminal paper showing that a large part of credit spreads cannot be explained by common structural models of default.[5] Our paper is also related to the theoretical literature on equilibrium maturity choice, particularly Brunnermeier and Oehmke (2013),[6] who show that the incentive to shorten the maturity structure in conjunction with an inability to commit to a maturity structure leads to a maturity rat race for financial firms. The outcome of this maturity rat

[5]In a recent paper, Feldhutter and Schaefer (2015) use a long history to estimate default probabilities and find a smaller credit spread puzzle. Another facet of the credit spread puzzle, the difficulty in explaining changes in yield spreads is illustrated by Collin-Dufresne, Goldstein, and Martin (2001). Other relevant papers focused on understanding yield spreads, returns, and their moments include Schaefer and Strebulaev (2008), who focus on hedge ratios and Campbell and Taksler (2003), Bao and Pan (2013), and Bao et al. (2014), who focus on yield spreads and volatilities. There is also an extensive literature focusing on the comovement between Treasury bonds and equities. Recent papers include Baele, Bekaert, and Inghelbrecht (2010), Baker and Wurgler (2012), and Campbell, Pflueger, and Viciera (2014). In addition, a line of literature examines bond and equity returns over corporate announcement windows, including Hotchkiss and Ronen (2002), Maxwell and Stephens (2003), and Maxwell and Rao (2003).

[6]See also Chen, Xu, and Yang (2012), and He and Milbradt (2015).

race is inefficiently short-term financing. In this paper, we do not aim to explain why a firm has chosen a particular maturity structure; instead, we take the outcome of maturity choice as given and focus on the empirical effects of a bond's position in its firm's maturity structure on its prices and returns. Corporate bond issuers will have both de facto senior and de facto junior bonds regardless of the equilibrium choice to largely issue short-term versus long-term bonds as de facto seniority is defined relative to bonds from the same issuer, not based on the absolute maturity of the bond. Importantly, we note that our results are robust to controlling for the average firm-level maturity (the outcome of the endogenous choices discussed in the aforementioned papers) and also the actual maturity of the bond.

1 De Facto Seniority and Credit Risk

As a simple benchmark model, we consider a Merton model in which firm value follows a geometric Brownian motion under the risk-neutral probability measure

$$d \ln V_t = \left(r - \frac{1}{2}\sigma_v^2\right) dt + \sigma_v dW_t^Q. \tag{1}$$

The firm has a single zero-coupon bond issue with face value K and equity is a call option on the firm. The single bond issue is equivalent to a risk-free bond short a put option on the firm. Its value is

$$B = V\left(1 - N(d_1)\right) + Ke^{-rT} N\left(d_2\right), \tag{2}$$

$$\text{where } d_1 = \frac{\ln\left(\frac{V}{K}\right) + \left(r + \frac{1}{2}\sigma_v^2\right)T}{\sigma_v\sqrt{T}} \text{ and } d_2 = d_1 - \sigma_v\sqrt{T}.$$

Bond yields can be directly inferred from $B = Ke^{-yT}$, and the yield spread equals $y - r$.

In addition to yield spreads, we also consider hedge ratios, the relative returns of corporate bonds and equities. As illustrated by Schaefer and Strebulaev (2008), the relative returns of the bond and equity (the hedge ratio) under the Merton model is

$$h_E \equiv \frac{\partial \ln B}{\partial \ln E} = \left(\frac{1}{N(d_1)} - 1\right)\left(\frac{V}{B} - 1\right). \tag{3}$$

The Merton model formalizes the important insight that corporate bonds and equities are linked through their exposures to the underlying firm value.[7] Intuitively, safe corporate bonds will be similar to Treasuries and have low hedge ratios. Corporate bonds with significant credit risk will have higher exposures to underlying firm values and will tend to have larger hedge ratios.

We extend the Merton model to analyze how the position of a bond in its issuer's maturity structure affects its yield spread and hedge ratio. The intuition behind why a bond's position affects its credit risk is that a firm in financial distress may remain solvent long enough to repay bond issues that mature early. However, the firm is then likely to suffer solvency issues when the bonds due later eventually mature. This creates a de facto seniority effect.[8] Our extension of the Merton model includes three zero-coupon bond issues, which have the same explicit seniority, but mature at different times. The three bond issues have face values K_i and maturities T_i where $T_1 < T_2 < T_3$. At T_i, a firm remains solvent if $V_i > K_i$.[9] Otherwise the firm defaults, V_i is discounted by a proportional bankruptcy cost (L), and the remaining bond issues share the remaining firm value in proportion to their face values.[10,11] This model,

[7]Stochastic interest rates, an important source of variation in bond prices, are not modeled here as the tie between bonds and equities through interest rates is indirect and less important than the tie through firm value. See Shimko, Tejima, and van Deventer (1993) for an extension of the Merton model to stochastic interest rates and Schaefer and Strebulaev (2008) and Bao and Pan (2013) for applications of this model.

[8]Brunnermeier and Oehmke (2013) use similar intuition in their theoretical analysis to motivate an incentive to shorten maturities, which, in turn, leads to a maturity rat race for financial firms. They posit that nonfinancial firms are better able to commit to a maturity structure and avoid a rat race.

[9]If the firm is solvent at T_i, firm value drops to $V_i - K_i$ and the firm value process follows a geometric Brownian motion between T_i and T_{i+1}.

[10]We do not formally model the decision to rollover debt, but the states where V_i is barely larger than K_i are the states where the rollover of debt would be particularly expensive, if not impossible. These states are primarily responsible for driving the wedge between bond issues that creates de facto seniority. See He and Xiong (2012) and He and Milbradt (2014) for recent papers that examine the issue of rollover risk.

[11]The way that we model default is akin to assuming that all defaults are resolved in bankruptcy courts. We abstract away from complexities such as out-of-court settlements and exchange offers where some bondholders may receive larger recoveries than other bondholders. Firms that decide to try to avoid bankruptcy by making exchange offers have incentives to make these exchange offers to debt that is maturing soon since this is the

although a simplification of the complex capital structure typical in large U.S. corporations, allows us to examine the yield spread and hedge ratio, while varying the bond's position in the firm's maturity structure. By including three bonds, we are able to focus on the bond with the intermediate maturity, T_2, and adjust the relative amounts of debt due before and after it.[12] This changes the de facto seniority of the intermediate maturity bond, holding all else constant, allowing us to gauge the impact of de facto seniority on yield spreads and hedge ratios.

In this extended Merton model, equity remains a call option on the firm, but has intermediate monitoring points at each bond maturity

$$E = E_0^Q \left[e^{-rT_3} \mathbb{1}_{V_1 > K_1} \mathbb{1}_{V_2 > K_2} \mathbb{1}_{V_3 > K_3} \left(V_3 - K_3 \right) \right]. \tag{4}$$

Though there is no closed-form solution for equity value, it can be simplified to a function of normal cumulative distribution functions (CDFs) and integrals by noting that firm value returns are lognormal. Similarly, the value of the bond maturing at T_2 is

$$\begin{aligned} B = {} & E_0^Q \left[e^{-rT_2} \mathbb{1}_{V_1 > K_1} \mathbb{1}_{V_2 > K_2} K_2 \right] + E_0^Q \left[e^{-rT_1} \mathbb{1}_{V_1 < K_1} (1 - L) V_1 \frac{K_2}{K_1 + K_2 + K_3} \right] \\ & + E_0^Q \left[e^{-rT_2} \mathbb{1}_{V_1 > K_1} \mathbb{1}_{V_2 < K_2} (1 - L) V_2 \frac{K_2}{K_2 + K_3} \right], \end{aligned} \tag{5}$$

where the three terms represent solvency at T_2, default at T_1, and default at T_2, respectively. The yield spread can then be calculated from bond prices and the hedge ratio $\left(\frac{\partial \ln B}{\partial \ln E}\right)$ can be calculated using numerical procedures. Appendix A provides details for the pricing equations.

In Table 1, we consider the yield spreads for corporate bonds under both the Merton

debt for which they will have to service a significant face value in the near future. To the extent that firms need to make favorable offers to bondholders to convince bondholders to accept exchange offers, this also makes earlier maturing debt de facto senior.

[12]Our set-up essentially maps all bonds maturing prior to T_2 into a single bond that matures at T_1 and all bonds maturing after T_2 into a single bond that matures at T_3.

model and the extended Merton model for various leverage-asset volatility combinations.[13] In panel A, we focus on the Merton model as a benchmark, finding the expected result that as credit risk increases (leverage and asset volatility increase), yield spreads increase. This can also be seen in Figure 1(A). We note that the model yield spreads are somewhat lower than typical empirical yield spreads, consistent with Eom, Helwege, and Huang (2004) and Huang and Huang (2012), who show that Merton-type models typically underpredict yield spreads.

More importantly, in panel B of Table 1, we examine the yield spreads of bonds that are de facto senior and de facto junior. We consider two scenarios. In both scenarios, we fix the value of the bond due at T_2 to be 10% of the total market value of debt. In the first scenario, 80% of the firm's market value of debt is from the bond due at T_3 and only 10% of the market value of debt is from the bond due at T_1. The intermediate maturity bond, due at T_2, is de facto senior to most of the debt in the firm. In the second scenario, we flip the proportions of the market value of debt due to the bonds maturing at T_1 and T_3, making the intermediate maturity bond de facto junior to most of the firm's debt.[14] We set the maturities of the three bonds to be $T_1 = 5$, $T_2 = 7$, and $T_3 = 10$, and the bankruptcy cost to be $L = 0.5$. Panel B shows that, at extremely low levels of credit risk, whether a bond is de facto senior or de facto junior has little effect on the yield spread. At more moderate levels, we begin to see that de facto senior bonds continue to have very small yield spreads, whereas de facto junior bonds have higher yield spreads. For example, at an asset volatility of 20% and a leverage of 50%, the de facto senior bond still has a yield spread close to zero, whereas the de facto junior bond has a yield spread of 75 basis points. As a benchmark, in the basic Merton model, the single bond has a yield spread of 54 basis points. At high levels of credit risk, de facto seniority becomes even more important. For example, at an asset volatility of 40% and a leverage of 60%, the model yield spread is only 46 basis points

[13] The maturity T, in the Merton model, is set to 7 years to be in line with typical medium-term bonds.

[14] The proportion of debt due prior to the intermediate bond (10% in the first scenario and 80% in the second scenario) thus measures how de facto senior the intermediate bond is in these numerical examples. We will use the same variable to measure the de facto seniority of a bond in our empirical tests.

for the de facto senior bond as compared to 10% for the de facto junior bond.

In Table 2 and Figures 1(c) and 1(d), we study hedge ratios. Hedge ratios measure the relative returns of corporate bonds and equities, with higher hedge ratios representing cases where a bond is more equity-like. Our numerical results for hedge ratios bear out a similar story to yield spreads. As credit quality of a firm declines, hedge ratios increase, and much more so for the de facto junior bond. For example, under the Merton model, a firm with an asset volatility of 10% and a leverage of 20% has a hedge ratio of virtually zero under the Merton model. Under the extended Merton model, bonds issued by such a firm have a hedge ratio close to zero regardless of whether the bonds are de facto senior or de facto junior. For an asset volatility of 20% and a leverage of 50%, the hedge ratio for the Merton model is 7.1%. That is, a 10% equity return corresponds to a 0.71% corporate bond return. For the extended Merton model, we see that de facto seniority is important for such a firm. The de facto senior bond has a virtually zero hedge ratio. The de facto junior bond has a hedge ratio of 11.9%, so a 10% equity return corresponds to a 1.19% corporate bond return. Finally, for an asset volatility of 40% and a leverage of 60%, the de facto senior bond has a hedge ratio of 4.3%, whereas the de facto junior bond has a much larger hedge ratio at 38.4%.

The primary intuition for the numerical results from our extension of the Merton model is that it is exactly when firms have to make large repayments of debt where their financial situations can become particularly precarious. If a bond is de facto junior, debtholders know that if firm value is already low, the need to pay off a large amount of a de facto senior bond may push the firm close to bankruptcy prior to the payment of the de facto junior bond. That is, the firm may be continued when earlier debt is paid off, but this may put the firm in more jeopardy of being unable to pay off later debt if there are further negative shocks to the firm.[15] If a bond is de facto senior, such a scenario is less relevant.[16]

Our choice to use an extended Merton model to illustrate the effects of de facto seniority stems from a goal of using as parsimonious a model as possible to illustrate the intuition. Nevertheless, we recognize that other choices can be made in the mechanisms of structural models of default. Thus, in Appendices B.1, B.2, and B.3, we consider additional structural models of default in an effort to better understand the effect of different assumptions on the de facto seniority effect. Although full details of our implementations are described in the respective appendices, we briefly explain the economic intuition behind each of the models here. In Appendix B.1, we consider the Geske (1977) model, where retiring debt is paid off by equityholders rather than out of firm value. Equityholders need to decide when each debt issue matures whether they want to pay-in to continue the firm. The effect of this discrete pay-in is to make equityholders consider the firm's whole maturity structure when making a decision about continuing the firm. Even if only a small amount of debt is due today, equityholders may choose to default because they recognize that a large amount of debt is due in the future before they receive a payoff as residual claimants. Effectively, equityholders become less myopic about the firm. This has the effect of undoing the de facto seniority effect, predicting that de facto senior bonds could even have *higher* yield spreads and hedge ratios. This contrasts the extended Merton model, where equityholders do not have a pay-in and always want to continue the firm (if possible). In Appendix B.2, we extend the Geske model to allow for equityholders to pay-in an exogenously specified fraction of the face value of maturing debt. The Geske and extended Merton can be viewed as special cases of this model where the equity pay-ins are 100% and 0% of maturing debt, respectively. As would be expected, the de facto seniority effect weakens as the amount of equity pay-in increases.

[15] Within the model, this can be thought of as either $V_1 - K_1 < K_2$, in which case the repayment of the first bond has already driven firm value below what T_2 debtholders are owed or a case in which $V_1 - K_1 > K_2$, but not by that much. In such a case, T_2 debt has a high probability of not being fully paid if firm performance between T_1 and T_2 is poor.

[16] Another possibility is that bankruptcy courts treat bonds with different maturities as different classes in the resolution of bankruptcy. Guha (2002) notes that in most Chapter 11 cases, bonds with the same explicit seniority are put in the same class. But to the extent that bonds are occasionally put into different classes by maturity, this could also generate a de facto seniority effect.

Finally, we consider a Leland and Toft (1996) model in Appendix B.3, a model in which there is endogenous equity pay-in, but only if there is a cash shortfall. In this model, firms continuously roll-over debt and equity pay-ins are only required if the proceeds from newly issued debt and from a fractional liquidation of firm assets are insufficient to cover coupons from all of the firm's debt and the face value of maturing debt. This makes equity pay-ins infrequent and small. Though the Leland-Toft model makes the intuition significantly more complicated, the general effect is similar to an extended version of the Geske model with small equity pay-ins. There continues to be a de facto seniority effect, though one that is not quite as large as that in the extended Merton model.

2 Data and Summary Statistics

The corporate bond data set used in this paper is the Financial Industry Regulatory Authority's (FINRA) Trade Reporting and Compliance Engine (TRACE). This data set is the result of a regulatory initiative to increase price transparency in the corporate bond market and was implemented in three phases. On July 1, 2002, the first phase was implemented, requiring transaction information to be disseminated for investment-grade bonds with an issue size of $1 billion or greater and 50 legacy high-yield bonds from the Fixed Income Pricing System (FIPS). Approximately 520 bonds were included in phase I. Phase II, which was fully implemented on April 14, 2003, increased the coverage to approximately 4,650 bonds and included smaller investment-grade issues. Phase III, which was fully implemented on February 7, 2005, covered approximately 99% of secondary bond market transactions. In our study, we use TRACE data on corporate bonds from July 2002 to December 2013.

Bond transaction data from TRACE are merged with bond characteristics data from Mergent FISD, which allows us to determine bond characteristics such as age, maturity, amount outstanding, and rating. These data are then merged with equity return data from CRSP and accounting information from Compustat. Treasury data are obtained from the

Constant Maturity Treasury (CMT) series. Mergent FISD is used to eliminate bonds that are putable, convertible, or have a fixed-price call option.[17] CRSP is used to eliminate bonds issued by financial firms.[18] In addition, we only keep institutional-sized trades, defined as trades of \$100,000 or greater in volume.[19]

To calculate yield spreads, we use the last trade for a bond in a month and calculate yields in a standard manner before subtracting off the yield of a similar maturity Treasury bond. TRACE does provide yields, but we find that yields from TRACE can occasionally be unreliable. The Treasury yield is based on the U.S. Department of Treasury's Constant Maturity Treasury (CMT) series from which we linearly interpolate between provided maturities as necessary. As reported in Table 3, the mean yield spread in our sample is 1.81%, with means of 1.50% and 3.83% for investment-grade and speculative-grade bonds, respectively. As expected, yield spreads have an approximately 50% correlation with numerically coded ratings in the sample.

Equity returns can be directly obtained from CRSP, but both corporate bond and Treasury returns need to be calculated. To calculate monthly corporate bond returns, we use the last trade for a bond in a month and calculate log returns as

$$r_{t+1} = \ln\left(\frac{P_{t+1} + AI_{t+1} + C_{t+1}}{P_t + AI_t}\right), \tag{6}$$

where P_{t+1} is a clean price, AI_{t+1} is the accrued interest, and C_{t+1} is the coupon paid during

[17]Bonds where the only provision is a make whole call provision, which constitutes a significant portion of nonfinancial bonds, are kept. Make whole calls involve redemption at the maximum of par and the present value of all future cash flows using a discount rate of a comparable Treasury plus X basis points, where the most common values of X are 20, 25, and 50. Historically, the average AAA yield spread has been greater than 50 basis points, leaving make whole calls with little chance of being in-the-money. Powers and Tsyplakov (2008) show that theoretically, make whole calls have little effect on bond prices. They also find that by 2002-2004, the empirical effect of make whole calls on bond prices is extremely small.

[18]Though some corporate bond studies, primarily those on corporate bond illiquidity, retain financial firms, studies on structural models of default typically drop financial firms because leverage has different implications for financial firms. Furthermore, Brunnermeier and Oehmke (2013) argue that financial firms have incentives to enter a maturity rat race and are unable to commit to a maturity structure. Thus, any measure of maturity structure today for a financial firm is unlikely to reflect bondholders' expectations of future maturity structure.

[19]We also apply standard filters for corrected and canceled trades and eliminate obvious errors.

the month (if applicable).

Unlike equities, many corporate bonds do not trade every day. Thus, the returns that we calculate for a bond in a particular month may not necessarily be based exactly on month-end to month-end prices. To account for this, we make two adjustments. First, we match Treasury and equity returns to the exact dates that are used to calculate bond returns. This eliminates any issues of nonsynchronization as our goal is to compare contemporaneous bond, equity, and Treasury returns in our hedge ratio analysis. Second, we scale all log returns to make them monthly. For example, if a log bond return is calculated over 25 business days, we scale the return by $\frac{21}{25}$ to make it comparable to a return that actually occurs over exactly a one month period ($\approx$ 21 business days).[20] The mean monthly corporate bond return in our sample is 0.50% per month, with means of 0.47% and 0.69% for investment-grade and speculative-grade bonds, respectively. As calculating bond returns requires bond prices in consecutive months, our bond return sample, which will be used later to calculate hedge ratios, is more restrictive than our yield spread sample.

To calculate Treasury returns, we again use yields from the CMT series. The provided yields are par yields for on-the-run (and hence, liquid) bonds. Because the yields are par yields, we can calculate the return for a bond that trades at par at the start of a month by discounting cash flows using yields at the end of the month. Only discrete maturities are provided in the CMT series. Thus, we interpolate between maturities to calculate the return for a Treasury with the same maturity as the corporate bond being priced.

Table 3 also reports other summary statistics for our corporate bond sample. Our yield spread sample covers 9,382 distinct bonds and 301,291 bond-months, whereas our hedge ratio sample is somewhat smaller. The vast majority of our sample covers investment-grade bonds, with over 85% of our bond-months coming from the investment-grade sample.

[20] We also require trades to be at least 11 business days apart and no more than 31 business days apart to calculate returns as trades that deviate too much from being monthly could be nonrepresentative. For example, if a bond's consecutive last trades of the month are on the last day of the first month and the first day of the second month, we would be calculating a daily return and scaling up to a monthly return. This may create an outlier.

As bond-level characteristics do not differ much between the yield spread and hedge ratio samples, we will largely describe the yield spread sample. The average time-to-maturity in our sample is 9.37 years, with a slightly higher mean for investment-grade (9.57 years) than speculative-grade (8.07 years) bonds. The median is lower at 5.84 years, reflecting the fact that time-to-maturity is positively skewed. The average age of bonds in our sample is close to 5 years. To measure how de facto senior a bond is in its firm's maturity structure, we calculate the proportion of the issuer's total face value of current outstanding debt from FISD that has a shorter remaining maturity than the bond being studied. Note that this includes all debt in Mergent FISD, not just bonds traded in TRACE. We call this variable proportion due prior and find that its average value is 0.41 in our sample. For amount outstanding and coupons, we observe significant differences between investment-grade and speculative-grade bonds. Investment-grade bond issues have an average amount outstanding of \$578mm, whereas speculative-grade bond issues have an average amount outstanding of \$395mm, about two-thirds the size of investment-grade issues. The smaller issue sizes for speculative-grade bonds reflects the fact that poorer rated firms tend to be smaller. Average coupons are also higher for speculative-grade bonds at 7.10% as compared to 5.84% for investment-grade bonds, reflecting the fact that most bonds are issued at par. We also report summary statistics for four bond-level illiquidity measures (the Amihud measure, Amihud volatility, the IRC measure, and IRC volatility) in panel A. All four variables are scaled by 100 and show similar distributional statistics as Dick-Nielsen, Feldhutter, and Lando (2012). Overall, speculative-grade bonds are less liquid than investment-grade bonds.

In Table 4, we report summary stats for firm-level variables. We have fewer than 800 unique firms in our sample, reflecting the fact that many firms, even those with publicly traded equity, do not issue corporate bonds.[21] The mean equity market capitalization of firms in our sample is \$46bn, reflecting the large size of corporate bond issuers. There is

[21]Note that a firm-month can be represented in both the investment-grade subsample and the speculative-grade subsample if it has some bonds with investment-grade ratings and some bonds with speculative-grade ratings.

a drastic difference in the average size of investment-grade and speculative-grade issuers as investment-grade issuers average \$52bn in equity market capitalization compared to \$9bn for speculative-grade issuers. Investment-grade issuers also exhibit lower average equity volatility (28.00%) and leverage (30.25%) than speculative-grade issuers (40.44% equity volatility and 50.16% leverage). The higher numbers for speculative-grade firms are natural, as both variables reflect the higher credit risk of speculative-grade firms. Leverage is a direct measure of the amount of debt that a firm has issued, relative to firm value. Equity volatility reflects a combination of the leverage and the underlying asset volatility of the firm, both of which are positively related to default probabilities. In our empirical analysis, we include equity volatility as a credit risk control variable. In our sample, equity volatility has a significant 30% correlation with numerically coded ratings, suggesting that although there is significant overlap in credit risk as measured by the two variables, additional information can be provided by equity volatilities.

In addition to equity volatility, we also include book equity-to-market equity (BE/ME) as a measure of firm-level credit quality. The empirical literature on equity returns has found BE/ME to be related to the relative strength of a firm's economic fundamentals (Lakonishok, Shleifer, and Vishny 1994; Fama and French 1995). Furthermore, Fama and French (1992) show that BE/ME captures the effect of leverage, an important structural model input. Though there is much debate as to whether the return premium associated with book-to-market ratio is due to risk or mispricing (see, e.g., Fama and French 1993, 1996; Lakonishok, Shleifer, and Vishny 1994; Haugen 1995; MacKinlay 1995; and Daniel and Titman 1997), our use of the book-to-market ratio is much more basic. We simply take it as reflecting the market's assessment of a firm's strength.

We construct BE/ME in a similar manner to Asness and Frazzini (2013), who argue that it is important to use more timely stock price data relative to book data in order to better forecast future book-to-market ratio. For the book value of equity, we use the book value of common equity (CEQ) from Compustat and assume that it is publicly available three months after the fiscal year end. For the market value of equity, we use common shares outstanding (CSHO) times price at the end of the fiscal year (PRCC_F), but adjust this using returns without dividends from CRSP. For example, to calculate BE/ME for a firm in May 2010 whose last fiscal year ended in December 2009, we take the book equity and market equity (CSHO × PRCC_F) from Compustat at of the end of the 2009 fiscal year and scale the market equity by (1 + r), where r is the return of the firm's equity without dividends from December 2009 to May 2010.[22] We find that BE/ME is almost 60% higher for speculative-grade bonds as than for investment-grade bonds. We also note that BE/ME is significantly correlated with both numerically coded ratings and equity volatility, with correlations around 30%–40%.

The final firm-level variable that we report is the average firm-level maturity. To construct this variable, we take the amount outstanding-weighted average of the time-to-maturity of an issuer's bonds. This variable is used to capture the fact that some firms tend to issue bonds at a shorter maturity and some at a longer maturity. The mean and median of firm-level average maturity is somewhat higher than the reported average bond maturity in Table 3, because there is a positive correlation between the time-to-maturity and the amount outstanding.

3 Empirical Results

3.1 Yield spreads

We first discuss a case in our data to highlight the de facto seniority effect before turning to formal empirical analysis using regressions. In 2013, Amgen had two bonds with very similar time-to-maturity, a $1.25bn bond maturing on May 15, 2017 ("May bond"), and a $1.1bn bond maturing on June 1, 2017 ("June bond"). During 2013, the two bonds also

[22]Directly using market equity from CRSP for May 2010 introduces errors if the firm had significant issuance or repurchases between December 2009 and May 2010 that would be reflected in the market equity for May 2010, but not in the book equity for December 2009.

had similar levels of liquidity as measured by the Amihud (2002) measure and the implied round-trip cost measure of Feldhutter (2012). Nevertheless, during 2013, the June bond consistently traded at a yield spread higher than the May bond, with an average difference of 8 basis points. This was roughly 10% of the average yield spreads of the bonds during the year, despite the bonds having the same issuer, same rating, similar liquidity, and very close maturity. The primary reason for the yield spread difference between the bonds is that the sequential payment of debt means that, in the future, Amgen would have to pay off the May bond prior to paying off the June bond, hence making the May bond de facto senior to the June bond.

To formally examine the relation between yield spreads and de facto seniority, we next turn to a standard regression framework to examine a broader sample, while controlling for differences across bonds. Our empirical specification for examining the effect of de facto seniority on yield spreads is

$$\text{yield spread}_{it} = \alpha_t + \beta \times \text{proportion due prior}_{it} + \delta X_{it} + \varepsilon_{it}, \tag{7}$$

where X_{it} is a set of control variables that includes credit controls, illiquidity controls, firm- and bond-level maturity, and firm fixed effects. We also include time fixed effects to account for differences in yield spreads due to changes in macroeconomic conditions across time in our sample. Proportion due prior is our variable of interest. A lower proportion due prior corresponds to a bond that is earlier in its firm's maturity structure and therefore is de facto senior. In the extended Merton model examples in Section 1, we compare model-implied yield spreads for two hypothetical bonds with proportions due prior equal to 0.1 and 0.8.

In our baseline specification, reported in Column (1) of Table 5, panel A, we control only for a bond's maturity (T) and the bond-level Moody's credit rating (Rating).[23] We

[23]In our sample, the correlation between proportion due prior and T is high at 0.73. We run variance inflation factor (VIF) tests following Kennedy (1998), and find VIFs under four for all of our yield spreads specifications, far under the benchmark of 10 at which point multicollinearity may significantly affect statistical inference.

include the bond's maturity to ensure that proportion due prior is not simply proxying for a pure maturity effect. The coefficient on proportion due prior is a statistically and economically significant 95 basis points. All standard errors are two-way clustered by firm and time, following Cameron, Gelbach, and Miller (2011). Like Dick-Nielsen, Feldhutter, and Lando (2012), this allows for time series correlation (for all bonds from the same issuer), cross-correlation, and heteroscedasticity. To gauge the economic magnitude of the 95-basis-point coefficient on proportion due prior, we note that a one-notch decline in credit rating is associated with a 30-basis-point increase in yield spreads. Thus, the de facto seniority effect is equivalent to a decline in credit rating of more than three notches.

In Columns (2) to (5) of Table 5, panel A, we add additional controls. In Column (2), we add book equity-to-market equity (BE/ME) and equity volatility, both of which are empirical proxies for a firm's credit risk. In Column (3), we add the weighted-average maturity of all of a firm's corporate bonds (firm T). This reflects firms' endogenous choices to issue either debt with longer or shorter maturity. In Columns (4) and (5), we add the four main measures of illiquidity from Dick-Nielsen, Feldhutter, and Lando (2012): the Amihud measure, the implied round-trip cost (IRC) measure from Feldhutter (2012), and the volatilities of the two measures. Regardless of the specification, proportion due prior remains highly significant, with coefficients ranging from 42 to 81 basis points.

We consider subsamples in Columns (6) to (8). In Columns (6) and (7), we rerun the regression from Column (5), but do so for the subset of investment-grade and speculative-grade bonds, respectively. For both samples, we continue to find a significant effect for proportion due prior, though the coefficient is larger for speculative-grade bonds at 74 basis points compared to 34 basis points for investment-grade bonds. Such a difference likely reflects the fact that being very late in the maturity structure of a very safe firm still means that a bond is relatively safe, whereas the difference between an early maturing and late maturing bond for a speculative-grade firm is particularly important. Such firms may become insolvent exactly after they have paid off the early maturing debt, but are unable to raise new funding through new debt issues. In Column (8), we exclude the crisis period (July 2007 – June 2009) and rerun our regression. We find that the effect of proportion due prior is 50 basis points when excluding the crisis, slightly higher than the 42 basis points (Column (5)) when including the crisis. Thus, the effect we find is not a financial crisis-specific effect.

We include firm fixed effects in our specifications in panel B of Table 5. This controls for time-invariant firm-level effects including average credit quality and a firm's propensity to issue shorter or longer-term debt. We continue to include credit ratings, book-to-market, and equity volatility as these variables allow for time variation in credit quality. Indeed, our results suggest that our time-varying credit controls remain important in measuring credit quality as evidenced by the similar coefficients on credit controls in panels A and B. We also continue to include the average firm-level maturity of debt as this potentially proxies for the time-varying component of a firm's propensity to choose shorter- or longer-term debt. However, we find that this variable is much less significant when including firm fixed effects, suggesting that a firm's propensity to issue longer- or shorter-term debt is not highly time varying. We also maintain illiquidity controls as illiquidity can be bond specific. Even with all of these controls, we continue to find a significant effect for proportion due prior. In particular, the coefficient on proportion due prior is 0.48 when including all controls (Column (5)), similar to the results without firm fixed effects. This effect is larger than the effect of decreasing credit rating by two notches (21 basis points per notch). We also continue to find subsample results similar to those in panel A. In Appendix C, we consider robustness checks where we use alternative credit controls such as asset volatility and model-implied leverage and also include their squared terms. Our results are similar.

As an additional test of the de facto seniority effect, we consider paired sample analysis.[24] We match bonds issued by the same firm with close maturities. For each bond, we match to bonds with maturities between one and 90 days later. Then, we calculate the difference in yield spreads and the difference in proportion due prior between the bonds. The de facto

[24]We thank an anonymous referee for suggesting this test.

seniority effect implies that a greater difference in proportion due prior is associated with a greater difference in yield spreads, controlling for other differences between the bonds. Hence, our empirical specification is

$$\begin{aligned}\text{Yield spread}_{jt} - \text{Yield spread}_{it} = \alpha_t &+ \beta_1(\text{prop due prior}_{jt} - \text{prop due prior}_{it}) \\ &+ \beta_2(T_{jt} - T_{it}) + \beta_3(\text{Rating}_{jt} - \text{Rating}_{it}) \\ &+ \beta_4(\text{Liquidity}_{jt} - \text{Liquidity}_{it}) + \varepsilon_{jit},\end{aligned} \tag{8}$$

where bond j is the later maturing bond in the pair. Restricting the pairs to bonds with very close maturity has two possible benefits. First, there is little variation in the maturity difference, making it unlikely that maturity differences can explain yield spread differences. Second, the correlation between proportion due prior differences and maturity differences is smaller than the correlation in levels. Both of these benefits could help with the identification of the proportion due prior effect, though with the caveat that we can only include a subsample of the bonds that were in the original sample. A further benefit of this matched sample analysis is that, because we match by issuer, firm-level effects drop out.[25]

In Table 6, we estimate specification (8), finding a de facto seniority effect of 81 basis points when controlling for differences in all four measures of illiquidity in addition to controlling for differences in time-to-maturity and rating. We note that this specification has only 25,576 observations as compared to 201,233 observations in the comparable regression in Table 5. When we further restrict our sample to cases where bonds i and j are close in illiquidity (Columns (3) and (4)),[26] our sample drops further to fewer than 20,000 observation and we find a 104-basis-point de facto seniority effect. Thus, our results on de facto seniority are robust to an alternative matched sample analysis.

Overall, our results are consistent with a bond's place in its issuer's maturity structure

[25] We include differences in ratings as a control where a positive difference indicates that bond j has a poorer credit rating. For the vast majority of cases, the difference in ratings is zero.

[26] We separately sort the panel by Amihud and IRC and retain only pairs for which both measures are within 20 percentile points.

affecting its price, even after controlling for time-invariant firm effects, time-varying credit quality proxies, illiquidity variables, the actual maturity of a bond, and the average maturity of bonds issued by the issuer. The results continue to hold in matched sample analysis that focuses on bonds with similar maturities. Our results are consistent with the market understanding the impact of *relative* maturity on credit risk and suggest that rating agencies should consider de facto seniority in addition to explicit priority structure when notching bonds.

3.2 Hedge ratios

Next, we turn to hedge ratios. Whereas yield spreads measure credit quality using the levels of prices, hedge ratios are measured using the joint dynamics of corporate bond and equity returns. Hence, hedge ratios provide a useful alternative test of the effect of de facto seniority. Schaefer and Strebulaev (2008) theoretically show that even if the level of bond prices is different than in a hypothetical frictionless world, models that do not have frictions may match hedge ratios correctly if they provide a reasonable measure of credit risk. The intuition is that although there might be a component in the level of prices related to illiquidity and hence, in returns to corporate bonds due to changes in illiquidity, a regression of bond returns on equity returns will give a coefficient that is largely determined by the covariance of the credit component of corporate bond returns with equity returns. Empirically, Schaefer and Strebulaev (2008) find that hedge ratios are in line with those predicted by the Merton model. For most of this section, we follow the Schaefer and Strebulaev (2008) argument and focus on credit-related variables, but later consider robustness to illiquidity controls. The standard estimate of hedge ratios are from a regression of corporate bond returns on equity returns and Treasury returns,[27]

$$r_D = \beta_0 + \beta_E r_E + \beta_T r_T + \varepsilon. \tag{9}$$

Intuitively, bonds that have very little credit risk will move very closely with a Treasury of comparable maturity but very little with equities issued by the same firm. The equity hedge ratio estimate, β_E, would be relatively low, whereas the Treasury hedge ratio estimate, β_T, would be relatively high.

We estimate hedge ratios in a pooled regression, but allow hedge ratios to vary with different firm and bond characteristics. Before considering the effect of maturity structure, we consider a baseline regression of

$$r_D = \beta_0 + \beta_E r_E + \beta_T r_T + \beta_{E,rat} r_E \times \text{Rating} + \beta_{T,rat} r_T \times \text{Rating} + \beta_{rat}\text{Rating} + \varepsilon. \tag{10}$$

Results are reported in panel A of Table 7. The estimated equity hedge ratio of any bond is given by $\beta_E + \beta_{E,rat} \times \text{Rating}$ and the estimated Treasury hedge ratio is given by $\beta_T + \beta_{T,rat} \times \text{Rating}$. In Column (1), we report the estimates of this regression. For a Aaa-rated bond, the regression estimates imply an equity hedge ratio of $0.0153 + 0.0075 \times 1 = 0.0229$ (t-stat $= 1.34$) and a Treasury hedge ratio of 0.9450 (t-stat $= 15.03$), which are reported in panel B of Table 6. As the regression coefficient on $r_E \times$ Rating is positive and the coefficient on $r_T \times$ Rating is negative, equity hedge ratios increase and Treasury hedge ratios decrease as ratings decline (numerically coded rating increases). In panel B, we also report the regression-implied hedge ratios for other ratings, along with t-statistics. We find that starting with an Aa rating, estimated equity hedge ratios begin to be statistically significant. Treasury hedge ratios decline precipitously as ratings decline, all the way to a negative estimated value for B-rated bonds. In Columns (2) and (3) of panel A, we restrict our baseline regression to only

[27] An alternative would be to simply scale realized corporate bond returns by realized equity returns. Such an estimate would be very imprecise as cases of small equity returns relative to large corporate bond returns would create extreme observations.

investment-grade and speculative-grade bonds, respectively. One difference of note is that although equity hedge ratios increase as credit quality declines, we find that the coefficient on $r_E \times$ Rating is insignificant for the speculative-only sample, suggesting that hedge ratios are relatively flat across ratings for speculative-grade bonds.

To study the de facto seniority effect, we introduce an interaction term between equity returns and proportion due prior to the regression and report the results in Table 8. The estimate of a particular bond's equity hedge ratio is now

$$\beta_E + \sum_i (\text{coefficient on } r_E \times \text{char}_i) \times \text{char}_i, \tag{11}$$

where char_i is a bond or firm characteristic, including proportion due prior. The coefficient on $r_E \times$ proportion due prior measures the marginal effect of proportion due prior on the equity hedge ratio. We also include interaction terms between equity returns and bond maturity (T), equity book-to-market (BE/ME), equity volatility, and average firm-level bond maturity of the issuer (Firm T) in addition to the interactions with ratings and proportion due prior.[28] We find an economically and statistically significant effect for proportion due prior on hedge ratios. Controlling for the effects of ratings, book-to-market, equity volatility, bond maturity, and firm-level maturity on hedge ratios (Column (3)), we find that a bond that is the latest bond in its issuer's maturity structure has an equity hedge ratio that is 0.0861 larger than the earliest bond in its issuer's maturity structure.[29] Compared to

[28] In these hedge ratio regressions, $r_E \times$ proportion due prior is highly correlated with both r_E and $r_E \times T$, which raises the issue of multicollinearity. Variance inflation factor tests confirm this potential concern. To diagnose the possibility that our estimates are significantly affected by multicollinearity, we use the fact that multicollinearity has the symptom of producing wide swings in parameter estimates with even small changes in data (Greene (2003)). We randomly drop half of our observations and reestimate our main hedge ratio specification in 1,000 simulations. We find that our results are stable, inconsistent with a significant multicollinearity effect.

[29] As our focus is on equity hedge ratios, we allow the equity hedge ratio to vary with firm characteristics. Potentially, Treasury hedge ratios can also vary with these same characteristics. As a robustness check, we add $r_T \times$BE/ME and $r_T \times$Equity vol to our specifications. Furthermore, we include $r_T \times$proportion due prior. The coefficient on $r_E \times$ proportion due prior is 0.0850 (t-stat = 5.13), little changed from our base specifications. The coefficient on $r_T \times$ proportion due prior is -0.1540 (t-stat = -3.48), again consistent with the fact that bonds due later in their issuer's maturity structure are more equity-like and less Treasury-like. The coefficients on $r_T \times$ BE/ME and $r_T \times$ Equity vol are both negative and statistically significant, consistent with Treasury hedge ratios being lower for firms with greater credit risk.

estimated hedge ratios of 0.0606 and 0.0832 for A and Baa bonds (which represent 78% of our bond-month observations) in Table 7, respectively, this is an economically large effect.

Running regressions for only investment-grade (Column (4)) and only speculative-grade (Column (5)) bonds, we continue to find a significant effect of proportion due prior on equity hedge ratios. However, we find that the effect for speculative-grade bonds is not much higher than for investment-grade bonds.[30] Focusing on only noncrisis periods (omitting July 2007 to June 2009) in specification (6), we find a marginally lower, but still economically and statistically significant coefficient on $r_E \times$ proportion due prior, suggesting that our results are not driven solely by the financial crisis.

In panel B of Table 8, we introduce interaction terms between equity returns and firm fixed effects along with the fixed effects themselves. This allows for a firm-specific effect in equity hedge ratios. We find that this has little impact on the marginal effect of proportion due prior on hedge ratios. A bond that is latest in its firm's maturity structure has a hedge ratio that is larger than the earliest bond by 0.0852 (Column (3)).

Throughout this subsection, we have left out liquidity variables. This is because Schaefer and Strebulaev (2008) theoretically and empirically show that the impact of nondefault components of bond prices on hedge ratios is small even even though they have large effects on the levels of prices. Nevertheless, we augment specification (3) of Table 8, panel B with $r_E \times$ Amihud and $r_E \times$ IRC (along with the corresponding level terms) as a robustness check. We find that the coefficient on $r_E \times$ proportion due prior is 0.0752 (t-stat = 3.97), as compared to 0.0852 (t-stat = 4.59) without liquidity controls. Whereas $r_E \times$ Amihud is statistically insignificant, $r_E \times$ IRC is significant with a t-stat of 2.85. A move from the 10th to 90th percentile of IRC (a relatively large move) is associated with a change in hedge ratio of 0.0167, a relatively small effect.[31] Thus, our results (similar to the theoretical arguments in Schaefer and Strebulaev 2008), are consistent with illiquidity playing a relatively minor

[30] This contrasts our findings for yield spreads where the de facto seniority effect is stronger for the speculative-grade subsample. We investigate this difference in Section 3.3.

[31] Further adding $r_E \times$ Amihud vol and $r_E \times$ IRC vol has little effect on our results.

role in hedge ratios. Overall, our results suggest that in addition to yield spreads, there is also a very significant de facto seniority effect in hedge ratios.

3.3 Model versus empirical effect

Though the extended Merton model developed in Section 1 is largely designed to illustrate the intuition of how the de facto seniority affects yield spreads and hedge ratios rather than fully reflect the many complexities of firms' debt structures, here we consider how closely our empirical estimates match the model-implied effects of de facto seniority. Similar to Schaefer and Strebulaev (2008), we are not claiming that simple structural models are precise representations of a firm, but are instead interested in whether such models produce reasonable quantitative approximations.

To calculate model-implied de facto seniority effects, we start with the (σ_v, market leverage, proportion due prior) triplet for each observation in our sample. For each observation, we calculate the model-implied yield spread effect as

$$\frac{f(\sigma_v, \text{mkt lev}, \text{prop due prior} + a) - f(\sigma_v, \text{mkt lev}, \text{prop due prior} - a)}{2a}, \tag{12}$$

where $f(.)$ is a function representing the model yield spread as a function of asset volatility, market leverage, and proportion due prior. Essentially, our goal is to calculate the marginal change in yield spreads for a small change in proportion due prior. Similarly, we calculate a model-implied hedge ratio effect. Appendix D provides additional details of our calculations.

After obtaining a model-implied de facto seniority effect in yield spreads for each observation in our sample, we estimate a seemingly unrelated regression (SUR), which allows for covariances in coefficient estimates across equations,

$$\text{Model estimated yield spread effect}_{it} = \zeta_0 + e_{it} \tag{13}$$

$$\text{Actual yield spread}_{it} = \alpha_j + \beta_1 \text{prop due prior}_{it} + \beta_2 T_{it} + \beta_3 \text{Rating}_{it} + \beta_4 X_{it} + \varepsilon_{it}, \tag{14}$$

where X_{it} is a set of controls. Equation (14) is the same regression from Table 5, but is reestimated together with model-implied yield spread effects to allow for covariances in the parameter estimates across equations. To test the model, we run a Wald test with a null hypothesis that the model-implied effect and empirical effect are equal, $\zeta_0 = \beta_1$. In panel A of Table 9, we report our tests using yield spreads. We consider both the full sample and also investment-grade and junk subsamples because, as we will discuss later, there are reasons to believe that our model will fit investment-grade firms better. As shown in rows (1) to (3), the model is consistently rejected when the full sample is used, regardless of what controls are included in the empirical specification. The empirical estimates of the de facto seniority effect are statistically and economically smaller than the model-implied effect. However, in Columns (4) to (6), we see that for the investment-grade subsample, the model cannot be rejected in two out of three specifications. Rows (7) to (9) show that the model is strongly rejected for the junk bond subsample as p-values are less than 0.01 for all specifications. Thus, despite the fact that empirically the de facto seniority effect is stronger for junk bonds than investment grade bonds, these tests suggest that the relative increase in the de facto seniority effect when going from investment-grade to junk is not nearly large enough as compared to what the extended Merton model predicts.

Similarly, we test model hedge ratios in panel B of Table 9. These tests also show that the model fits better for investment-grade bonds than for junk bonds. In all of the specifications, we see that the model cannot be rejected for investment-grade bonds, whereas the model is strongly rejected for junk bonds. In contrast to the yield spread results, we find that the extended Merton model cannot be rejected for the full sample. The strong rejection of the extended Merton model for junk bonds as compared to its reasonable fit for investment-grade bonds is consistent with complexities in junk bond debt structures that the model is failing to capture. We now turn to discussing some of these complexities, including covenants, firms extremely close to bankruptcy, and risk shifting.

In the extended Merton model, we abstract away from modeling covenants. Covenants on public debt are relatively weak and often are only incurrence covenants (Chava and Roberts (2008) and Maxwell and Shenkman (2010)). Thus, firms can relatively easily avoid violating such covenants in most cases. In our sample, the most common types of covenants are (1) consolidation/merger, (2) negative pledge, and (3) asset sales covenants. Consolidation/merger covenants restrict mergers and should have little direct effect on de facto seniority. Negative pledge covenants prevent secured debt issuance, showing that bondholders are concerned about explicit seniority. Asset sales covenants restrict the use of proceeds when assets are sold (Maxwell and Shenkman (2010)). Typically, proceeds can be used to permanently repay debt or invest in replacement assets. Thus, such covenants explicitly allow firms to sell assets to repay debt, consistent with the extended Merton model where maturing debt is paid off from firm value.[32]

Although bond covenants are unlikely to undo de facto seniority, Rauh and Sufi (2010) show that junk firms are likely to have heterogeneous debt and, in particular, bank debt with tight covenants along with nonbank debt with loose covenants. In contrast, high credit quality firms have little bank debt. More importantly, bank debt often has financial covenants which firms can violate through poor accounting performance even if they are still able to service debt. Common examples include maximum debt-to-EBITDA, minimum interest coverage, and minimum fixed charge coverage ratios. This means that there is likely to be an earlier default trigger. Hence, the combination of the fact that junk firms are much more likely to have bank debt along with the earlier contingent control that bank debt gives to creditors suggests that the empirical effect of de facto seniority is likely to be muted relative to what the extended Merton model suggests.

A second reason for why the empirical effect of de facto seniority for junk firms may be muted relative to the model is what happens when a firm is very close to bankruptcy. The model suggests that as credit quality worsens, the effect of de facto seniority becomes

[32]The only other covenants in at least 20% of our sample are cross acceleration, change of control puts (related to consolidation/merger covenants), and sales leaseback (similar to negative pledge covenants in preventing what is economically similar to secured debt).

stronger. This is true for most levels of credit quality, but once a firm crosses the threshold of being very likely to default in the near future, almost all of the value of its bonds comes from expected recovery. Since recovery in bankruptcy is based on explicit seniority and Guha (2002) shows that explicit priority is usually followed in Chapter 11, de facto seniority no longer applies. In the extended Merton model, this corresponds to cases where K_1, the face value of the first bond, is high enough that the firm is likely to default the first time it has to service a bond. Reality is more complicated as a combination of a shortage of cash flows with an inability to liquidate assets to service debt could lead to default even if a firm's balance sheet suggests that its assets are large enough to service debt. Using the subsample of firm-months where firms have a distance-to-default of less than 1.5 (roughly the 1% of observations closest to default), we find that the relation between yield spreads and proportion due prior is statistically and economically insignificant.[33] Hence, the de facto seniority effect does disappear for the firms most likely to default. To the extent that the model cannot fully and precisely account for the firms that are at the extreme for default probability, the model is likely to significantly overestimate the de facto seniority effect in such cases.

Finally, the model is less likely to fit hedge ratios for junk firms because managers at junk firms may choose to risk shift, decoupling corporate bond returns from equity returns. When managers take actions that affect firm value or the market reassesses a company's expected cash flows, bondholders and equityholders are affected in the same direction. In the extended Merton model, exposure to firm value shocks are what drives the comovement of corporate bonds and equities. Asset volatility, strictly speaking, is a constant in the model. In reality, managers may take risk-shifting actions. Around the period when such an action is taken, equity returns are likely to be positive and bond returns negative. The hedge ratio, estimated over many periods, is then lower compared to what a constant volatility model would suggest. Risk shifting is much more likely to occur in distressed firms (Eisdorfer

[33]The empirical effect is -2 basis points with a t-stat of -0.08.

(2008)), potentially helping to explain why the proportion due prior effect is only slightly higher for junk firms than investment-grade firms when we examine hedge ratios in Table 8, even though the model suggests that hedge ratios should be much higher for junk firms.

Overall, our results suggest that the extended Merton model is a better representation of investment-grade firms than junk firms. Junk firms have more complex capital structures, stricter covenants, extreme observations, and managerial decisions that make our simple extension of the Merton model deviate further from reality than for investment-grade firms. Although the extended Merton model produces de facto seniority effects roughly in line with empirical estimates for investment-grade firms, the model is, of course, not a full representation of all of the complexities of a firm's debt structure. Similar to the results on hedge ratios by Schaefer and Strebulaev (2008), our results show that a relatively simple model can give a first order approximation of an empirical effect.

4 Conclusion

In this paper, we have studied the effect of a bond's place in its issuer's maturity structure on credit risk. Using an extension of the Merton model, we illustrated the mechanism by which a bond that is late in its issuer's maturity structure may have more credit risk than a bond due early in its issuer's maturity structure. The intuition follows from the sequential repayment of debt. Even if a firm is in some financial trouble, it may be able to pay back the first few issues of debt that mature. However, it may be unable to pay back later issues as its credit quality further deteriorates. In reality, the repayment of earlier debt may even put the firm in a more precarious position.

The de facto seniority concept has implications for both the levels of bond prices and returns. Thus, we studied the effects of a bond's place in its issuer's maturity structure on both yield spreads and hedge ratios. Our main empirical finding is that bonds due later in their issuer's maturity structure have both higher yield spreads and higher hedge ratios.

This result is robust to including a series of controls for credit risk, illiquidity, the bond's maturity, and the average maturity of all of the issuer's bonds.

Benchmarking the model-implied de facto seniority effect against our empirical estimates, we found that the extended Merton model is rejected for junk bonds, but is not rejected for investment-grade bonds in most specifications. These results are consistent with the literature showing that the capital structure of junk firms is significantly more complicated than for investment-grade firms. The extended Merton model, largely designed to provide intuition and motivate the de facto seniority effect, deviates more from the complex structure of junk-rated firms. Overall, our results suggest a strong de facto seniority effect in the corporate bond market reflected in both the levels of bond prices and the dynamics of returns.

Table 1. Model yield spreads

A. Merton model

		σ_v						
		0.1	0.15	0.2	0.25	0.3	0.4	0.5
Market leverage	0.1	0.0000	0.0000	0.0033	0.1795	1.8191	23.3688	95.0277
	0.2	0.0000	0.0070	0.5421	5.0495	19.6809	99.2050	262.8057
	0.3	0.0004	0.3458	5.3895	23.9262	62.5342	211.1534	460.5633
	0.4	0.0401	3.2000	21.0989	62.9217	131.9890	353.8877	685.6167
	0.5	0.7336	13.6751	54.1020	126.3897	230.3939	529.3418	943.3421
	0.6	5.1229	39.0175	111.2248	220.3074	363.7037	745.5550	1,245.5468
	0.7	20.7393	89.1734	202.8052	356.0352	544.9413	1,020.0144	1,614.9851

B. Extended Merton model

		σ_v						
		0.1	0.15	0.2	0.25	0.3	0.4	0.5
Market leverage	0.1	0.0000	0.0000	0.0000	0.0000	0.0003	0.2851	6.9545
		0.0000	0.0000	0.0002	0.0370	0.7223	15.6811	75.7137
	0.2	0.0000	0.0000	0.0000	0.0003	0.0296	3.2024	31.0985
		0.0000	0.0005	0.1928	3.2304	16.0604	94.8426	259.9769
	0.3	0.0000	0.0000	0.0000	0.0074	0.2631	10.3957	65.2067
		0.0000	0.1184	4.1320	23.6731	67.4071	234.7669	505.9163
	0.4	0.0000	0.0000	0.0003	0.0521	0.9820	21.1628	102.7301
		0.0053	2.4346	23.6895	77.5608	165.0325	430.6490	802.983
	0.5	0.0000	0.0000	0.0022	0.1861	2.3027	33.6428	138.9410
		0.3388	16.2183	75.1135	177.4995	316.5454	683.2978	1,155.9533
	0.6	0.0000	0.0000	0.0084	0.4244	4.0014	45.6987	170.4882
		5.0106	59.6523	175.7486	337.2298	533.5227	1,007.8228	1,571.5186
	0.7	0.0000	0.0000	0.0188	0.6912	5.5846	55.4812	196.0989
		31.2864	158.1604	348.5061	578.4603	836.3610	1,414.3348	2,063.3007

Panel A reports Merton model yield spreads, where the bond price follows from Equation (2) and yields are calculated from the bond price before the risk-free rate (3%) is subtracted. Panel B reports Merton model yield spreads for the intermediate maturity bond priced in Equation (5). A firm is assumed to have three zero-coupon bonds with maturities $T_1 = 5$, $T_2 = 7$, and $T_3 = 10$. For each market leverage-asset volatility combination, the face values of the three bond issues, K_1, K_2, and K_3, are chosen to match the market leverage. The top number for each market leverage-asset volatility combination corresponds to 10% of the market value being attributable to the short maturity bond, 10% to the intermediate maturity bond, and 80% to the long maturity bond. In this case, most of the firm's debt is due after the intermediate bond, so the intermediate bond is de facto senior. The bottom number corresponds to 80% attributable to the short maturity bond, 10% to the intermediate maturity bond, and 10% to the long maturity bond. In this case, the intermediate bond is de facto junior. Yield spreads are reported in basis points.

Table 2. Model hedge ratios

A. Merton model

		σ_v						
		0.1	0.15	0.2	0.25	0.3	0.4	0.5
Market leverage	0.1	0.0000	0.0000	0.0018	0.0621	0.4412	3.2324	8.4878
	0.2	0.0000	0.0042	0.1898	1.1643	3.2411	9.6727	17.1089
	0.3	0.0003	0.1437	1.3279	3.9790	7.5999	15.7851	23.6740
	0.4	0.0243	0.9330	3.7700	7.8166	12.2781	21.0071	28.7355
	0.5	0.2987	2.8144	7.1155	11.9300	16.6855	25.3360	32.6755
	0.6	1.3750	5.6615	10.8029	15.8607	20.5773	28.8424	35.7118
	0.7	3.5755	9.0054	14.3865	19.3400	23.8277	31.5562	37.9315

B. Extended Merton model

		σ_v						
		0.1	0.15	0.2	0.25	0.3	0.4	0.5
Market leverage	0.1	0.0000	0.0000	0.0000	0.0000	0.0002	0.0695	1.0461
		0.0000	0.0000	0.0001	0.0174	0.2339	2.7979	8.4882
	0.2	0.0000	0.0000	0.0000	0.0001	0.0099	0.5905	3.5871
		0.0000	0.0004	0.0917	0.9799	3.3836	11.3312	20.1151
	0.3	0.0000	0.0000	0.0000	0.0028	0.0696	1.5494	6.1945
		0.0000	0.0679	1.3394	4.9732	10.0149	20.4587	29.3097
	0.4	0.0000	0.0000	0.0001	0.0159	0.2121	2.6408	8.3368
		0.0047	0.9530	5.3511	11.6261	17.8715	28.2927	36.0544
	0.5	0.0000	0.0000	0.0008	0.0467	0.4153	3.6005	9.8621
		0.1952	4.3125	11.9132	19.2059	25.2896	34.3312	40.6166
	0.6	0.0000	0.0000	0.0026	0.0888	0.6138	4.2703	10.7585
		1.8473	10.6608	19.5015	26.2566	31.3300	38.3678	43.1563
	0.7	0.0000	0.0000	0.0048	0.1226	0.7392	4.5833	11.0669
		7.0904	18.6201	26.5155	31.6959	35.2889	40.1597	43.7222

Panel A reports hedge ratios for the Merton model, $\frac{\partial \ln B}{\partial \ln E}$. The Merton hedge ratio follows from Equation (3). Panel B reports extended Merton model hedge ratios. Parameters are from Table 1. Hedge ratios are reported in percentage.

Table 3. Bond summary statistics

	A. Yield spread sample								
	All bonds			Investment grade			Speculative grade		
Bonds	9,382			8,587			2,205		
Bond-months	301,291			261,372			39,919		
	Mean	Med	SD	Mean	Med	SD	Mean	Med	SD
Yield spread	1.81	1.33	1.57	1.50	1.18	1.21	3.83	3.45	2.08
Time-to-maturity	9.37	5.84	9.97	9.57	5.93	10.08	8.07	5.41	9.11
Age	4.86	3.83	4.00	4.73	3.70	3.95	5.74	4.82	4.20
Prop due prior	0.41	0.39	0.29	0.41	0.39	0.29	0.38	0.35	0.30
Amount out	554.11	400.00	553.08	578.38	400.00	572.68	395.20	300.00	363.68
Coupon	6.01	6.10	1.60	5.84	5.95	1.57	7.10	7.13	1.34
Rating	7.95	8.00	2.83	7.22	8.00	2.20	12.73	12.00	1.59
Amihud	1.17	0.53	1.78	1.12	0.51	1.72	1.47	0.63	2.11
Amihud vol	1.68	1.10	1.80	1.62	1.07	1.74	2.05	1.39	2.08
IRC	0.28	0.19	0.28	0.27	0.18	0.27	0.36	0.27	0.30
IRC vol	0.28	0.20	0.26	0.26	0.19	0.25	0.34	0.25	0.29
	B. Hedge ratio sample								
	All bonds			Investment grade			Speculative grade		
Bonds	7,373			6,611			1,614		
Bond-months	239,862			208,317			31,545		
	Mean	Med	SD	Mean	Med	SD	Mean	Med	SD
Bond return	0.50	0.38	2.70	0.47	0.35	2.52	0.69	0.67	3.67
Time-to-maturity	9.34	5.96	9.57	9.51	5.97	9.69	8.22	5.75	8.64
Age	4.46	3.49	3.75	4.32	3.35	3.68	5.40	4.51	4.04
Prop due prior	0.42	0.40	0.29	0.42	0.40	0.28	0.40	0.37	0.29
Amount out	628.00	500.00	576.11	655.40	500.00	596.35	447.06	350.00	370.82
Coupon	5.97	6.00	1.61	5.79	5.90	1.57	7.19	7.25	1.28
Rating	7.95	8.00	2.82	7.22	8.00	2.19	12.75	12.00	1.59

This table reports bond characteristics for our sample. Panel A reports the bonds in our yield spread analysis and panel B the bonds in our hedge ratio analysis. The mean, median, and standard deviations are reported for the whole sample, the investment grade subsample, and the speculative grade subsample. The number of bonds in the investment grade plus speculative grade subsamples is greater than the total number of bonds because some bonds are investment grade for part of the sample and speculative grade for part of the sample. *Yield spread* is the difference between the yield of a bond and a Treasury with similar maturity from the Constant Maturity Treasury (CMT) series in percentage. *Time-to-maturity* is reported in years. *Age* is the number of years since issuance. *Prop due prior* is the proportion of an issuer's face value of debt due prior to a particular bond. *Amount out* is the face value outstanding in $mm. *Coupon* is the coupon rate in percentage. *Rating* is a bond's rating where Aaa=1 and C=21, with intermediate ratings also coded. *Amihud*, *Amihud vol*, *IRC*, and *IRC vol* are the Amihud measure, the volatility of the Amihud measure, implied round-trip cost, and the volatility of implied round-trip cost, respectively. All four are calculated following Dick-Nielsen, Feldhutter, and Lando (2012), but scaled by 100. *Bond return* is the monthly log return of a bond in percentage.

Table 4. Firm summary statistics

	A. Yield spread sample								
	All firms			Investment grade			Speculative grade		
Firms	757			643			290		
Firm-months	53,900			44,087			11,015		
Observations	301,291			261,372			39,919		
	Mean	Med	SD	Mean	Med	SD	Mean	Med	SD
Equity market cap	46.44	21.09	64.77	52.20	25.72	67.62	8.65	5.90	8.91
Equity vol	29.64	25.76	14.82	28.00	24.50	13.54	40.44	36.35	17.97
Pseudo-leverage	32.89	29.48	19.87	30.25	26.90	18.17	50.16	49.13	21.72
BE/ME	0.51	0.44	0.34	0.48	0.42	0.30	0.75	0.62	0.51
Firm maturity	10.58	10.37	4.16	10.79	10.62	4.19	9.18	9.01	3.66
	B. Hedge ratio sample								
	All firms			Investment grade			Speculative grade		
Firms	734			617			273		
Firm-months	48,483			39,662			9,785		
Observations	239,862			208,317			31,545		
	Mean	Med	SD	Mean	Med	SD	Mean	Med	SD
Equity return	0.78	1.26	9.03	0.86	1.29	8.10	0.22	0.96	13.65
Equity market cap	47.04	22.51	62.92	52.84	27.12	65.49	8.66	5.81	9.18
Equity vol	29.90	25.92	15.03	28.27	24.73	13.70	40.64	36.16	18.57
Pseudo-leverage	32.03	28.91	18.92	29.40	26.34	17.27	49.39	49.02	20.17
BE/ME	0.50	0.44	0.33	0.47	0.42	0.29	0.72	0.61	0.47
Firm maturity	10.58	10.38	4.14	10.80	10.65	4.15	9.13	8.80	3.72

This table reports firm characteristics for our sample. Panel A reports firms in our yield spread analysis and panel B the firms in our hedge ratio analysis. *Equity market cap* is the equity market capitalization in \$bn. *Equity vol* is the volatility of a firm's equity using daily log returns over the past year, annualized in percentage. *Pseudo-leverage* is the sum of debt in current liabilities (DLC) and Long-Term Debt (DLTT) divided by DLC + DLTT + equity market cap. *BE/ME* is the book value of equity divided by the market value of equity like in Asness and Frazzini (2013). *Equity return* is the monthly log equity return in percentage. Note that the sum of investment grade and speculative grade firm-months is slightly higher than total firm months because, in rare cases, a firm may have both an investment grade and speculative grade bond.

Table 5. Yield spreads

A. Without firm fixed effects								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full	Full	Full	Full	Full	IG	Junk	No crisis
Proportion due prior	0.95	0.81	0.70	0.48	0.42	0.34	0.74	0.50
	[5.49]	[6.57]	[7.07]	[6.74]	[5.84]	[5.35]	[5.60]	[7.35]
T	-0.0054	-0.0004	0.0039	0.0037	0.0041	0.0078	-0.0013	0.0058
	[-0.98]	[-0.10]	[1.58]	[1.87]	[1.90]	[4.11]	[-0.28]	[2.81]
Rating	0.30	0.21	0.21	0.22	0.22	0.15	0.29	0.21
	[9.70]	[8.40]	[8.62]	[10.87]	[11.12]	[9.29]	[7.61]	[11.01]
BE/ME		1.02	1.04	0.87	0.81	0.70	0.97	0.72
		[5.44]	[5.50]	[7.26]	[8.04]	[7.64]	[6.74]	[6.16]
Equity vol		0.0300	0.0292	0.0262	0.0252	0.0184	0.0160	0.0220
		[11.39]	[11.45]	[11.02]	[10.19]	[8.67]	[2.50]	[8.88]
Firm T			-0.01	-0.02	-0.02	-0.01	0.00	-0.01
			[-2.33]	[-3.06]	[-3.23]	[-2.30]	[0.18]	[-2.29]
Amihud				0.06	0.05	0.05	0.08	0.08
				[4.38]	[2.77]	[4.35]	[2.88]	[3.66]
IRC				0.74	0.90	0.77	0.73	0.87
				[13.65]	[10.56]	[9.79]	[4.98]	[9.64]
Amihud vol					0.04	0.03	0.07	0.04
					[6.99]	[5.89]	[5.59]	[5.36]
IRC vol					-0.03	-0.06	0.21	0.01
					[-0.48]	[-1.50]	[1.51]	[0.19]
R^2	0.62	0.71	0.71	0.74	0.75	0.72	0.73	0.68
Observations	301,270	293,499	293,499	240,037	201,233	175,385	25,848	168,117

B. With firm fixed effects								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full	Full	Full	Full	Full	IG	Junk	No crisis
Proportion due prior	0.70	0.67	0.66	0.54	0.48	0.47	0.85	0.57
	[12.33]	[11.70]	[11.49]	[10.72]	[9.46]	[11.32]	[6.53]	[10.95]
T	0.0045	0.0060	0.0062	0.0063	0.0071	0.0070	0.0059	0.0084
	[3.89]	[5.85]	[6.46]	[5.59]	[5.70]	[5.93]	[1.76]	[6.28]
Rating	0.27	0.20	0.20	0.21	0.21	0.12	0.23	0.20
	[9.48]	[9.52]	[9.56]	[9.91]	[9.89]	[9.59]	[5.39]	[8.45]
BE/ME		1.20	1.20	1.14	1.12	1.02	1.10	0.97
		[11.00]	[11.01]	[12.49]	[13.06]	[9.72]	[9.16]	[9.17]
Equity vol		0.0326	0.0326	0.0310	0.0302	0.0227	0.0214	0.0265
		[10.14]	[10.04]	[10.21]	[9.91]	[7.47]	[3.99]	[8.84]
Firm T			-0.00	-0.01	-0.01	0.00	0.03	-0.00
			[-0.27]	[-0.95]	[-1.21]	[0.26]	[1.73]	[-0.61]
Amihud				0.03	0.03	0.04	0.03	0.05
				[5.12]	[3.05]	[5.07]	[2.78]	[4.26]
IRC				0.40	0.51	0.46	0.36	0.48
				[10.81]	[8.91]	[7.84]	[3.95]	[7.64]
Amihud vol					0.02	0.02	0.05	0.02
					[6.18]	[4.99]	[5.74]	[5.00]
IRC vol					-0.04	-0.06	0.18	-0.01
					[-0.93]	[-1.82]	[2.47]	[-0.19]
R^2	0.76	0.80	0.80	0.82	0.83	0.79	0.82	0.79
Observations	301,270	293,499	293,499	240,037	201,233	175,385	25,848	168,117

The dependent variable in this table is yield spread in percentage. Panel A reports results without firm fixed effects, and panel B includes firm fixed effects. All regressions include time fixed effects to control for time-varying macroeconomic conditions. *Proportion due prior* is the proportion of the face value of an issuer's debt due before a bond, expressed in decimals. T is the time-to-maturity in years. *Rating* is Moody's rating coded as Aaa=1 and C=21, with intermediate ratings coded. *BE/ME* is book equity divided by market equity for the bond issuer, expressed in decimals. *Equity vol* is an annualized equity volatility calculated from daily returns in the last year in percentage. *Firm T* is the weighted-average time-to-maturity of all of the issuer's bonds outstanding, weighted by amount outstanding. *Amihud*, *Amihud vol*, *IRC*, and *IRC vol* are the Amihud measure, the volatility of the Amihud measure, implied round-trip cost, and the volatility of implied round-trip cost, respectively. All four are calculated following Dick-Nielsen, Feldhutter, and Lando (2012), but scaled by 100. t-stats are in brackets and use standard errors two-way clustered by firm and time.

Table 6. Matched sample analysis

	(1)	(2)	(3)	(4)
Prop due prior$_{jt}$ - Prop due prior$_{it}$	0.86	0.81	1.06	1.04
	[2.91]	[3.01]	[2.27]	[2.38]
T$_{jt}$ - T$_{it}$	-0.03	-0.21	0.03	-0.21
	[-0.12]	[-1.38]	[0.13]	[-1.07]
Rating$_{jt}$ - Rating$_{it}$	0.21	0.23	0.19	0.21
	[3.11]	[3.63]	[2.62]	[3.65]
Amihud$_{jt}$ - Amihud$_{it}$	0.03	0.04	0.01	0.01
	[3.24]	[3.08]	[0.81]	[1.06]
IRC$_{jt}$ - IRC$_{it}$	0.12	0.23	0.16	0.23
	[5.11]	[5.02]	[5.88]	[2.98]
Amihud vol$_{jt}$ - Amihud vol$_{it}$		0.02		0.01
		[1.88]		[1.64]
IRC vol$_{jt}$ - IRC vol$_{it}$		-0.04		0.01
		[-0.56]		[0.14]
R^2	0.06	0.11	0.02	0.04
Observations	44,283	25,576	19,365	11,969

The sample in this table consists of matched pairs of bonds from the same issuer, with yield spreads measured in the same month. Paired bonds mature within 90 days of each other to minimize differential maturity effects. The dependent variable is the yield spread of the longer maturity bond minus the yield spread of the shorter maturity bond. The independent variables are similarly differences in variables, where *Prop due prior*, *T*, *Rating*, *Amihud*, *IRC*, *Amihud vol*, and *IRC vol* are defined in Table 5. In the first two columns, we match only on maturity (within firm-month). In Columns (3) and (4), we also restrict the matched bonds to have similar *Amihud* and *IRC*. Regressions include time fixed effects. t-stats are in brackets and use standard errors two-way clustered by firm and time.

Table 7. Hedge ratios, baseline

A. Baseline hedge ratio regressions

	(1) Full	(2) IG	(3) Junk
r_E	0.0153	0.0106	0.0551
	[0.87]	[0.70]	[1.08]
r_T	1.0142	0.9133	0.7393
	[14.96]	[15.53]	[3.97]
$r_E \times$ Rating	0.0075	0.0082	0.0045
	[7.39]	[3.46]	[1.37]
$r_T \times$ Rating	-0.0692	-0.0538	-0.0572
	[-9.21]	[-7.46]	[-4.04]
Rating	0.0005	0.0003	0.0005
	[4.16]	[2.46]	[2.32]
Constant	-0.0006	0.0005	0.0001
	[-0.81]	[0.93]	[0.04]
R^2	0.2440	0.2650	0.1845
Observations	239,837	208,294	31,543

B. Estimated hedge ratios

Rating	Aaa	Aa	A	Baa	Ba	B
Column (1)						
h_E	0.0229	0.0380	0.0606	0.0832	0.1058	0.1284
t-stat	1.34	2.38	4.11	5.89	7.48	8.67
h_T	0.9450	0.8067	0.5992	0.3917	0.1841	-0.0234
t-stat	15.03	14.71	12.14	7.30	2.80	-0.28
Columns (2) & (3)						
h_E	0.0188	0.0352	0.0598	0.0844	0.1088	0.1222
t-stat	1.35	2.84	4.50	4.86	7.08	10.94
h_T	0.8595	0.7520	0.5907	0.4295	0.0530	-0.1186
t-stat	15.67	15.31	12.31	7.68	0.73	-1.43

Panel A reports regressions where the dependent variable is log corporate bond returns in decimals. r_E is the log equity return of the same issuer as the corporate bond and r_T is the log Treasury bond return of a Treasury bond with the same maturity as the corporate bond. Both r_E and r_T are expressed in decimals. *Rating* is Moody's rating coded as Aaa=1 and C=21, with intermediate ratings coded. Panel B uses the estimated coefficients in panel A to estimate hedge ratios. In particular, $h_E = \hat{\beta}_E + \hat{\beta}_{E,rat} \times$ Rating, where β_E is the coefficient on r_E and $\beta_{E,rat}$ is the coefficient on $r_E \times$ Rating. The standard error of h_E uses the variance-covariance matrix from the regressions in panel A and is calculated as SD($\hat{\beta}_E + \hat{\beta}_{E,rat} \times$ Rating). Similarly, $h_T = \hat{\beta}_T + \hat{\beta}_{T,rat} \times$ Rating. t-stats are in brackets and use standard errors two-way clustered by firm and time.

Table 8. Hedge ratios

A. Without firm fixed effects						
	(1)	(2)	(3)	(4)	(5)	(6)
	Full	Full	Full	IG	Junk	No crisis
$r_E \times$ Prop due prior	0.0791	0.0716	0.0861	0.0829	0.0994	0.0693
	[5.97]	[5.74]	[5.28]	[4.06]	[5.21]	[5.95]
r_E	-0.0385	-0.0492	-0.0693	-0.0714	-0.0297	-0.0863
	[-3.22]	[-3.59]	[-5.48]	[-3.79]	[-0.51]	[-6.20]
r_T	1.0112	1.0161	1.0143	0.9124	0.7932	0.9688
	[15.01]	[15.07]	[15.04]	[15.30]	[3.97]	[17.85]
$r_E \times$ T	0.0015	0.0018	0.0012	0.0017	-0.0008	0.0017
	[2.62]	[3.42]	[3.10]	[4.38]	[-0.83]	[4.10]
$r_E \times$ Rating	0.0085	0.0059	0.0061	0.0051	0.0046	0.0044
	[8.13]	[4.23]	[4.23]	[2.20]	[1.19]	[4.01]
$r_E \times$ BE/ME		0.0314	0.0313	0.0427	0.0192	0.0578
		[2.24]	[2.25]	[2.78]	[1.23]	[6.20]
$r_E \times$ Equity vol		0.0274	0.0307	0.0257	0.0361	0.0454
		[0.94]	[1.05]	[0.74]	[0.92]	[1.30]
$r_E \times$ Firm T			0.0016	0.0017	0.0016	0.0016
			[1.78]	[1.91]	[1.22]	[1.85]
$r_T \times$ Rating	-0.0671	-0.0676	-0.0673	-0.0516	-0.0610	-0.0513
	[-8.81]	[-8.60]	[-8.52]	[-7.05]	[-3.89]	[-7.12]
Prop due prior	0.0012	0.0003	0.0009	0.0012	0.0002	0.0016
	[1.57]	[0.50]	[0.94]	[1.16]	[0.11]	[2.01]
T	-0.0000	0.0000	-0.0000	-0.0000	0.0000	-0.0000
	[-0.10]	[0.34]	[-0.25]	[-0.58]	[0.73]	[-0.47]
Rating	0.0005	-0.0000	-0.0000	-0.0000	-0.0001	0.0002
	[4.08]	[-0.16]	[-0.13]	[-0.04]	[-0.23]	[1.71]
BE/ME		0.0022	0.0021	0.0016	0.0030	0.0006
		[2.19]	[2.12]	[1.39]	[1.99]	[0.93]
Equity vol		0.0248	0.0248	0.0251	0.0241	0.0174
		[4.43]	[4.42]	[4.31]	[3.51]	[4.96]
Firm T			0.0001	0.0001	0.0001	0.0000
			[1.14]	[1.06]	[1.08]	[1.39]
Constant	-0.0011	-0.0054	-0.0061	-0.0060	-0.0062	-0.0046
	[-1.56]	[-3.97]	[-3.60]	[-3.07]	[-2.00]	[-4.14]
R^2	0.2573	0.2845	0.2850	0.3076	0.2218	0.3604
Observations	239,837	233,706	233,706	205,055	28,651	194,822

B. With firm fixed effects						
	(1)	(2)	(3)	(4)	(5)	(6)
	Full	Full	Full	IG	Junk	No crisis
r_E × Prop due prior	0.0732	0.0721	0.0852	0.0856	0.0881	0.0742
	[4.73]	[4.69]	[4.59]	[4.22]	[4.01]	[6.44]
r_T	1.0109	1.0142	1.0144	0.9116	0.8100	0.9710
	[15.15]	[15.50]	[15.51]	[15.52]	[4.00]	[17.90]
r_E × T	0.0018	0.0019	0.0015	0.0017	0.0006	0.0019
	[5.34]	[5.40]	[4.33]	[4.10]	[1.06]	[4.52]
r_E × Rating	-0.0002	-0.0007	-0.0004	0.0004	-0.0039	0.0017
	[-0.08]	[-0.29]	[-0.18]	[0.15]	[-0.70]	[0.52]
r_E × BE/ME		0.0269	0.0283	0.0364	0.0253	0.0425
		[1.51]	[1.65]	[1.46]	[1.64]	[2.96]
r_E × Equity vol		0.0013	0.0006	-0.0141	0.0124	0.0084
		[0.04]	[0.02]	[-0.36]	[0.28]	[0.21]
r_E × Firm T			0.0063	0.0056	0.0092	0.0044
			[2.73]	[2.80]	[1.80]	[3.19]
r_T × Rating	-0.0671	-0.0670	-0.0670	-0.0511	-0.0622	-0.0517
	[-8.91]	[-8.67]	[-8.67]	[-7.24]	[-3.89]	[-7.32]
Prop due prior	0.0016	0.0012	0.0011	0.0012	0.0015	0.0016
	[1.62]	[1.23]	[1.02]	[1.11]	[0.89]	[1.78]
T	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	[-0.75]	[-0.43]	[-0.39]	[-0.52]	[-0.13]	[-0.64]
Rating	0.0010	0.0004	0.0004	0.0002	0.0002	0.0005
	[5.72]	[2.18]	[2.12]	[1.41]	[0.54]	[2.68]
BE/ME		0.0049	0.0048	0.0047	0.0051	0.0025
		[2.13]	[2.10]	[1.92]	[1.71]	[1.73]
Equity vol		0.0312	0.0313	0.0323	0.0279	0.0224
		[4.61]	[4.62]	[4.44]	[3.45]	[4.78]
Firm T			-0.0000	-0.0001	0.0001	-0.0000
			[-0.50]	[-0.65]	[0.16]	[-0.33]
R^2	0.2877	0.3167	0.3176	0.3363	0.2784	0.3946
Observations	239,837	233,706	233,706	205,055	28,651	194,822

The dependent variable in this table is log corporate bond returns in decimals. r_E is the log equity return of the same issuer as the corporate bond and r_T is the log Treasury bond return of a Treasury bond with the same maturity as the corporate bond. Both r_E and r_T are expressed in decimals. *Proportion due prior* is the proportion of the face value of an issuer's debt due before a bond, expressed in decimals. *T* is the time-to-maturity in years. *Rating* is Moody's rating coded as Aaa=1 and C=21, with intermediate ratings coded. *BE/ME* is book equity divided by market equity for the bond issuer, expressed in decimals. *Equity vol* is an annualized equity volatility calculated from daily returns in the last year in decimals. *Firm T* is the weighted-average time-to-maturity of all of the issuer's bonds outstanding, weighted by amount outstanding. t-stats are in brackets and use standard errors two-way clustered by firm and time.

Table 9. Model versus empirical estimates

A. Yield spreads

		Model		Empirical			Model test	
		Avg	SE	Coeff	SE	Controls	χ^2	p
(1)	Full	1.1253	0.1678	0.7001	0.0567	T, Rating, time FE, firm FE	5.5384	0.0186
(2)	Full	1.0993	0.1679	0.6625	0.0576	(1) + BE/ME, Eq vol, Firm T	5.5009	0.0190
(3)	Full	1.1811	0.1733	0.4773	0.0504	(2) + Liquidity	13.4658	0.0002
(4)	IG	0.8110	0.1453	0.6448	0.0537	T, Rating, time FE, firm FE	1.3180	0.2509
(5)	IG	0.8110	0.1458	0.6229	0.0521	(4) + BE/ME, Eq vol, Firm T	1.5843	0.2081
(6)	IG	0.8467	0.1442	0.4670	0.0412	(5) + Liquidity	6.1588	0.0131
(7)	Junk	3.1838	0.4155	0.9848	0.1280	T, Rating, time FE, firm FE	20.3059	0.0000
(8)	Junk	3.1345	0.4391	1.1060	0.1481	(7) + BE/ME, Eq vol, Firm T	14.6705	0.0001
(9)	Junk	3.4480	0.4493	0.8510	0.1292	(8) + Liquidity	25.1677	0.0000

B. Hedge ratios

		Model		Empirical			Model test	
		Avg	SE	Coeff	SE	Controls (interacted with r_E)	χ^2	p
(1)	Full	0.0820	0.0082	0.0732	0.0154	T, Rating, firm FE	0.2601	0.6100
(2)	Full	0.0800	0.0081	0.0852	0.0185	(1) + BE/ME, Eq vol, Firm T	0.0660	0.7972
(3)	Full	0.0831	0.0082	0.0704	0.0159	(2) + Liquidity	0.5147	0.4731
(4)	IG	0.0659	0.0079	0.0735	0.0171	T, Rating, firm FE	0.1792	0.6720
(5)	IG	0.0658	0.0080	0.0856	0.0202	(4) + BE/ME, Eq vol, Firm T	0.8850	0.3468
(6)	IG	0.0674	0.0080	0.0665	0.0213	(5) + Liquidity	0.0019	0.9657
(7)	Junk	0.1886	0.0150	0.0777	0.0179	T, Rating, firm FE	21.1105	0.0000
(8)	Junk	0.1818	0.0137	0.0881	0.0218	(7) + BE/ME, Eq vol, Firm T	12.0823	0.0005
(9)	Junk	0.1924	0.0137	0.0832	0.0130	(8) + Liquidity	33.3422	0.0000

This table compares extended Merton model-implied yield spreads and hedge ratio effects with empirically estimated effects. Panel A considers yield spreads and panel B hedge ratios. The model columns display the average effect after calculating observation-by-observation model effects and the standard error is for the average. The empirical columns have estimates that correspond to the coefficient on proportion due prior in the yield spread regressions and $r_E \times$ proportion due prior in the hedge ratio regressions. For the hedge ratio regressions, the controls include both interaction terms with r_E and also the controls on their own. The last two columns present the results of Wald test for which the null hypothesis is that the model and empirical effects are equal. Standard errors are two-way clustered by firm and time.

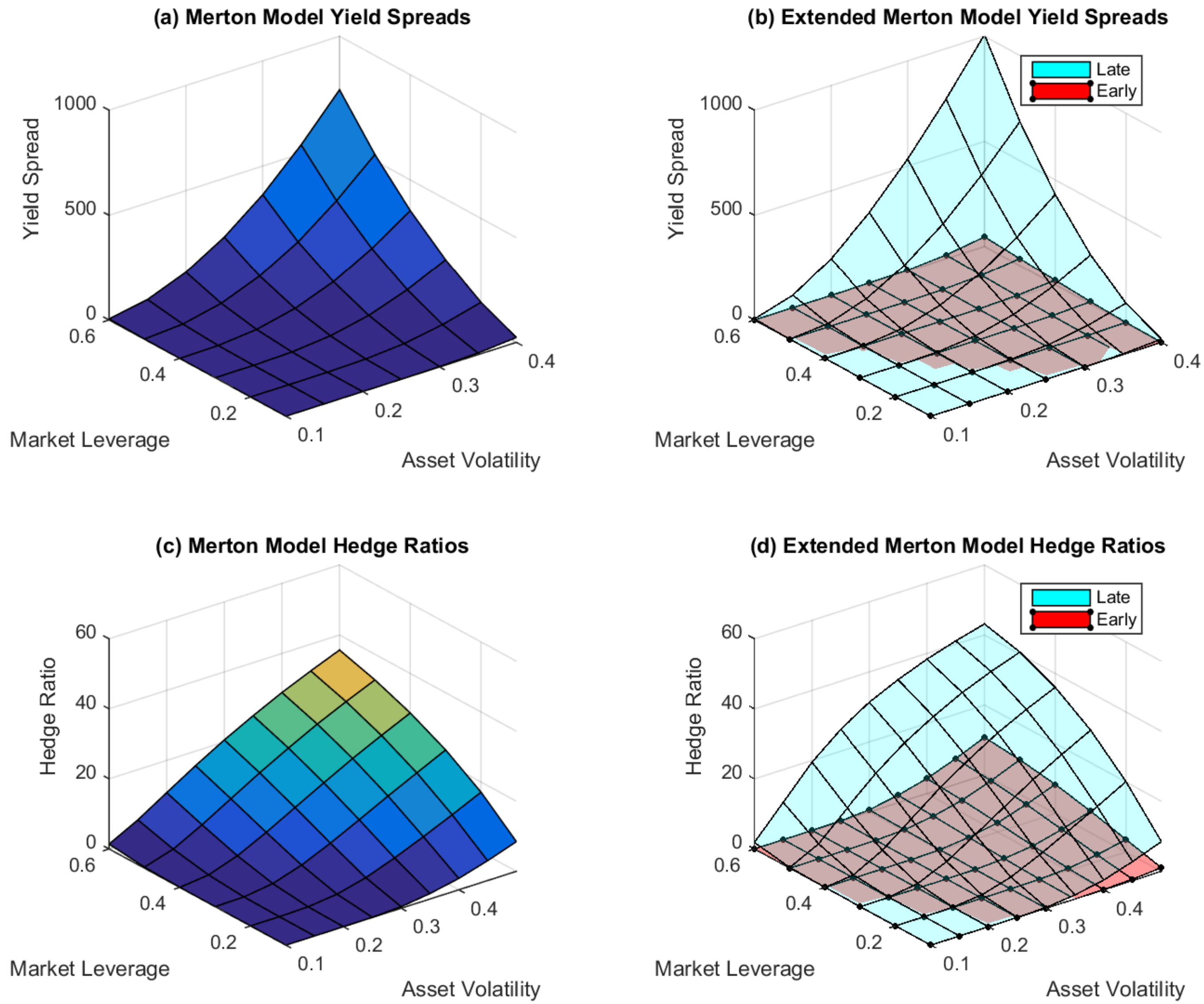

Figure 1. Yield spreads and hedge ratios for the Merton and extended Merton models. The cyan surfaces represent the case in which a bond is late in its firm's maturity structure and the red surfaces with point markers represent the case in which a bond is early in its firm's maturity structure (B and D).

Appendix

A Extending the Merton Model

In our extension of the Merton model, the firm has three zero-coupon bond issues with face values K_1, K_2, and K_3, and maturities $T_1 < T_2 < T_3$. All of the bonds share the same seniority. For example, suppose that the firm defaults prior to T_1. The proportion of the total recovered value of the firm paid to bond 1 is $\frac{K_1}{K_1+K_2+K_3}$. In addition, we also allow for a proportion L of the residual firm value to be lost in bankruptcy. That is, if the value of the firm at default is $V_{default}$, the proportion payable to bondholders is $(1-L)V_{default}$.

A.1 Equity Value

$$E = E_0^Q \left[e^{-rT_3} \mathbb{1}_{V_1>K_1} \mathbb{1}_{V_2>K_2} \mathbb{1}_{V_3>K_3} \left(V_3 - K_3\right) \right]$$

The firm value process is lognormal

$$V_1 = V_0 \exp \left[\left(r - \frac{1}{2}\sigma_v^2 \right) T_1 + \sigma_v \sqrt{T_1} w_1 \right], \tag{A.1}$$

where $w_1 \sim N(0,1)$.

Similarly,

$$V_2 = (V_1 - K_1) \exp \left[\left(r - \frac{1}{2}\sigma_v^2 \right) (T_2 - T_1) + \sigma_v \sqrt{T_2 - T_1} w_2 \right]$$

if $V_1 > K_1$

and

$$V_3 = (V_2 - K_2) \exp \left[\left(r - \frac{1}{2}\sigma_v^2 \right) (T_3 - T_2) + \sigma_v \sqrt{T_3 - T_2} w_3 \right]$$

if $V_2 > K_2$.

In particular, note that if the firm is solvent at T_i, then K_i is paid out of firm value for the maturing bond.

After some algebra, it can be shown that

$$E = \frac{e^{-rT_2}}{2\pi}\int_{-d_2}^{\infty}\int_{-\tilde{d}_2}^{\infty}\exp\left(-\frac{1}{2}z_2^2-\frac{1}{2}z_1^2\right)(V_2-K_2)N\left(\tilde{\tilde{d}}_1\right)dz_2dz_1 \tag{A.2}$$
$$-K_3\frac{-e^{-rT_3}}{2\pi}\int_{-d_2}^{\infty}\int_{-\tilde{d}_2}^{\infty}\exp\left(-\frac{1}{2}z_2^2-\frac{1}{2}z_1^2\right)N\left(\tilde{\tilde{d}}_2\right)dz_2dz_1,$$
$$\text{where } \tilde{\tilde{d}}_2 = \frac{\ln\left(\frac{V_2-K_2}{K_3}\right)+\left(r-\frac{1}{2}\sigma_v^2\right)(T_3-T_2)}{\sigma_v\sqrt{T_3-T_2}}, \tilde{\tilde{d}}_1 = \tilde{\tilde{d}}_2+\sigma_v\sqrt{T_3-T_2}$$
$$\text{and } \tilde{d}_2 = \frac{\ln\left(\frac{V_1-K_1}{K_2}\right)+\left(r-\frac{1}{2}\sigma_v^2\right)(T_2-T_1)}{\sigma_v\sqrt{T_2-T_1}}.$$

A.2 Bond Value

Our focus is on the intermediate bond with maturity T_2 and face value K_2. The price of this bond can be written as the sum of three expectations, which correspond to (1) solvency at T_2, (2) default at T_1, and (3) default at T_2. The value of each of these pieces corresponds to

1. $E_0^Q\left[e^{-rT_2}\mathbb{1}_{V_1>K_1}\mathbb{1}_{V_2>K_2}K_2\right]$;
2. $E_0^Q\left[e^{-rT_1}\mathbb{1}_{V_1<K_1}(1-L)V_1\frac{K_2}{K_1+K_2+K_3}\right]$; and
3. $E_0^Q\left[e^{-rT_2}\mathbb{1}_{V_1>K_1}\mathbb{1}_{V_2<K_2}(1-L)V_2\frac{K_2}{K_2+K_3}\right]$.

After some algebra, it can be shown that the three pieces are

1. $K_2\frac{e^{-rT_2}}{\sqrt{2\pi}}\int_{-d_2}^{\infty}\exp\left(-\frac{1}{2}z_1^2\right)N\left(\tilde{d}_2\right)dz_1$;
2. $V_0(1-L)\frac{K_2}{K_1+K_2+K_3}N(-d_1)$; and
3. $\frac{K_2(1-L)e^{-rT_1}}{(K_2+K_3)\sqrt{2\pi}}\int_{-d_2}^{\infty}\exp\left(-\frac{1}{2}z_1^2\right)(V_1-K_1)N\left(-\tilde{d}_1\right)dz_1$.

Corporate bond yields can then be calculated from prices and yield spreads are attained from subtracting off the relevant Constant Maturity Treasury yield.

A.3 Hedge Ratios

In principle, numerical partial derivatives can be calculated once we have bond prices. However, in our implementation of the extended Merton model, we find that numerical partial derivatives calculated for prices that are determined though numerical integration can become quite imprecise. Thus, we apply Leibniz's rule to first calculate partial derivatives as functions of integrals (much like the bond prices themselves) before numerically integrating. In particular, the three pieces of the partial derivative of the bond price (from A.2) with respect to firm value ($\partial B/\partial V$) are

1. $K_2 e^{-rT_2} \int_{-d_2}^{\infty} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{1}{2}z_1^2\right) n\left(\tilde{d}_2\right) \frac{V_1}{V_0} \frac{1}{(V_1-K_1)\sigma_v\sqrt{T_2-T_1}} dz_1$;
2. $\frac{(1-L)K_2 N(-d_1)}{K_1+K_2+K_3} - \frac{(1-L)K_2 n(-d_1)}{(K_1+K_2+K_3)\sigma_v\sqrt{T_1}}$; and
3. $\frac{(1-L)K_2 e^{-rT_1}}{K_2+K_3}\left[\int_{-d_2}^{\infty} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{1}{2}z_1^2\right) \frac{V_1}{V_0} N\left(-\tilde{d}_1\right) dz_1 - \int_{-d_2}^{\infty} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{1}{2}z_1^2\right) \frac{(V_1-K_1)n(-\tilde{d}_1)V_1}{\sigma_v\sqrt{T_2-T_1}(V_1-K_1)V_0} dz_1\right]$.

The hedge ratio can then be calculated by taking $\frac{\partial B}{\partial V}\frac{V}{B}$ and dividing by the numerically calculated $\frac{\partial E}{\partial V}\frac{V}{E}$.

B Other Models

B.1 Geske Model

The extended Merton model in Section 1 and Appendix A is based on the assumption that upon bond maturity, the face value of the bond is paid out of the value of the firm. There is no explicit choice for equityholders to make (though given the choice, they would always choose to continue the firm as the value of their residual claim if the firm defaults is zero). Another class of structural models of default, endogenous default models, force equityholders to directly bear the cost of payouts (coupons, face value payments, or both) to bondholders.[34]

[34] Masulis and Korwar (1986) find that in a sample of 1,406 announcements of stock offerings, 372 offerings are planned exclusively to refund outstanding debt. This suggests that there is a realistic role for equityholders in paying off debt.

Thus, at each moment that there is a payoff, equityholders make a decision by trading-off the value they must pay to continue the firm against their claim to the value of the firm as a going concern. This pay-in induces equityholders to consider the full maturity structure of the firm when deciding whether to continue the firm.

Here, we consider the Geske (1977) model.[35] In the Geske model, like in most structural models of default, equityholders are residual claimants of the firm. That is, if the firm survives to the very last promised payment to bondholders at time T, equityholders receive $\max(0, V_T - K_T)$, where V_T is the value of the firm at T and K_T is the last promised payment. At any prior time t with a payment to bondholders of K_t, equityholders must decide whether to pay K_t and allow the firm to continue or to force the firm to default and put the firm to bondholders. Effectively, equityholders are making an optimal decision based on the market value of $\max(0, V_T - K_T)$ at t compared to the payment K_t.

Similar to our extension of the Merton model, we include three zero-coupon bonds with maturities $T_1 < T_2 < T_3$ and focus on the intermediate maturity bond, while varying the proportion of the firm's debt value due to the first and third bonds. We again consider two scenarios, the first where the bond maturing at T_3 accounts for 80% of the firm's debt value and the second where the bond maturing at T_1 accounts for 80% of the firm's debt value. This allows us to compare the case in which most of the firm's debt is due after the intermediate maturity bond and the case in which most of the firm's debt is due before the intermediate maturity bond.

Rather than providing the full set of Geske pricing formulas for general cases, we instead focus on the intuition of the Geske model under the special case that we implement, which is best understood through a recursive framework. In the Geske model, firm value follows a geometric Brownian motion like in the Merton model. Also, like in the Merton model, if the firm survives until there is only one bond outstanding (the bond with maturity T_3 in our example), equity is a residual claim and receives a payoff of $\max(0, V_3 - K_3)$ at T_3.

[35] See also Leland (1994) and Leland and Toft (1996) for models that incorporate equityholders' decisions on whether or not to service debt. We discuss the Leland-Toft model in more detail in Appendix B.3.

Consider the value of equity and the long maturity bond at T_2 and suppose that equityholders have just decided to pay the face value of the intermediate maturity bond, K_2, to continue the firm. This becomes the standard Merton model as equityholders have no remaining decisions to make. The value of equity is now

$$
\begin{aligned}
E_2 &= V_2 N(d_1) - K_3 e^{-r(T_3-T_2)} N(d_2), \qquad \text{(A.3)}\\
d_1 &= \frac{\ln\left(\frac{V_2}{K_3}\right) + \left(r + \frac{1}{2}\sigma_v^2\right)(T_3 - T_2)}{\sigma_v\sqrt{T_3 - T_2}}, d_2 = d_1 - \sigma_v\sqrt{T_3 - T_2}.
\end{aligned}
$$

That is, equity is a call option on the firm and the long maturity bond is a risk-free bond short a put option on the firm.

We can now consider the optimal decision of equityholders at T_2. The decision that equityholders make is simple. If the value of equity given in Equation (A.3) is greater than K_2, they pay K_2 and continue the firm. Otherwise, equityholders force the firm to go bankrupt. Even if K_2 is small, equityholders may still choose bankruptcy because K_3 is very large and the continuation value of equity is very small. Equityholders' decision at T_1 is similar, though the trade-off that equityholders make is between the payment of the face value of the short maturity bond, K_1, and the value of equity as a going concern which is a compound call option. Because equityholders take into account the full maturity structure of the firm's debt, even bonds that mature relatively early can have significant exposure to underlying firm value. Intuitively, even if the debt due early has a low face value, equityholders know that they will only receive a nonzero payoff in the future if the firm value is high enough to cover all face value payments in the future. Having large face values due in the future would be equivalent to buying an out-of-the-money call option, so even a relatively small pay-in may induce default.

As noted by Eom, Helwege, and Huang (2004), the Geske formula is not straightforward to implement accurately, particularly for long maturity bonds. Thus, we follow Huang (1997) and Eom, Helwege, and Huang (2004) and implement the Geske model using a Cox, Ross, and Rubinstein (1979) binomial tree, and the equity and bond values (from which we calculate yields), as well as the hedge ratio, are determined numerically. We also verify the accuracy of this numerical implementation by running simulations.

In Figure A.1, we present the yield spreads and hedge ratios for the intermediate maturity bond for the scenarios where (1) the bond is early in its issuer's maturity structure and (2) the bond is late in its issuer's maturity structure. Recall that for the extended Merton model, the yield spread and hedge ratio are generally lower in the first scenario. The intuition follows from the fact that if most of the debt is due after T_2, the firm would very likely have enough value to pay bondholders at T_2 directly from firm value. Thus, the intermediate bond has a higher price and lower sensitivity to firm value. In the Geske model, the intuition is less clear. Even if most of the firm's debt is due at T_3, equityholders may still choose to default at T_2 as their payoff at T_3 contingent on continuation, $\max(0, V_3 - K_3)$, may have a low expected value due to the large amount of debt due at T_3. Intuitively, this is akin to an investor choosing whether to pay a price for an out-of-the-money call option. The out-of-the-money call option will be cheaper than an in-the-money call, but the investor is not necessarily more likely to buy it. We find that for the same set of parameters as the extended Merton model in Section 1, the Geske model generates slightly lower yield spreads and hedge ratios for scenario 2 than scenario 1 for almost all leverage-asset volatility combinations.[36] Effectively, the significant discrete pay-in induces equityholders to consider the firm's full maturity structure when making continuation decisions.

B.2 Extending the Geske Model to Incorporate Partial Pay-In

Thus far, we have considered an extended Merton model in Section 1 and Appendix A and the Geske model in Appendix B.1. These two models make very different assumptions about how maturing bonds are paid off. In the extended Merton model, a maturing bond is paid

[36] The slightly lower yield spreads and hedge ratios for the case in which the bond is relatively late in the maturity structure is attributable to the fact that we model bonds as zero-coupon bonds and the recovery as being in proportion to the face value. Thus, bonds late in the maturity structure receive a slightly disproportionate recovery relative to market values.

from firm assets, whereas in the Geske model, equityholders pay the full face value of the maturing bond. Here, we consider an intermediate case, allowing the maturing bond to be paid partially from firm assets and partially by equityholders. Define α to be the proportion of the maturing bond face value that can be paid from firm assets. If $\alpha K_t \leq V_t$, αK_t is paid from firm assets and equityholders decide whether to pay $(1-\alpha)K_t$ to continue the firm.

The extended Merton and Geske models are the two special cases that correspond to $\alpha = 1$ and $\alpha = 0$, respectively. In the extended Merton model, equityholders always continue the firm if $V_t > K_t$, whereas in the Geske model, equityholders sometimes choose to default even if $V_t > K_t$ because the pay-in to continue the firm is too high relative to the value of their potential future payoff. Whether decreasing the equity pay-in significantly increases the likelihood of equityholders continuing the firm is unclear as the decreased pay-in comes at the cost of decreasing firm value. To illustrate the point, suppose that a firm has a zero-coupon bond maturing at time T_2 with a face value of 20 and another zero-coupon bond maturing at time $T_3 = T_2 + 3$ with a face value of 30. Suppose that the firm value is 45 at T_2 and it only has these two bond issues outstanding. Naturally, at $\alpha = 1$, equityholders always continue the firm. If $\alpha = 0$, equityholders need to decide whether to pay 20 in exchange for a call option maturing in three years with a strike of 30 and a current underlying asset value of 45. In this case, the value of the call option is 17.25 and equityholders choose to let the firm default. Consider instead $\alpha = 0.5$. In this case, equityholders only need to pay $(1-\alpha) \times 20 = 10$ to continue the firm. However, the other 10 is paid out of firm value, so equityholders are deciding whether to buy a call option with a strike of 30 and an underlying asset value of 35. Despite the decreased pay-in, equityholders still choose to let the firm default because the value of the call option is only worth 8.52 because the option is less in-the-money than before. In Figure A.2, we plot the value of the call option and the cost to equityholders to continue the firm. By definition, between the two extreme cases of $\alpha = 0$ and $\alpha = 1$, there is an $\alpha \in [0, 1]$ where equityholders are indifferent. In this example, this α is slightly less than 0.8.

In Figures A.3 and A.4, we plot the difference between the yield spreads and hedge ratios of the intermediate maturity bond when most of the firm's debt is due before the bond and when most of the firm's debt is due after the bond for different levels of α, using the same parameters from Section 1. For low values of α, the difference in yield spreads and hedge ratios between the two scenarios is close to 0. At $\alpha = 0.8$, we begin to see some evidence of de facto seniority, as the yield spread and hedge ratio of the intermediate maturity bond when most of the firm's debt is due before it becomes higher. What drives the relatively high α needed to generate de facto seniority is that there is typically a wide set of asset values where V_i is not much larger than K_i and the continuation value of equity is low. Significant required pay-in by equityholders would result in equityholders choosing default, whereas a zero pay-in ($\alpha = 1$) would lead to continuation.

B.3 Leland-Toft Model

As a final alternative model, we consider a Leland and Toft (1996) model where equityholders continuously rollover maturing debt. All debt is rolled over at a prespecified (exogenously given) maturity. An exogenously specified fraction δ of firm value is paid out to debtholders and equityholders. If the sum of proceeds from newly issued debt and δV is not large enough to cover coupons to debtholders and the face value of maturing debt, equityholders may choose to inject capital to continue the firm. The decision about whether or not to inject capital to continue leads to an endogenously determined default boundary. Compared to the previously explored models in this paper, the Leland-Toft model adds a number of layers of complexity. First, debt is rolled over rather than allowed to mature like in the extended Merton, Geske, and extended Geske models explored earlier. Second, although default is endogenous like in the Geske model, injections of capital do not always occur. In the Geske model, shareholders always pay to retire existing debt. In the Leland-Toft model, shareholder payments only occur if there is a cash shortfall. Third, shareholder injections of cash (when necessary) tend to be small and continuous in the Leland-Toft model, rather than large and discrete like in the Geske model. Fourth, the default boundary is endogenously determined in the Leland-Toft model, in contrast to all of the models previously examined in this paper. While such dynamics are interesting and potentially more realistic, they also complicate the intuition due to the large number of simultaneously moving parts.

To implement the Leland and Toft (1996) model, we follow equation (13) in their paper to determine the optimal default boundary. Bond pricing follows from equation (3) of their paper and we also choose the coupon rate so that newly issued debt sells at par (equation (14) in their paper). We choose $r = 0.03$, a firm-level payout ratio $\delta = 0.05$, $\alpha = 0.5$ (the deadweight loss of bankruptcy) and $\tau = 0.35$ (tax rate). We try a number of asset volatility (σ_v) and book leverage combinations. Our analysis focuses on a comparison of a 5-year bond in two examples. First, we consider a firm where all newly issued debt has a 5-year maturity. In particular, 20% of the firm's debt is rolled over each year. Next, we consider a firm where all newly issued debt has a 15-year maturity. In the former case, the 5-year bond is due late in its firm's maturity structure (i.e., is *de facto* junior) and in the latter, it is due relatively early.

In Figure A.5, we plot the yield spreads and hedge ratios of the two scenarios. We find that yield spreads are higher when a bond is *de facto* junior. Our results on hedge ratios show that for asset volatilities and leverages at levels consistent with typical firms in our sample (asset volatility around 0.2 and leverage around 0.4), bonds that are due relatively late in their firm's maturity structure have higher hedge ratios. The intuition behind these results is somewhat more complicated than the previous models due to the additional moving parts. Like the extended Merton model, equityholders will tend to continue the firm when possible, making the bonds due early in the maturity structure safer than bonds due later in the maturity structure. However, there is occasionally the need for equityholders to pay-in, making equityholders more likely to default than in the extended Merton model. The intuition is similar to the extended Geske model. Pay-ins are less frequent than the Geske model, but more frequent than the extended Merton model (which has no equity pay-in), making the gap in yield spreads an intermediate case between the Geske and extended Merton cases.

The intuition for hedge ratios in the Leland-Toft model is significantly more complicated. A bond that is due relatively early in its firm's maturity structure is less sensitive to asset value because it is safer. In particularly, its hedge ratio relative to firm assets, $\frac{\partial \ln B}{\partial \ln V}$ is lower if it is early in its firm's maturity structure. However, the sensitivity of equity to firm value also decreases when we move from a firm rolling over 5-year bonds to a firm rolling over 15-year bonds. This arises from the fact that the firm rolling over 15-year bonds chooses a lower default boundary than a firm rolling over 5-year bonds. This causes $\frac{\partial \ln E}{\partial \ln V}$ to be significantly lower in some cases with higher leverage and for $\frac{\partial \ln B}{\partial \ln E}$ to be higher for the 5-year bond issued by a firm rolling over 15-year bonds than the 5-year bond issued by a firm rolling over 5-year bonds. The general prediction of the Leland-Toft model is that a bond that is later in its issuer's maturity structure will tend to have higher yield spreads and higher hedge ratios, though the effect is not as uniform as the extended Merton model predicts.

C Alternative Controls

In Sections 3.1 and 3.2, we present empirical results showing that yield spreads and hedge ratios are higher for bonds that are de facto junior. Here, we consider the robustness of our results to alternative control variables. Our primary empirical analysis uses equity volatility and BE/ME as two simple credit controls that are meant to aggregate market information about credit risk. In the results that follow, we replace equity volatility and BE/ME with $\frac{K}{V}$ and asset volatility (σ_v), two credit variables that are directly motivated by structural models of default. To calculate $\frac{K}{V}$ and asset volatility, we follow Campbell, Hilscher, and Szilagyi (2008) and calculate them from two equations,

$$E = VN(d_1) - Ke^{-rT}N(d_2) \tag{A.4}$$

and

$$\sigma_E = N(d_1)\frac{V}{E}\sigma_v. \tag{A.5}$$

Furthermore, we also augment our empirical analysis to allow for a number of nonlinear controls. In addition to controlling for both firm and time fixed effects like in panel B of Table 5, we include ratings fixed effects (rather than numerically coded ratings). We also allow for squared terms for time-to-maturity (T), $\frac{K}{V}$, and asset volatility. In Table A.1, we find that the effect of de facto seniority on yield spreads is largely similar to Table 5.

We next turn to hedge ratio in Table A.2. To allow for additional variation in hedge ratios, we interact ratings fixed effects with equity returns and also allow for interactions between equity returns and T, T^2, asset volatility, asset volatility^2, $\frac{K}{V}$, and $\left(\frac{K}{V}\right)^2$. Even with these controls, we continue to find an economically and statistically significant effect of de facto seniority, though the magnitudes are somewhat smaller than in Table 8.

D Fitting the Model

In Section 1, we examine the implications of the extended Merton model using a case in which 10% of a firm's debt is due prior (10/10/80) and one where 80% of a firm's debt is due prior (80/10/10). Here, we extend our numerical calculations to allow for 5%, 20%, 30%, 40%, 50%, 60%, 70%, and 85% of a firm's debt to be due prior to the intermediate bond in addition to the 10% and 80% cases. For each proportion due prior, our goal is to calculate a surface that determines yield spreads and hedge ratios as a function of a firm's asset volatility and market leverage. To do this, we perform numerical calculations over 546 grid points for each value of proportion due prior, intersecting asset volatilities that range from 2.5% to 65% and market leverage ranging from 2.5% to 90%. All of the grid points are also checked using simulations to verify accuracy. Once we have 546 grid points, each surface is generated by using Matlab to interpolate grid points. With the surfaces, we are able to calculate yield spreads and hedge ratios for (σ_v, market leverage, proportion due prior) triplets.

For each observation in our empirical sample, we determine its asset volatility using the calculations described in Equations (A.4) and (A.5) and its market leverage as (DLC + DLTT)/(DLC + DLTT + market equity). We then use the closest proportion due prior surface pair to calculate the marginal effect of yield spreads and hedge ratios for an observation, analogous to a numerical derivative. For example, the effect of de facto seniority estimated for a bond with a proportion due prior of 0.35 is estimated using the 30% and 40% proportion due prior grids as

$$\frac{f(\sigma_v, \text{market leverage}, 0.4) - f(\sigma_v, \text{market leverage}, 0.3)}{0.4 - 0.3}, \tag{A.6}$$

where $f(.)$ is the function for the model yield spread or hedge ratio.

Table A.1. Yield spreads with nonlinear controls

	Full	IG	Junk
Proportion due prior	0.46	0.39	0.77
	[8.16]	[9.04]	[5.41]
T	0.0113	0.0137	0.0111
	[4.56]	[5.64]	[1.30]
T^2	-0.0001	-0.0001	-0.0001
	[-2.31]	[-3.03]	[-0.71]
K/V	1.87	2.22	2.37
	[3.07]	[3.69]	[1.90]
$(K/V)^2$	3.48	2.28	2.98
	[3.35]	[1.76]	[2.13]
Asset vol	-0.0020	0.0046	0.0033
	[-0.33]	[0.78]	[0.18]
Asset vol^2	0.0003	0.0002	0.0002
	[3.99]	[2.40]	[0.75]
Firm T	-0.01	-0.01	0.03
	[-1.86]	[-1.07]	[1.90]
Amihud	0.03	0.03	0.03
	[3.13]	[5.11]	[3.02]
IRC	0.50	0.46	0.37
	[8.55]	[7.44]	[4.26]
Amihud vol	0.02	0.02	0.05
	[6.31]	[5.57]	[5.65]
IRC vol	-0.02	-0.04	0.17
	[-0.70]	[-1.52]	[2.66]
R^2	0.83	0.78	0.81
Observations	205,822	177,311	28,511

The dependent variable in this table is yield spread in percentage. All regressions include three sets of fixed effects: time fixed effects, firm fixed effects, and ratings fixed effects (by notch). *Proportion due prior* is the proportion of the face value of an issuer's debt due before a bond, expressed in decimals. T is the time-to-maturity in years. K/V (in decimals) and *Asset vol* (in percentage) are calculated following Campbell, Hilscher, and Szilagyi (2008). *Firm T* is the weighted-average time-to-maturity of all of the issuer's bonds outstanding, weighted by amount outstanding. *Amihud*, *Amihud vol*, *IRC*, and *IRC vol* are the Amihud measure, the volatility of the Amihud measure, implied round-trip cost, and the volatility of implied round-trip cost, respectively. All four are calculated following Dick-Nielsen, Feldhutter, and Lando (2012), but scaled by 100. t-stats are in brackets and use standard errors two-way clustered by firm and time.

Table A.2. Hedge ratios with nonlinear controls

	Full	IG	Junk
$r_E \times$ Prop due prior	0.0590	0.0556	0.0823
	[2.89]	[2.39]	[4.15]
$r_E \times T$	0.0034	0.0038	0.0011
	[5.00]	[4.52]	[1.04]
$r_E \times T^2$	-0.0000	-0.0000	-0.0000
	[-4.40]	[-3.59]	[-0.70]
$r_E \times$ Asset vol	0.0044	0.0045	0.0041
	[1.78]	[1.65]	[1.35]
$r_E \times$ Asset vol^2	-0.0001	-0.0001	-0.0001
	[-1.88]	[-1.72]	[-1.57]
$r_E \times$ K/V	0.1069	0.0571	0.2576
	[0.91]	[0.53]	[2.01]
$r_E \times$ (K/V)^2	-0.0102	0.0554	-0.1484
	[-0.12]	[0.46]	[-1.54]
$r_E \times$ Firm T	0.0060	0.0045	0.0114
	[2.66]	[2.13]	[2.63]
Prop due prior	0.0018	0.0018	0.0011
	[1.77]	[1.76]	[0.71]
T	-0.0000	-0.0001	0.0000
	[-0.71]	[-0.74]	[0.46]
T^2	0.0000	0.0000	-0.0000
	[0.88]	[0.84]	[-0.32]
Asset vol	0.0003	0.0002	0.0006
	[1.24]	[0.98]	[1.38]
Asset vol^2	0.0000	0.0000	-0.0000
	[0.91]	[1.21]	[-0.39]
K/V	0.0210	0.0250	0.0223
	[2.33]	[2.51]	[1.45]
(K/V)^2	0.0037	0.0011	0.0009
	[0.36]	[0.08]	[0.08]
Firm T	-0.0001	-0.0001	-0.0002
	[-0.69]	[-0.60]	[-0.44]
R^2	0.32	0.34	0.28
Observations	238,449	207,067	31,382

The dependent variable in this table is log corporate bond returns in decimals. r_E is the log equity return of the same issuer as the corporate bond and r_T is the log Treasury bond return of a Treasury bond with the same maturity as the corporate bond. Both r_E and r_T are expressed in decimals. *Proportion due prior* is the proportion of the face value of an issuer's debt due before a bond, expressed in decimals. T is the time-to-maturity in years. K/V (in decimals) and *Asset vol* (in percentage) are calculated following Campbell, Hilscher, and Szilagyi (2008). *Firm T* is the weighted-average time-to-maturity of all of the issuer's bonds outstanding, weighted by amount outstanding. All regressions contain firm fixed effects, ratings fixed effects (by notch), firm fixed effects interacted with r_E, and ratings fixed effects interacted with r_E and r_T separately. t-stats are in brackets and use standard errors two-way clustered by firm and time.

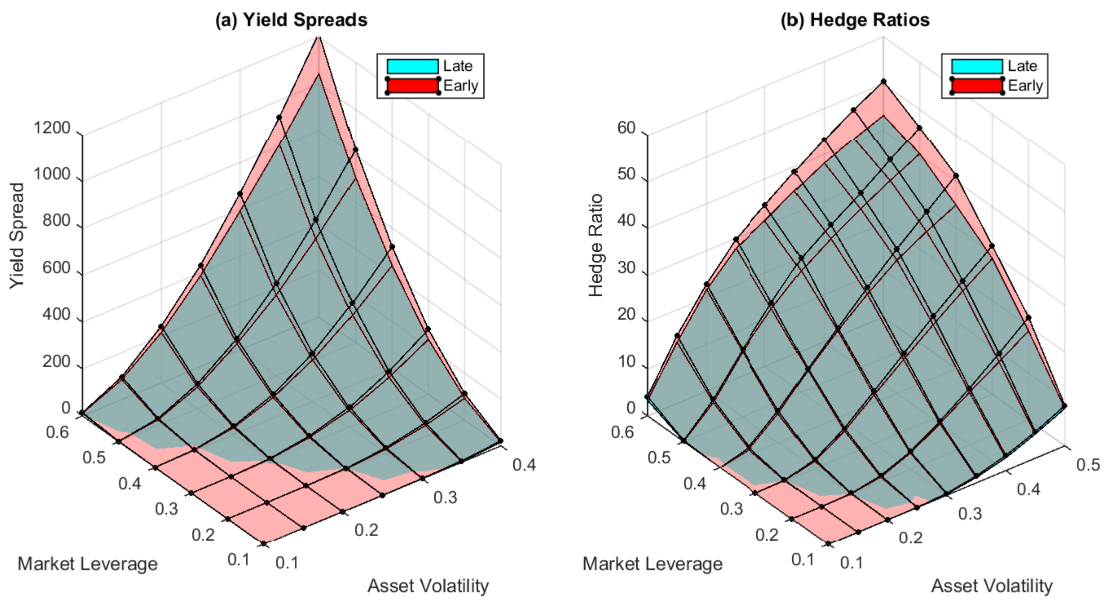

Figure A.1. Yield spreads and hedge ratios for the Geske (1977) model. Yield spreads are reported in basis points and hedge ratios in percentage. The cyan surfaces represent the case in which a bond is late in its issuer's maturity structure and the red surfaces with point markers represent the case in which a bond is early in its issuer's maturity structure.

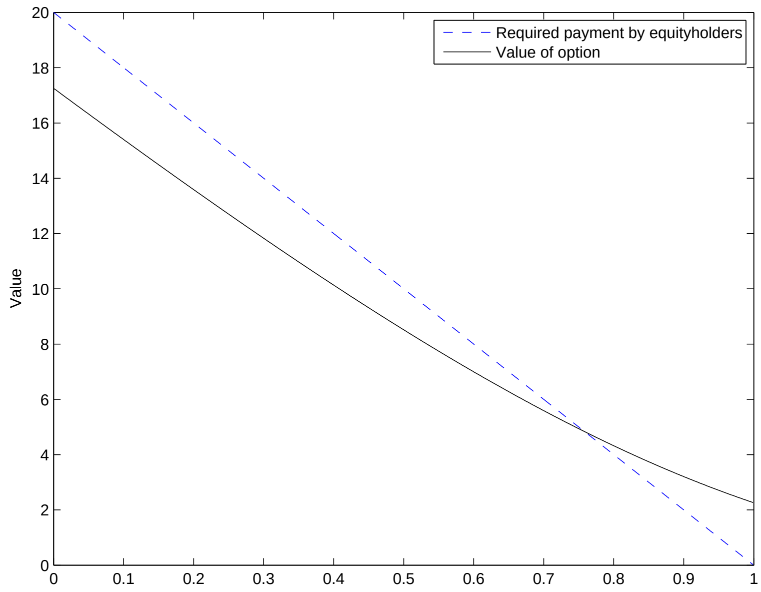

Figure A.2. Dashed line is the amount that equityholders need to pay-in to continue the firm for different levels of α in the extended Geske model. Dashed curve is the value of the call option that equityholders would hold if they choose to continue the firm.

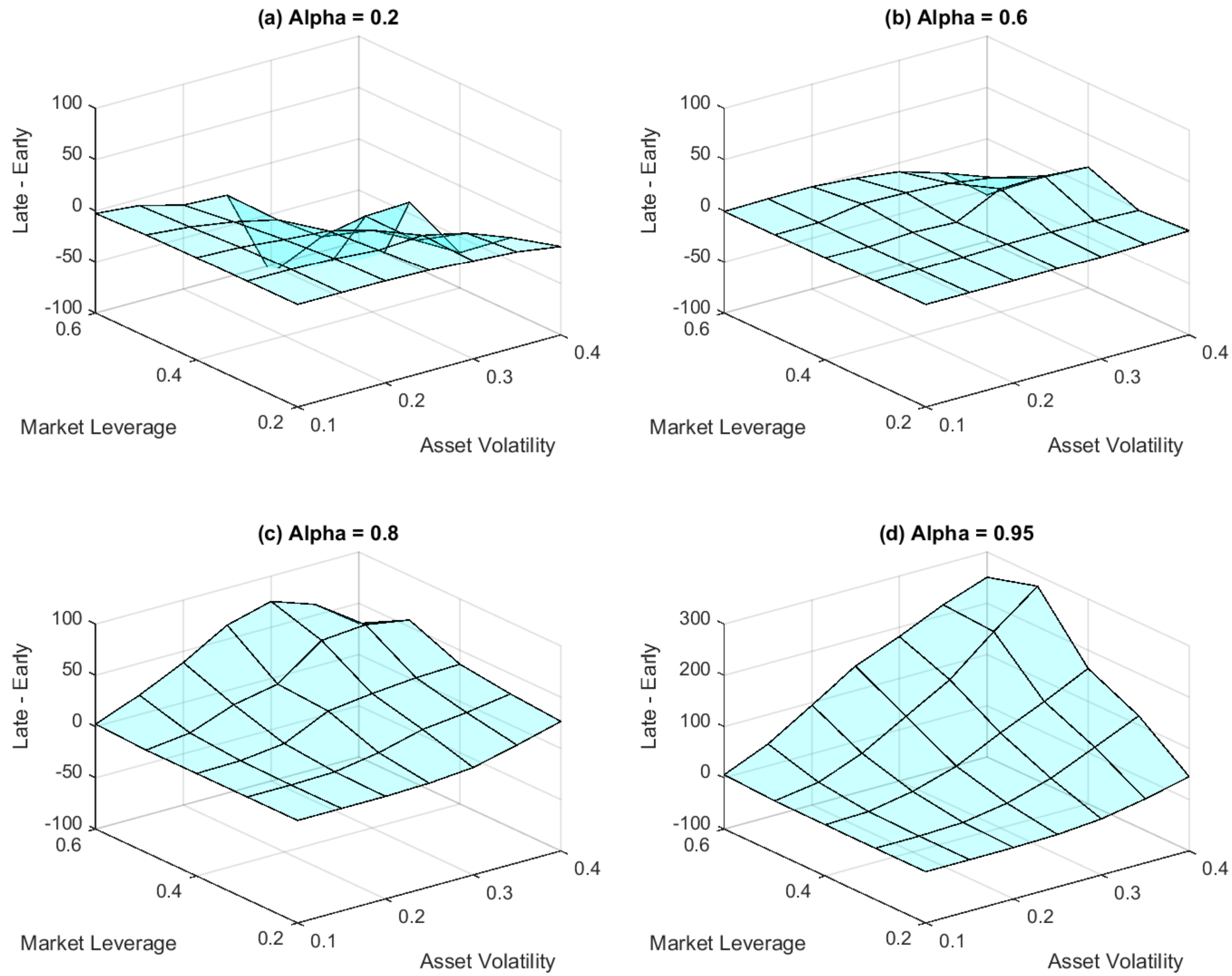

Figure A.3. Yield spreads for the the extended Geske model. The panels plot differences in yield spreads between bonds due late in a firm's maturity structure and bonds due early in a firm's maturity structure. α represents the proportion of maturing debt that is paid by liquidating firm assets.

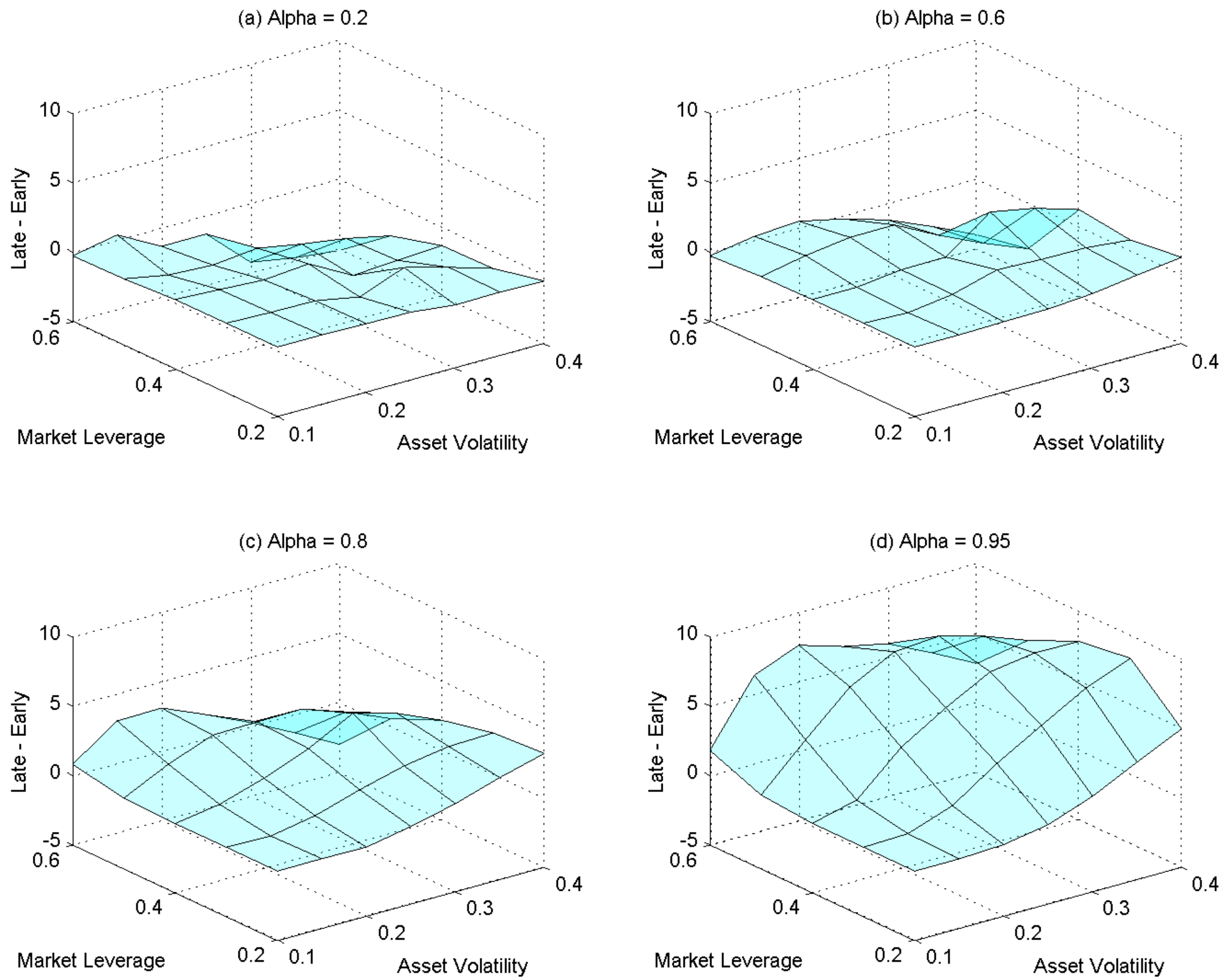

Figure A.4. Hedge Ratios for the the extended Geske model. The panels plot differences in hedge ratios between bonds due late in a firm's maturity structure and bonds due early in a firm's maturity structure. α represents the proportion of maturing debt that is paid by liquidating firm assets.

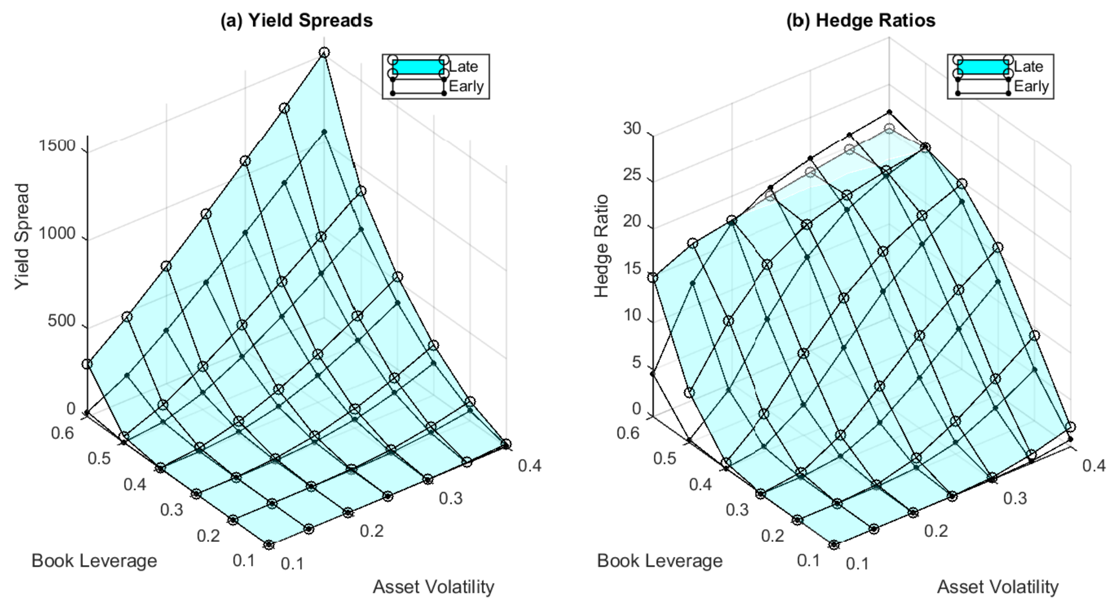

Figure A.5. Yield spreads and hedge ratios for the Leland and Toft (1996) model. Yield spreads are reported in basis points and hedge ratios in percentage. The cyan surfaces with circular markers represent cases where a bond is due late in its issuer's maturity structure and the white surfaces with point markers represent cases where a bond is due early in its issuer's maturity structure.

References

Amihud, Y. 2002. Illiquidity and stock returns: Cross-section and time-series effects. *Journal of Financial Markets* 5:31–56.

Asness, C., and A. Frazzini. 2013. The devil in HML's details. *Journal of Portfolio Management* 39:48–68.

Baele, L., G. Bekaert, and K. Inghelbrecht. 2010. The determinants of stock and bond return comovements. *Review of Financial Studies* 23:2374–428.

Baker, M., and J. Wurgler. 2012. Comovement and predictability relationships between bonds and the cross-section of stocks. *Review of Asset Pricing Studies* 2:57–87.

Bao, J., J. Chen, K. Hou, and L. Lu. 2014. Prices and volatilities in the corporate bond market. Working Paper, Federal Reserve Board, Peking University, and Ohio State.

Bao, J., and J. Pan. 2013. Bond illiquidity and excess volatility. *Review of Financial Studies* 26:3068–103.

Brunnermeier, M. K., and M. Oehmke. 2013. The maturity rat race. *Journal of Finance* 68:483–521.

Cameron, A. C., J. B. Gelbach, and D. L. Miller. 2011. Robust inference with multiway clustering. *Journal of Business & Economics Statistics* 29:238–49.

Campbell, J. Y., J. Hilscher, and J. Szilagyi. 2008. In search of distress risk. *Journal of Finance* 63:2899–939.

Campbell, J. Y., C. Pflueger, and L. M. Viciera. 2013. Monetary policy drivers of bond and equity risks. Working Paper, Harvard and UBC.

Campbell, J. Y., and G. B. Taksler. 2003. Equity volatility and corporate bond yields. *Journal of Finance* 58:2321–49.

Chava, S., and M. R. Roberts. 2008. How does financing impact investment? The role of debt covenants. *Journal of Finance* 63:2085–121.

Chen, H., Y. Xu, and J. Yang. 2012. Systematic risk, debt maturity, and the term structure of credit spreads. Working Paper, MIT and Bank of Canada.

Collin-Dufresne, P., R. S. Goldstein, and S. Martin. 2001. The determinants of credit spread changes. *Journal of Finance* 56:2177–207.

Cox, J. C., S. A. Ross, and M. Rubinstein. 1979. Option pricing: A simplified approach. *Journal of Financial Economics* 7:229–63.

Daniel, K., and S. Titman. 1997. Evidence on the characteristics of cross sectional variation in stock returns. *Journal of Finance* 52:1–33.

Dick-Nielsen, J., P. Feldhutter, and D. Lando. 2012. Corporate bond liquidity before and after the onset of the subprime crisis. *Journal of Financial Economics* 103:471–92.

Eisdorfer, A. 2008. Empirical evidence of risk shifting in financially distressed firms. *Journal of Finance* 63:609–37.

Eom, Y. H., J. Helwege, and J. Z. Huang. 2004. Structural models of corporate bond pricing: An empirical analysis. *Review of Financial Studies* 17:499–544.

Fama, E. F., and K. R. French. 1992. The cross-section of expected stock returns. *Journal of Finance* 47:427–65.

———. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* 33:3–56.

———. 1995. Size and book-to-market factors in earnings and returns. *Journal of Finance* 50:131–55.

———. 1996. Multifactor explanations of asset pricing anomalies. *Journal of Finance* 51:55–84.

Feldhutter, P. 2012. The same bond at different prices: identifying search frictions and selling pressures. *Review of Financial Studies* 25:1155–206.

Feldhutter, P., and S. Schaefer. 2015. The credit spread puzzle in the Merton model – Myth or reality? Working Paper, London Business School.

Fons, J., B. Havlicek, D. Fanger, D. Gates, E. de Bodard, and L. Exton. 2007. Updated summary guidelines for notching bonds, preferred stocks and hybrid securities of corporate issuers. Moody's Investor Services.

Geske, R. 1977. The valuation of corporate liabilities as compound options. *Journal of Financial and Quantitative Analysis* 12:541–52.

Greene, W. H. 2003. *Econometric analysis*, 5th ed. Upper Saddle River, NJ: Prentice Hall.

Guha, R. 2002. Recovery of face value at default: Theory and empirical evidence. Working Paper, London Business School.

Haugen, R. A. 1995. *The new finance – The case against efficient markets.* Upper Saddle River, NJ: Prentice-Hall.

He, Z., and K. Milbradt. 2014. Endogenous liquidity and defaultable bonds. *Econometrica* 82:1443–508.

———. 2016. Dynamic debt maturity. *Review of Financial Studies* 29:2677–736.

He, Z., and W. Xiong. 2012. Rollover risk and credit risk. *Journal of Finance* 67:391–429.

Hotchkiss, E. H., and T. Ronen. 2002. The informational efficiency of the corporate bond market: An intraday analysis. *Review of Financial Studies* 15:1325–54.

Huang, J. Z. 1997. Default risk, renegotiation, and the valuation of corporate claims. PhD thesis, NYU.

Huang, J. Z., and M. Huang. 2003. How much of the corporate-treasury yield spread is due to credit risk? Working Paper, Penn State and Stanford.

———. 2012. How much of the corporate-treasury yield spread is due to credit risk? *Review of Asset Pricing Studies* 2:153–202.

Kennedy, P. 1998. *A guide to econometrics*, 4th ed. Cambridge, MA: MIT Press.

Lakonishok, J., A. Shleifer, and R. W. Vishny. 1994. Contrarian investment, extrapolation, and risk. *Journal of Finance* 49:1541–78.

Leland, H. E. 1994. Corporate debt value, bond covenants, and optimal capital structure. *Journal of Finance* 49:157–96.

Leland, H. E., and K. Toft. 1996. Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads. *Journal of Finance* 51:987–1019.

MacKinlay, A. C. 1995. Multifactor models do not explain deviations from the CAPM. *Journal of Financial Economics* 38:3–28.

Masulis, R. W., and A. N. Korwar. 1986. Seasoned equity offerings: An empirical investigation. *Journal of Financial Economics* 15:91–118.

Maxwell, W. F., and R. Rao. 2003. Do spin-offs expropriate wealth from bondholders? *Journal of Finance* 58:2087–108.

Maxwell, W. F., and M. R. Shenkman. 2010. *Leveraged financial markets*. New York: McGraw-Hill.

Maxwell, W. F., and C. Stephens. 2003. The wealth effects of repurchases on bondholders. *Journal of Finance* 58:895–919.

Merton, R. C. 1974. On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance* 29:449–70.

Powers, E. A., and S. Tsyplakov. 2008. What is the cost of financial flexibility? Theory and evidence from make-whole call provisions. *Financial Management* 37:485–512.

Rauh, J. D., and A. Sufi. 2010. Capital structure and debt structure. *Review of Financial Studies* 23:4242–80.

Schaefer, S. M., and I. A. Strebulaev. 2008. Structural models of credit risk are useful: Evidence from hedge ratios on corporate bonds. *Journal of Financial Economics* 90:1–19.

Shimko, D. C., N. Tejima, and D. R. van Deventer. 1993. The pricing of risky debt when interest rates are stochastic. *Journal of Fixed Income* 3:58–65.