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The predictive performance of a path-dependent exotic-option credit risk model in the emerging market

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ABSTRACT

Most empirical research of the path-dependent, exotic-option credit risk model focuses on developed markets. Taking Taiwan as an example, this study investigates the bankruptcy prediction performance of the path-dependent, barrier option model in the emerging market. We adopt Duan's (1994) [11], (2000) [12] transformed-data maximum likelihood estimation (MLE) method to directly estimate the unobserved model parameters, and compare the predictive ability of the barrier option model to the commonly adopted credit risk model, Merton's model. Our empirical findings show that the barrier option model is more powerful than Merton's model in predicting bankruptcy in the emerging market. Moreover, we find that the barrier option model predicts bankruptcy much better for highly-leveraged firms. Finally, our findings indicate that the prediction accuracy of the credit risk model can be improved by higher asset liquidity and greater financial transparency.

1. Introduction

The standard theoretical paradigm for modeling credit risks is the contingent claims approach or *structural form credit risk model* pioneered by Black and Scholes [1] and Merton [2]. Much of the literature follows Merton [2] by explicitly linking the risk of a firm's bankruptcy to the variability in the firm's asset value and viewing the market value of firm's equity as the standard call option on the market value of firm's assets with strike price equal to the promised payment of corporate debts. Although these insights have a profound impact on financial economics, many researchers have formulated a variety of criticisms to the approach. Black and Cox [3], for instance, recognize one possible weakness of the approach in that default only occurs at the maturity of the debt. They propose to incorporate a barrier on the market value of firms' assets for triggering defaults prior to the maturity. Therefore, employing Merton's model to construct a credit risk model, Tudela and Young [4] release the default point setting which allows the sampling company defaults before the maturity of the debt. Meanwhile, Merton's model still embeds an unrealistic setting assuming that once at maturity the asset value is less than the debt value, then the company defaults. However, we often find that some companies are regarded as default even though their asset values are still higher than debt values. On the other hand, Crosbie and Bohn [5] point out that in some cases companies are still in business even though their asset values are below their debt values; these companies were regarded as default till their asset values are *far* below their debt values. This phenomenon implies that there exists a unique *default barrier level* for each company, and a company is deemed to be default when its asset value touches the default barrier

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level from above. According to historical default data, Moody's KMV arbitrarily claims that any company's default barrier level equals the summation of its short-term debt and a half of its long-term debt. Through simulation Leland and Toft [6] demonstrate that the default barrier level of a company is around 27% and 36% of its asset value. As a result, a down-and-out barrier call option is proposed to model the firm's equity value, and the credit risks are estimated from the barrier-option credit risk framework.

Brockman and Turtle [7] provide empirical validation of the barrier option model by deriving the default barriers from the market value of firm's equity and showing that implied default barriers are statistically and economically significant for a large sample of industrial firms. Reisz and Perlich [8] and Wong and Choi [9] also employ a barrier option framework to construct a credit risk model, and both the results of Monte Carlo simulation and empirical study show that a unique default barrier level does exist for each company. Reisz and Perlich [8] also point out that Merton's model, in which the default barrier is set to zero, implies that the managers can unlimitedly invest in high risk projects; on the other side, the barrier-option credit risk model, in which the default barrier is positive, is a more realistic model since it restricts the capital budgeting activities of the managers. Reisz and Perlich [8] claim that the sampling company's default level is about 30% of its asset value, which is very close to the ratio estimated by Leland and Toft [6].

The key to the structural form credit risk model is the estimation of the unobservable variables including company's asset value and its asset value volatility. Three estimation approaches are found in the literature: the ad hoc approach, the Ronn and Verma [10] method, and the transformed-data Maximum Likelihood Estimation (MLE) proposed by Duan [11,12]. The ad hoc approach adopt by Brock and Turtle [7] uses the sum of the market value of firm's equity and the book value of firm's debt as a proxy for the market value of firm's assets. However, Wong and Choi [9] and Chou and Wang [13] argue that the empirical findings of Brockman and Turtle [7] seem to convey some biases. They provide both theoretical and empirical evidence to show that the proxy adopted by Brockman and Turtle [7] for the market value of firm's assets is inappropriate for testing the validity of the barrier option model.

The second estimation approach is the Ronn and Verma (RV) method. Basically the RV method tries to estimate the unobservable parameters through solving some nonlinear equations. Many deposit insurance models use the RV method to estimate model parameters, such as Jones et al. [14], Duan and Yu [15] and Duan, Moreau and Sealey [16]. However, Duan and Yu [15] criticize the RV method in the essence that it is merely a calculation process, not an approach for statistical estimation. Meanwhile, as argued by Duan [11,12], the assumption in the RV method, a *constant* asset volatility, is not consistent with the premises of Merton's model. Duan [11,12] hence proposes a transformed-data MLE method to directly estimate the market value of firm's assets along with the asset value volatility and the default barrier from the market value of firm's equity. Duan et al. [17] point out that the RV method is only a special case of the MLE method. Duan et al. [18,19], Duan et al. [17], Erission and Reneby [20], Reisz and Perlich [8], and Chou and Wang [13] all employ the MLE method to estimate asset value and asset value volatility in the study.

The purpose of this study is to investigate the empirical performance of the barrier option model in the case of Taiwan. Most of the related studies focus on developed markets. Developed markets, for example, US and Japan, where firms are bigger and more mature, are more liquid and more efficient than emerging markets like Mexico and Taiwan. To the best of our knowledge, no research has ever used a sample of firms from emerging markets to examine the bankruptcy prediction performance of the barrier option model. We thus adopt Duan's [11,12] transformed-data MLE method to directly estimate the unobserved capital structure parameters, and compare the bankruptcy predictive ability of the barrier option model to the commonly adopted credit risk model, Merton's model.

The contribution of this study is threefold: (1) it focuses on the credit risk in an emerging market, (2) it adopts the transformed-data MLE method, not the RV method or the ad hoc method, to estimate model parameters, and (3) it uses a sample of Taiwanese listed and non-listed firms to examine the impact of asset liquidity and financial transparency on the forecasting ability of the barrier-option credit risk model. We believe that the empirical results of this study can fill a void in the credit risk literature by providing empirical evidence on the predictive performance of a barrier-option credit risk in the emerging market.

The remainder of this paper is organized as follows. Section 2 presents the barrier option model. Section 3 describes our data sample. Section 4 describes the methodology of transformed-data MLE method. Section 5 reports and interprets our empirical findings. Section 6 concludes.

2. Model

According to Black and Cox [3], the market value of firm's equity can be viewed as a European down-and-out call (DOC) option[1] on the market value of firm's assets. If the firm's asset value falls below a pre-specified barrier level, the firm's equity can be knocked out by bankruptcy.

Assuming that the market value of firm's assets follows a geometric *Brownian motion* in a risk-neutral world,[2] the dynamics of the firm's asset value can be written as

$$\mathrm{d}\ln V_t = (r - \sigma^2/2)\mathrm{d}t + \sigma \mathrm{d}Z_t, \tag{1}$$

[1] i.e., a barrier option.

[2] *Brownian motion* has been used in Physics to describe the motion of a particle that is subject to a large number of small molecular shocks and is usually assumed for the price dynamics of financial assets, as in the case of the Black–Scholes model. However, the *Brownian motion* model requires an assumption