Journal of Economic Dynamics & Control 47 (2014) 263–281

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Corporate credit risk prediction under stochastic volatility and jumps

Di Bu [a], Yin Liao [b,*]

[a] University of Queensland, Brisbane, QLD 4001, Australia
[b] Queensland University of Technology, Brisbane, QLD 4000, Australia

ARTICLE INFO

Article history:
Received 30 September 2013
Received in revised form
1 August 2014
Accepted 7 August 2014
Available online 23 August 2014

JEL classification:
C22
G13

Keywords:
Credit risk
CDS spread
Merton model
Stochastic volatility
Jumps

ABSTRACT

This paper examines the impact of allowing for stochastic volatility and jumps (SVJ) in a structural model on corporate credit risk prediction. The results from a simulation study verify the better performance of the SVJ model compared with the commonly used Merton model, and three sources are provided to explain the superiority. The empirical analysis on two real samples further ascertains the importance of recognizing the stochastic volatility and jumps by showing that the SVJ model decreases bias in spread prediction from the Merton model, and better explains the time variation in actual CDS spreads. The improvements are found particularly apparent in small firms or when the market is turbulent such as the recent financial crisis.

1. Introduction

The recent financial crisis has spurred renewed interest in developing sophisticated methods to model the corporate credit risk. Structural and reduced form approaches represent the two primary classes of such models, and play increasingly important roles in corporate risk management and performance evaluation processes. While the reduced form approach models credit defaults as exogenous events driven by a stochastic process, the structural approach provides an explicit relationship between default risk and corporate capital structure. In this sense, structural models are more referring to economic fundamentals and provide an endogenous explanation for corporate default.

The first model by Merton (1974) laid the foundation to the structural approach and this has served as the cornerstone for all other structural models. Despite the great success of the Merton model, the assumption in the model that asset return follows a pure diffusion has long been criticized. There are many studies showing that the pure diffusion assumption is overly restrictive and causes the Merton model to estimate the credit risk measures with a large bias. In theory, the log-normal pure diffusion model fails to reflect many empirical phenomena, such as the asymmetric leptokurtic distribution of the asset return, volatility smile and the large random fluctuations in asset returns. Since all of these features play key roles in structural credit risk modeling, one will produce misleading risk estimates because of ignoring them. For example,

* Corresponding author. Tel.: +61 7 3138 2662.
E-mail addresses: d.bu@business.uq.edu.au (D. Bu), yin.liao@qut.edu.au (Y. Liao).

http://dx.doi.org/10.1016/j.jedc.2014.08.006
0165-1889/

Jones et al. (1984) analyzed 177 bonds issued by 15 firms and found that the Merton model overestimated bond prices by 4.5% on average. Eom et al. (1994) empirically tested the performance of the Merton model in predicting corporate bond spreads and suggests that the predicted spreads from the Merton model are too much lower than the true counterparts. Tarashev (2005) claimed that the default probability generated by the Merton model is significantly less than the empirical default rate and Huang and Hao (2008) documented the inability of the existing structural models to capture the dynamic behavior of credit default swap (CDS) spreads and equity volatility. These empirical findings pointed potential roles of time-varying asset volatility and jumps in credit risk modeling.

The objective of this paper is to generalize the structural model to allow for stochastic volatility and jumps (SVJ) in the underlying asset returns, as well as study the property of the SVJ structural model in corporate credit risk prediction. Basically, the SVJ model is not novel as it has been widely used in the option pricing literature. However, its application in credit risk modeling is relatively new. The only related work was Fulop and Li (2013) which showed an application of the structural model with stochastic volatility (SV) in evaluating the credit risk of Lehman Brothers. However, their work mainly focused on the estimation of the SV structural model. This paper goes further to also consider jumps and examining the impact of allowing for both stochastic volatility and jumps in a structural model on corporate credit risk prediction. To the best of our knowledge, this is the first time an explicit study has been done on the benefit of recognizing stochastic volatility and jumps in asset returns for credit risk prediction. The research is useful for current practice where structural credit risk models with constant asset volatility still predominate. Specifically, we employ Bates (1996) model as an example of a SVJ model to describe the evolution of the asset returns. Jumps in Bates (1996) only appear in the return equation and are treated as a poisson process with constant intensity. The empirical observations in recent financial market turmoils have suggested that jumps are extreme events which tend to be clustered, and jumps in asset returns tend to be associated with an abrupt movement in asset volatility. This presents the possibility to allow for jumps in both asset returns and volatilities and therefore to use self-exciting jump clustering in structural models to improve credit risk predictions. We leave these interesting possibilities for later work.

Despite its attractiveness, the estimation of the SVJ model poses substantial challenges. In essence, the SV structural model is a non-linear and non-Gaussian state-space model. But it differs from the standard state-space model in several ways. First, after allowing the asset return to have stochastic volatility and jumps, the likelihood function of the observed equity prices is no longer available in a closed form. The commonly used MLE type estimation cannot be applied. Furthermore, the additional state variables that determine the level of volatility increase the dimension of the latent states. Thirdly, the additional jump related unknowns increase the dimension of parameter uncertainty. We employ a Bayesian learning algorithm by following the marginalized resample-move (MRM) approach of Fulop and Li (2013) to solve this estimation problem. This algorithm is able to deliver exact draws from the joint posteriors of the latent states and the static parameters.

A Monte Carlo study is conducted to examine the property of the SVJ model in corporate credit spread prediction. The exercise is based on a comprehensive set of simulation designs, which embody several features of the asset return data. To illustrate the benefit of allowing for time-varying volatility, we compare the SVJ model with the Merton model under a jump diffusion process with stochastic volatility and a pure diffusion with constant volatility. To reveal the important role of jumps, we compare the SVJ model with the SV model based on a jump diffusion process with stochastic volatility and a stochastic volatility process without jumps. The simulation results suggest that when the actual return is a pure diffusion, the results from all three models are almost identical with the Merton model performing slightly better. However, in more realistic situations where the actual return has a stochastic volatility or has both stochastic volatility and jumps, the SVJ and SV models largely outperform the Merton model, and the SVJ model with jumps shows further improvement over the SV model. In short, the SVJ model turns out to be the best of the models, and three sources are analyzed to show its superiority. First, the volatility dynamics and jumps allowed in the SVJ model can better depict the mean level of credit spread. Second, the SVJ model better tracks the changes in credit spread because of the time-varying volatility and the more realistic functional form between asset and equity values. Lastly, the jump component in the SVJ model better captures the extreme movements in credit spread.

We further implement the SVJ model on two real samples to empirically evaluate its ability. The first samples consists of 20 Dow Jones firms which represent the large-cap companies, and the second includes 200 firms randomly selected from CRSP which represent the general population of the US corporate sector. From each sample, we indeed find significant stochastic volatility and jumps in the asset returns. The impact of ignoring asset volatility dynamics and jumps in credit risk modeling is also studied. We find that the SVJ and SV models always provide better credit spread predictions than the Merton model, and the SVJ model shows further improvement over the SV model. On average, the SVJ model raises the spread prediction from the Merton model by 6.5 basis points in the 20 Dow Jones firms, and 8 basis points in the 200 CRSP firms. Meanwhile, the SVJ model provides a better explanation of the time variation in actual 5-year CDS spreads by increasing the R^2 of the Mincer–Zarnowitz regression up to 8% and 10% in the two samples studied. These prediction improvements are found to be particularly apparent in small firms or when the market is turbulent such as in the recent financial crisis.

The remainder of this paper is organized as follows. Section 2 presents in detail the SVJ model specification, estimation and application in credit risk prediction. Section 3 conducts a Monte Carlo simulation to study the property of the SVJ model in credit risk prediction. Section 5 provides two empirical analyses of the SVJ structural model using 20 Dow Jones firms and 200 randomly selected CRSP firms, and Section 4 is the conclusion.