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Evaluating corporate bonds and analyzing claim holders' decisions with complex debt structure ☆

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ABSTRACT

Although many different aspects of debt structures such as bond covenants and repayment schedules are empirically found to significantly influence values of bonds and equity, many theoretical structural models still oversimplify debt structures and fail to capture phenomena found in financial markets. This paper proposes a carefully designed structural model that faithfully models typical complex debt structures containing multiple bonds with various covenants. For example, the ability for an issuing firm to meet an obligation is modeled to rely on its ability to meet previous repayments, and the default trigger is shaped according to the characteristics of its debt structure such as the amount and schedule of bond repayments. Thus our framework reliably provides theoretical insight and concrete quantitative measurements consistent with extant empirical research such as the shapes of yield spread curves under various firm's financial statuses, and the impact of payment blockage covenants on newly-issued and other outstanding bonds. We also develop the forest, a novel quantitative method to handle contingent changes in the debt structure due to premature bond redemptions. A forest consists of several trees that capture different debt structures, for instance those before or after a bond redemption. This method can be used to analyze how poison put covenants in the target firm's bonds influence the bidder's costs of debt financing for a leveraged buyout, or investigate how the presence of wealth transfer among the remaining claim holders due to a bond redemption influences the firm's call policy, or further reconcile conflicts among previous empirical studies on call delay phenomena.

1. Introduction

Corporate bonds are fundamental financing instruments that are widely held by institutional investors or fund managers. According to reports from the Securities Industry and Financial Markets Association (SIFMA), the amount of issuances (outstandings) in the US market grew from 343.7 billion (2247.9 billion) in 1996 to 1440.9 billion (7822.3 billion) in 2014.[1] Clearly corporate bonds play an important role in capital markets; their prevalence has further led academics and practitioner communities to devote their energies to the analysis of bond evaluations and relevant claim holders' decisions (e.g., premature redemptions of bonds).

While a *default-free* bond (e.g., a Treasury bond) can be *separately* evaluated without considering the presence of other simultaneously outstanding default-free bonds, the value of a corporate bond may be greatly influenced by the existence of other outstanding bonds of the same issuing firm due to the claim dilution effect. For example, Fama and Miller (1972) indicate that new bond issuances may dilute the values of previously-issued bonds. Ingersoll (1987) further points out that the issuances of short-term junior bonds may deteriorate the credit quality of previously-issued long-term senior bonds. Indeed, empirical investigations in Rauh and Sufi (2010) and Colla et al. (2013) show that most firms have very complicated debt structures, such as multiple outstanding bonds with different maturities, seniorities and embedded covenants. To analyze the relationships among a firm's debt structure, the values of its outstanding bonds and equity, and

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[1] See http://www.sifma.org/research/statistics.aspx.

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the relevant claim holders' decisions, we develop a quantitative framework that endogenously associates the firm's insolvency risk with its prevailing debt structure by taking advantage of the structural model pioneered by Merton (1974). This framework provides theoretical insight and concrete quantitative measurements for the empirical literature on debt structure.

To reduce mathematical or computational difficulty in modeling complex features of a firm's debt structure, many structural models oversimplify the debt structure; hence as examined in Jones et al. (1984), Eom et al. (2004) and Huang and Huang (2012), they perform poorly when evaluating corporate securities. For example, some models use a "representative bond" to stand for the overall complex debt structure (e.g., Merton, 1974; Kim et al., 1993; Leland, 1994); however, this simplification prevents us from analyzing the impacts of coexistent bonds with different covenants on the values of the firm's securities. Another popular approach, the "portfolio of zeroes approach", decomposes all outstanding bonds of the same firm into a portfolio of equal-priority zero-coupon bonds and evaluates them separately (e.g., Longstaff and Schwartz, 1995; Collin-Dufresne and Goldstein, 2001). Eom et al. (2004) indicate that this approach inaccurately estimates the default probability of each zero-coupon bond since each bond is evaluated without considering whether all previously-matured bonds are honored. In addition, many models put naive settings on default triggers to preserve mathematical tractability. For example, Black and Cox (1976) and Zhou (2001) assume that a firm defaults when its asset value falls below a unified default boundary without considering the debt repayment schedule implied by the firm's debt structure. Other work considers repayment schedules with naive financing settings. For example, Geske (1977) assumes that all debt repayments are financed by issuing new equities. Leland and Toft (1996) assume that a firm should keep the amounts of its outstanding bonds unchanged regardless of its financial status on repayment dates. However, Davydenko (2012) empirically shows that it is hard to identify a unified boundary level to exactly separate insolvent firms from solvent ones; in addition, much empirical evidence confirms that a firm's financing policy may depend on its current financial status, its investment opportunities, or the macroeconomic condition.[2]

Much effort has been devoted to enhancing the empirical validity of structural models. For example, Eom et al. (2004) empirically show that the "compound option approach" is much better than the aforementioned portfolio of zeros approach. Specifically, the former approach views the question of whether a due bond principal or coupon repayment is honored as an option on other options—whether previously-matured repayments are fulfilled. Thus the default probability for each repayment is evaluated conditionally on the default probabilities for previous repayments in the former approach; this is more reasonable than the latter approach's independent modeling of default events. In addition, some work elaborates structural models by considering the interdependence of a firm's investment policies and different facets of its debt structure such as bond maturities (e.g., Barclay et al., 2003), priorities (e.g., Hackbarth and Mauer (2012)), and leverage ratios (e.g., Kuehn and Schmid, 2014).

To appropriately associate a firm's insolvency risk with the different observable facets of its debt structure based on the compound option approach, we develop a novel evaluation framework by exploiting the tree method, a popular numerical technique proposed by Cox et al. (1979). With the flexibility of the tree method, our framework easily models the debt-structure-dependent default trigger shaped according to the repayment schedule and covenants embedded in the firm's outstanding bonds, thus providing theoretical insight into Davydenko (2012)'s observation that default triggers are widely dispersed among firms. Specifically, to measure a firm's ability to repay a certain obligation with internal or external funds under the burdens of previously-matured payments, we introduce "remaining assets", a novel proxy defined as the remainder of the firm's asset value after repaying all required payments that matured prior to that obligation. This proxy allows our framework to implicitly incorporate the spirit of the compound option approach without adopting naive financing settings, for instance, financing all repayments by raising new equities as in Geske (1977) or keeping the amounts of outstanding bonds stationary as in Leland and Toft (1996). To model the influence of repayment schedules and covenants, a default event is triggered once the firm's remaining asset value minus the values of the assets pledged for other outstanding bonds is less than its matured payment implied by its debt structure. As mentioned in Section 2, although introducing the concepts of remaining assets and the debt-structure-dependent default trigger complicates the resulting mathematical model, the flexibility of our framework overcomes these difficulties to provide reliable evaluations and theoretical insight into many empirical studies.

To demonstrate how simplifying debt structures and adopting naive financing settings generates inaccurate bond evaluation results, Fig. 1 illustrates the yield spread curves for simultaneously issued bonds (i.e., serial bonds) of the same firm extracted from empirical data and those generated from different structural models. The empirical studies in Helwege and Turner (1999) and Huang and Zhang (2008) suggest that most yield spread curves implied by serial bonds are upward-sloping despite the issuing firm's financial status.[3] Two typical examples of the yield spread curves for investment-grade issuer DIRECTV Holdings (in the black curve) and speculative-grade issuer Rockies Express Pipeline (in the gray curve) are illustrated in Fig. 1(a) to demonstrate this upward-sloping nature. We examine the reliability of different structural models by evaluating the issuing prices of three otherwise identical serial bonds issued by a hypothetical firm with maturities of 5, 10, and 20 years. In Fig. 1(b), the three serial bonds are either evaluated separately without considering the presence of other bonds (denoted by dashed curves) or by using our quantitative framework (solid curves). As noted by Jones et al. (1984, 1993), the former setting ignores the impacts of coexistent bonds and thus severely underestimates the bond yield spreads when the issuing firm is healthy as plotted in the black dashed curve. Furthermore, as the firm's creditworthiness deteriorates, the former setting generates a hump-shaped (plotted in dashed light gray) yield spread curve or a downward-sloping (dashed dark gray) one; these shapes are inconsistent with the upward-sloping nature found in the empirical studies. In contrast, our framework captures how the repayments of short-term bonds deteriorate the firm's solvency to further jeopardize the credit quality of the long-term bonds. Thus, it does not

[2] For example, Barclay et al. (2003) indicate that the issuing firm's choices of bond maturity are closely related to its investment opportunity. In addition, Rauh and Sufi (2010) and Hackbarth and Mauer (2012) show that unhealthy issuing firms may spread priority across debt classes. In addition, Chen et al. (2013) show that firms with high systematic risk favor long-term bond issuances and possess more stable debt maturity structure over the business cycle. Xu (2014) shows that speculative-grade firms actively extend their debt maturity structure in good times. Similarly, Kahl et al. (2015) show that, instead of continuing to use short-term bonds like commercial papers, firms with high rollover risk often issue long-term bonds to replace maturing short-term bonds.

[3] The empirical results in Helwege and Turner (1999) show that, in the primary market, over 80% of the yield spread curves implied by equal-priority bonds issued on the same day by the same speculative-grade issuer are upward-sloping; over 60% of the yield spread curves for those in the secondary market are also upward-sloping. The empirical investigation into the broader sample sets by Huang and Zhang (2008) shows that more than 80% of the yield spread curves for the cases of investment- and speculative-grade issuers are upward-sloping.