



Firm-specific credit risk estimation in the presence of regimes and noisy prices[☆]



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ABSTRACT

Security prices are important inputs for estimating credit risk. Yet, to obtain an accurate firm-specific credit risk assessment, one needs a reliable model and a methodology that filters the elements unrelated to the firm's fundamentals from market prices.

In this article, we introduce a hybrid credit risk model defined in a Markov-switching environment. It captures firm-specific changes in the leverage uncertainty during crises. We also propose a new efficient method to estimate the model, and a numerical scheme based on trinomial lattices to price credit derivatives. The estimation is finally performed on more than 200 firms using maximum likelihood estimation.

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1. Introduction

Credit risk is one of the most important risk faced by portfolio managers. Yet, it is difficult to assess this risk as defaults are rare events. To overcome this challenge, a common practice is to use credit ratings as a proxy for firm-specific credit risk. However, in the aftermath of the crisis, credit ratings were criticized and many stakeholders started advocating for market-based valuation of credit risk, which uses security prices as the primary input in the assessment. Indeed, market prices are forward-looking measures and are updated frequently by market participants, allowing for a market-consistent credit risk appraisal.

Yet, the market-based valuation brings new challenges: for instance, the observed prices can diverge from their theoretical values as risks unrelated to their fundamentals could be priced (e.g., illiquidity, asymmetric information, price dis-

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creteness, market noise). To obtain an accurate firm-specific credit risk assessment, a methodology that filters the elements unrelated to the firm's fundamentals is needed. In the literature of credit risk, some recent estimation procedures allow for noisy observations. Indeed, [Duan and Fulop \(2009\)](#) propose an estimation technique based upon particle filtering for [Merton \(1974\)](#) model while accounting for trading noise in observed equity prices. The authors show that ignoring noise inflates the estimate of the asset volatility. [Huang and Yu \(2010\)](#) introduce an alternative estimation technique based on Markov-chain Monte Carlo (MCMC) methods for the same credit risk framework. According to the authors, noises are positively correlated with firms' values. In a hybrid credit risk framework, [Boudreault et al. \(2013\)](#) use the unscented Kalman filter (UKF) to extract the latent creditworthiness from credit default swap (CDS) premiums. More recently, [Kwon and Lee \(2015\)](#) use MCMC to estimate the [Black and Cox \(1976\)](#) model, whereas [Guarin et al. \(2014\)](#) propose a filtering technique to extract the time-varying default risk from CDS premiums.

Firm-specific estimation of credit risk in the previously cited papers is simplified because these frameworks are based on single-factor models. As the last financial crisis showed, credit spreads and other solvency indicators exhibit structural changes. Regime-switching dynamics are able to capture behaviour changes similar to those associated with a crisis by allowing for dynamic levels of uncertainty. Such regime-switching approaches are also very intuitive in the context of crises; in its most simplistic form, one could have a regime associated with 'good' times and another with 'bad' times.¹ However, maximum likelihood estimation (MLE) in the presence of regimes and noisy market prices is complicated because both regimes and noises are not directly observed.

This paper contributes to the current credit risk literature by proposing a Markov-switching model and a consistent estimation technique for the assessment of credit risk. Our credit risk model includes a firm-specific statistical regime variable that accommodates for changes in the leverage uncertainty. The endogenous random recovery rates are negatively related to default probabilities as they both depend on the firm's financial health. Finally, the framework accounts for the presence of noise as market prices potentially include measurement errors.

The model is estimated by MLE using a filtering approach that we design for the issue at hand: two latent variables (i.e., leverage and regime) shall be filtered simultaneously in addition to the model's parameters, which need to be estimated for each firm. The proposed filter has numerous advantages: (1) it is possible to use multiple data sources to help disentangle some effects that cannot be separated using a single product, (2) it allows us to use time series of derivatives to capture the dynamics under both objective and risk-neutral probability measures simultaneously, and (3) the numerical implementation of the filter is fast and efficient. Since the model estimation is based on security prices, we also propose a numerical scheme based on trinomial lattices that allow for pricing in the framework. The model is then estimated with CDS premiums for each of the 225 firms of both CDX North American IG and HY indices.

The rest of this paper is organized as follows. The joint default and loss model is presented in [Section 2](#). [Section 3](#) explains the model estimation approach and the pricing methodology. The estimation results are discussed in [Section 4](#). Finally, [Section 5](#) concludes.

2. Credit risk model

In this paper, the shell approach of [Boudreault et al. \(2013\)](#) is extended to capture the time-varying nature of the leverage volatility.² The shell is essentially an intensity process that depends on the firm's leverage, which is modelled by Markov-switching dynamics. We favour a regime-switching framework instead of a time varying volatility model – either GARCH-type or stochastic volatility (SV) model – for two main reasons. First, regime switches allow for fast and steep changes in volatility whereas GARCH or SV models implicitly assume that volatility changes steadily. Second, derivative pricing under a regime-switching model is numerically efficient. Indeed, considering a continuum of values for the volatility increases the computational burden; one way to circumvent this issue is by using a small number of potential values, which is the case proposed in our hidden Markov chain framework.

This flexible approach allows for an endogenous recovery rate that is both stochastic and negatively correlated with the firm's probability of default. The estimation method and derivative pricing procedure under the new Markov-switching generalization require the implementation of sophisticated numerical methods, as explained in [Section 3](#) of this article.

Let L_t and A_t be the time t present value of the firm's liabilities and the time t market value of the firm's assets, respectively. The leverage ratio is defined as the quotient of these two values.³ Because the asset volatility is not constant in time, the model should be flexible enough to capture the changes in the state variable dynamics. Hence, the market value of the firm's log-leverage is characterized by the following regime-switching dynamics:

$$\log\left(\frac{L_t}{A_t}\right) \equiv x_t = x_{t-1} + \left(\mu_{s_t}^{\mathbb{P}} - \frac{1}{2}\sigma_{s_t}^2\right)\Delta + \sigma_{s_t}\sqrt{\Delta}\epsilon_t^{\mathbb{P}}, \quad (1)$$

¹ As documented by various authors, CDS premium dynamics and credit spreads change during financial crises. The dynamics of CDS premiums are investigated by [Huang and Hu \(2012\)](#) during the 2008 crisis by applying a smooth-transition autoregressive model. [Maalaoui Chun et al. \(2014\)](#) study regimes by applying a regime-detection technique that distinguishes between level and volatility regimes in credit spreads and show that most breakpoints occur around economic downturns, thus linking the statistical regimes to financial crises.

² Volatility is important in credit risk models. For instance, [Zhang et al. \(2009\)](#) show that volatility risk predicts 48% of the variation in the CDS spreads using a Merton-type structural model, a calibration approach and equity data.

³ The leverage ratio L_t/A_t is not constrained to lie within the unit interval since L_t is the liabilities value and not the debt value. The liabilities value L_t could thus be larger than A_t . We prefer market-based estimates of A_t and L_t over book values as book values are only available four times per year.

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