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Credit spreads with dynamic debt ☆

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ABSTRACT

This paper extends the baseline Merton (1974) structural default model, which is intended for *static* debt spreads, to a setting with *dynamic* debt, where leverage can be ratcheted up as well as written down through pre-specified exogenous policies. We provide a different and novel solution approach to dynamic debt than in the extant literature. For many dynamic debt covenants, ex-ante credit spread term structures can be derived in closed-form using modified barrier option mathematics, whereby debt spreads can be expressed using combinations of single barrier options (both knock-in and knock-out), double barrier options, double-touch barrier options, in-out barrier options, and one-touch double barrier binary options. We observe that debt principal swap down covenants decrease the magnitude of credit spreads but increase the slope of the credit curve, transforming downward sloping curves into upward sloping ones. On the other hand, ratchet covenants increase the magnitude of ex-ante spreads without dramatically altering the slope of the credit curve. These covenants may be optimized by appropriately setting restructuring boundaries, which entails a trade-off between the reduction in spreads against restructuring costs. Overall, explicitly modeling this latent option to alter debt leads to term structures of credit spreads that are more consistent with observed empirics.

1. Introduction

Predicting and pricing the likelihood of default is important to investors, lenders, and debtors alike, and accordingly, a substantial body of work attempts to model and price risky debt claims, and to determine related credit spreads. Beginning with Black and Scholes (1973) and Merton (1974), standard structural models start with a riskless claim, subtracting out the value of a guarantee on a *fixed* debt level, which represents the value of the borrower's option to default. Empirically, however, firms that issue debt, actively manage their debt structure and levels, and debt rarely remains fixed. This paper models in closed form, using barrier options, the magnitude of and changes to ex-ante spreads when accounting for the fact that debt is dynamically updated under flexible rules. This analytic and parsimonious extension of the Merton model generates spread curves for high-yield debt that match the shapes observed in practice.

In the classic Merton (1974) framework with *static* zero-coupon debt, the risky debt discount is priced by a plain vanilla put option on the underlying firm with a strike equal to the current debt principal, the value of which can be translated into credit spreads on the firm's debt. To this model, we add features that allow debt to be ratcheted up or written down. That is, we allow for a possible increase in a firm's debt level (i.e., a *ratchet*) in response to increases in underlying firm value; we also allow for a possible decrease in its debt level (i.e., a *swap down*) that replaces debt principal with equity in response to decreases in underlying firm value, a process also referred to as "de-leveraging".[1]

Specifically, we show that extensions of the static debt Merton model to debt discounts for credit risk (and hence spreads) on *dynamic* debt can be derived analytically using barrier options, a class of exotic derivatives that are activated or de-activated upon accessing a pre-determined barrier. This paper provides a range of solutions for spreads on dynamic debt using different barrier

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[1] We use the term "swap down" instead of debt write down because we specifically mean a replacement of debt with equity, and not a mere write down of debt. Correspondingly, when debt is "ratcheted" up we reduce the amount of equity by an equal amount.

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option types, such as single barrier options (both knock-in and knock-out), double barrier options, double-touch barrier options, in-out barrier options, and one-touch double barrier binary options.

Intuitively, if the underlying assets increase sufficiently in value, then the firm can use the extra collateral to support more debt, thereby *ratcheting* the debt to firm value ratio upward and increasing the debt discount. That is, once the underlying firm value appreciates to an upper barrier, the original put option on debt is knocked out and replaced by another put at a higher strike representing the increased level of debt. Thus, in contrast to the plain vanilla put representing the Merton discount on non-renegotiable debt, the value of a discount on debt with the option to ratchet is decomposed into two single-barrier options: an up-and-out put option to capture the discount on the original level of debt, and an up-and-in put option to capture the new discount at the increased debt level.

Analogously, *swap downs* may occur when the underlying assets decrease substantially in value, and the put option to default becomes deep in-the-money. To stave off default, lenders can swap debt principal for equity to make the default option less profitable to exercise from the borrower's standpoint.[2] Thus, the value of a discount on debt that may subsequently be reduced can be expressed as the sum of two single-barrier options: a down-and-out put option struck at the original debt level, and a down-and-in put option struck at the reduced debt level.

Under this framework, we obtain closed-form solutions for the ex-ante value of the debt discount and corresponding credit spread term structure, explicitly modeling the latent option to either ratchet or swap down debt after issuance. We also extend this pricing model to allow for various combinations of possible ratchets and swap downs. Although the resulting barrier-option representation of the debt discount in such a setting is much more complex than in the single ratchet or single swap down cases, the solutions are analytical and lead to intuitive and empirically known shapes of the term structures of credit spreads. These results may also be extended recursively to more complicated repetitive opportunities to alter debt.

Overall, this parsimonious extension of the static debt structural model in closed-form using barrier options results in more empirically tenable term structures of credit spreads. The main results of our analyses are as follows:

1. *Level effect*: (a) Debt discounts and credit spreads increase with ratchets and decrease with principal swap down features. (b) The ratchet effect is more pronounced for medium-debt firms than for high-debt firms, because ratchets occur at lower leverage. Similarly, the swap down effect is more pronounced for high-debt firms (than for medium-debt firms).
2. *Slope effect*: For high-debt firms, accounting for the swap down feature removes the downward bias in the slope of the yield curve, matching empirical evidence presented by Helwege and Turner (1999) and Huang and Zhang (2008).
3. *Optimal covenants*: (a) Covenants that restructure debt at a pre-specified market leverage (debt-to-value) ratio reduce ex-ante spreads, and these boundaries may be optimally chosen to trade off benefits of spread reduction against costs of frequent restructuring. (b) As the restructuring leverage level is reduced, spreads drop rapidly at first and then slowly; set against restructuring costs that are convex in restructuring likelihood and frequency, implies an optimal restructuring barrier.

Ours is not the first paper to extend the classic Merton (1974) structural model for risky debt.[3] However, credit spreads and curves predicted by these other models do not adequately match empirical observations of actual spreads and curves, as evidenced in Eom et al. (2004), who empirically test five different structural models for corporate spreads. Although the Merton model produces spreads that are too low, these newer models produce spreads that are generally far too high. For example, the Longstaff and Schwartz (1995), Leland and Toft (1996) and Collin-Dufresne and Goldstein (2001) models predict spreads that are oftentimes more than double the actual spread. We depart from these studies in the following ways.

First, in contrast to these models, we use barrier options to explicitly model the option to ratchet or de-leverage, whereby the option to alter debt is exercised discretely upon accessing a threshold and the debt level does not undergo continuous changes. In practice, debt levels do not change continuously as modeled by Collin-Dufresne and Goldstein (2001), and in modeling discrete, periodic, firm value-dependent revisions in debt levels, we observe substantive differences in predicted credit spreads and curves.

Second, structural models based on mean-reverting models of leverage do not place explicit bounds on the levels of debt the firm might carry, though by increasing the rate of mean reversion, the expected range in which the leverage lies can be controlled. In these models, sufficiently high speeds of adjustment are necessary to generate the upward sloping credit curves empirically observed on high-yield debt. But paradoxically, imposing high speeds of mean reversion results in leverage itself being less dynamic, and firms do not usually evidence such strict adherence to a target capital structure. In contrast, our "leverage barrier" model permits free movement of leverage within the pre-specified barriers and generates mean reverting capital structures with dynamic and periodic debt adjustments, concomitant with actual practice and consistent with the literature on bounded capital structures arising from costly readjustment, as modeled in Fischer et al. (1989a).

Third, the extant literature has focused on different trade-offs than the one we consider here. Leland (1994) and Leland and Toft (1996) model firm-value optimizing debt policies trading off tax shields and deadweight bankruptcy costs. These debt policies are endogenous, and are more apt when considering policy making by a firm. In contrast to these papers, we minimize the cost of debt funding (spreads) by trading off the cost of restructuring versus the reduction in spreads from covenants that impose de-leveraging. The restructuring boundaries in our paper are exogenous, making the model simpler to implement, and more apt for use by investors, who might use credit spreads to infer implied restructuring boundaries, or firms, who choose ex-ante restructuring boundaries to manage their credit spreads. Hence, we depart from traditional optimal capital structure based models of dynamic debt choice to a model with simpler closed-form barrier option-based solutions that easily match observed empirical characteristics of yield

[2] This is now a prevalent practice in the mortgage markets, supported by government regulation (e.g., see the HAMP-PRA scheme). A recent example in the case of sovereign debt is the forgiveness of principal on Greek debt.

[3] Other studies departing from this traditional paradigm include Longstaff and Schwartz (1995), who extend the structural class of models to default with the additional feature of stochastic interest rates; Leland (1994) and Leland and Toft (1996), who consider credit spread term structures under the choice of optimal capital structure and debt maturity with taxes and an endogenous bankruptcy barrier; Goldstein et al. (2001), who allow for possible increases in future debt levels; and Collin-Dufresne and Goldstein (2001), (CDG), who examine credit spreads under a mean-reverting capital structure in a setting where leverage is a stochastic process continuously tracking a pre-determined target. Our paper differs from CDG in the following ways. First, the debt level (default barrier) in CDG is continuously changing, whereas ours ratchets or swaps down only when barriers are breached. These punctuated changes in leverage are more natural. Second, mean-reverting leverage models assume both increases and decreases in leverage as mean-reversion occurs, and are less flexible than a model in which debt levels may increase or decrease separately, providing more varied features to the spread term structure. In our model we allow separate handling of increases and decreases in debt, with the same number of parameters as in CDG.