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Optimal default and liquidation with tangible assets and debt renegotiation

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A B S T R A C T

We propose a pricing model for corporate securities issued by a levered firm with the possibility of debt renegotiation, where the firm's earnings follow a geometric Brownian motion with stochastic collaterals. While equity holders can default the firm when the earnings become insufficient, they may liquidate it by repaying the face value of debt when the value of collaterals becomes sufficiently high. Unlike the existing models, the bivariate structure enables us to distinguish strategic default, liquidity default and ordinary liquidation, which makes the contribution of strategic debt service to credit spreads lower than that obtained in the previous models.

1. Introduction

As a seminal paper in the structural approach, Leland (1994) considered the optimal capital structure of a firm based on the balancing theory. However, as Mella-Barral (1999) pointed out, credit spreads calculated by the Leland model are close to those observed in the market only for significantly high default costs. Also, Eom, Helwege, and Huang (2004) noted that the models by Merton (1974) and Geske (1977) underestimate the credit spreads, while the models by Longstaff and Schwartz (1995), Leland and Toft (1996) and Collin-Dufresne and Goldstein (2001) overestimate. Since then, several attempts have been made to overcome the deficiency in the structural approach. Among them, Anderson & Sundaresan (1996) and Mella-Barral and Perraudin (1997) proposed a structural model with debt renegotiation. In reality, debt is considered to be renegotiated, because liquidation is costly and debt holders cannot suffer from liquidation (see Franks and Torous (1989)). Hence, equity holders have an incentive to renegotiate in order to reduce the contractual debt service.

Following Anderson and Sundaresan (1996) and Mella-Barral and Perraudin (1997), Mella-Barral (1999) considered a model with departures from absolute priority rule, while Fan and Sundaresan (2000) incorporated the medium bargaining power and provided the Nash bargaining solution. François and Morellec (2004) develop the framework that captures the features of renegotiations under Chapter 11 of the U.S. Bankruptcy Code. Annabi, Breton, and François (2012) also develop a contingent claims model with a formal account for renegotiations under the U.S. bankruptcy procedure. Structural pricing models with debt renegotiation suggest that, when creditors have little bargaining power, a large part of credit spreads may be due to the possibility of strategic default risk. Debt renegotiation by strategic debt service provides higher credit spreads, whereby the models mentioned above succeed to generate realistic credit spreads.

However, recent empirical studies such as Davydenko and Strebulaev (2007) pointed out that the contribution of strategic debt service to credit spreads suggested by the theoretical models is too large. In fact, Davydenko and Strebulaev (2007) found that bond prices do appear to be affected by the possibility of debt renegotiation, while their quantitative contribution to both the average level and the cross-sectional level of credit spreads is below transaction costs.[1] Based on

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[1] Davydenko and Strebulaev (2007) also found the fact that the bond prices are likely to be affected by the possibility of debt renegotiation, especially when the costs of liquidation are likely to be high and credit quality of the issuer is relatively low.

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this result, they are inclined to suggest that debt holders are likely to have significant bargaining power, which limits equity holders' strategic behavior. Also, Acharya, Huang, Subrahmanyam, and Sundaram (2006) introduced the additional option that firms can carry cash reserves as protection against costly liquidation and concluded that debt renegotiation typically has a negligible effect on the yield spreads c of Anderson and Sundaresan (1996).

In this paper, we extend the existing models to the bivariate framework by introducing the value of tangible assets, which plays the role of collaterals. Because of the bivariate feature, we can distinguish strategic default, liquidity default and the ordinary liquidation. The possibility of liquidity default and liquidation without entering debt renegotiation is quite important from the pricing perspectives. If renegotiation always occurs in a given model, the effect of strategic debt service will be overstated and its contribution to credit spreads evaluated from the model becomes too high, which can explain the empirical findings in Davydenko and Strebulaev (2007). In fact, our model can produce credit spreads consistent with the empirical findings even when equity holders have full bargaining power. The contribution of strategic debt service to default premium depends on the underlying variables, in contrast to the existing models such as Mella-Barral and Perraudin (1997).

2. Debt valuation with tangible assets

We consider a firm with a set of tangible (or physical) assets that can yield revenues. Both the value of tangible assets, V, and the firm's EBIT (earnings before interest and tax), P, are modeled with correlation in a dynamic setting.[2] The instantaneous risk-free interest rate is assumed to be constant and denoted by r. Since we focus on the change of default strategy by introducing stochastic collaterals rather than the capital structure, we neglect the tax benefit and assume that corporate tax rate is zero for simplicity.

2.1. Basic assumptions

Suppose that the asset value V follows a geometric Brownian motion (GBM):

$$\frac{\mathrm{d}V(t)}{V(t)} = \mu_v\,\mathrm{d}t + \sigma_v \mathrm{d}B_1(t), \quad V(0) = v, \tag{1}$$

where μ_v and σ_v are some constants and B_1 is a standard Brownian motion. The asset needs to be maintained by expending a proportional cost ηV.[3]

On the other hand, the firm's EBIT P is assumed to follow another GBM:

$$\frac{\mathrm{d}P(t)}{P(t)} = \mu_p \mathrm{d}t + \sigma_p \mathrm{d}B_2(t), \quad P(0) = p, \tag{2}$$

where μ_p and σ_p are some constants and B_2 is another standard Brownian motion with constant correlation $\mathbb{E}[\,\mathrm{d}B_1 \mathrm{d}B_2] = \rho \mathrm{d}t$.

Note that our model can be seen as a bivariate extension of existing models in the literature. For example, if we replace the asset value V and the firm's EBIT P by a constant scrap value γ and earnings $p - w$, respectively, and neglect the maintenance cost ηV of tangible assets, then our model is reduced to the one considered in Mella-Barral and Perraudin (1997).[4]

[2] Many papers such as Mella-Barral & Perraudin (1997) and Mella-Barral (1999) consider a single state variable that is supposed to be positively correlated to revenues. In this paper, we explicitly consider both tangible assets and revenues with correlation.

[3] As we explain later, equity holders have an incentive to supply short-term funds by increase in capital even if the EBIT is substantially low.

[4] A concise proof is available from the authors upon request.

Throughout the paper, we assume that $\mu_v, \mu_p < r$ in order to ensure the existence of value functions of interest. Furthermore, for a levered firm, we assume the following.

Assumption 1. Levered firm

The firm issues a perpetual debt with contractual coupon rate c, face value c/r and collateral $\underline{C}(t) = \min\{V(t), c/r\}$. Moreover,

1. Equity holders can voluntarily default the firm. Upon default, debt holders own the residual assets and take over the firm as new equity holders.
2. Equity holders can liquidate the firm's tangible assets and repay the collateral to debt holders. In this case, the firm cannot go on.
3. The firm cannot redeem the debt. That is, the firm cannot turn back to a pure equity firm unless it experiences a default.

Hence, equity holders have options either to default or to liquidate the firm, depending on the state of the variables (V,P). If the firm is defaulted, debt holders take over the firm and it becomes a pure equity firm. If the firm is liquidated, debt holders receive the collateral $\underline{C}$ and equity holders will get the residual. Note that, after the firm becomes a pure equity firm, debt holders can liquidate the firm either immediately or after some time, depending on the state of the variables (V,P). We shall explain how default and liquidation occur in this setting later.

2.2. Pure equity firm

Before proceeding, we first consider a pure equity firm as a benchmark to the levered firm. To do so, we denote by W^* the equity value of the firm without debts (hence, W^* is equal to the firm value). Note that equity holders can receive the EBIT P minus the maintenance cost ηV as dividends. Hence, they will liquidate the firm against either a decrease in profits or defrayment of maintenance cost, and upon liquidation, they receive V as the liquidation payoff.

Suppose that $P(0) = p$ and $V(0) = v$, and consider the value function $W^*(p, v)$ of the pure equity firm. Let τ_0 be the liquidation time chosen by equity holders to maximize their own value. The value function is given by

$$W^*(p, v) = \sup_{\tau_0 \in \mathcal{T}_0} \mathbb{E}\left[\int_0^{\tau_0} \mathrm{e}^{-rt}(P(t) - \eta V(t))\mathrm{d}t + \mathrm{e}^{-r\tau_0} V(\tau_0)\right], \tag{3}$$

where $\mathcal{T}_0$ denotes the set of admissible stopping times in [0, ∞).

In order to preclude arbitrage opportunities, it is well known that the value function W^* satisfies the partial differential equation (PDE for short)

$$\mathcal{A}W^*(p, v) + p - \eta v = 0, \tag{4}$$

where the partial differential operator $\mathcal{A}$ is defined by

$$\mathcal{A}W^* = \frac{1}{2}p^2\sigma_p^2 W^*_{pp} + \frac{1}{2}v^2\sigma_v^2 W^*_{vv} + pv\sigma_p\sigma_v\rho W^*_{pv} + \mu_p p W^*_p + \mu_v v W^*_v - rW^*. \tag{5}$$

Note that the PDE (4) has no constant term and the payoff can be represented in terms of p/v only. Hence, we can find the value function $W^*(p, v)$ analytically by using the change-of-variable $z = p/v$. The proof of the next result is standard and omitted.

Proposition 1. Pure equity firm

The value function of the pure equity firm is given by

$$W^*(p, v) = \begin{cases} \dfrac{p}{r - \mu_p} - \dfrac{\eta v}{r - \mu v} + \dfrac{(r - \mu_v + \eta)v}{(1 - \lambda)(r - \mu_v)}\left(\dfrac{p}{b^* v}\right)^{\lambda}, & for\ \dfrac{p}{v} > b^*, \\ v, & for\ \dfrac{p}{v} \le b^*, \end{cases} \tag{6}$$