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Credit rating dynamics and Markov mixture models ☆

Halina Frydman [a,1], Til Schuermann [b,*]

[a] Stern School of Business, New York University, New York, NY 10012, United States
[b] Federal Reserve Bank of New York and Wharton Financial Institutions Center, 33, Liberty Street, New York, NY 10045, United States

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Abstract

Despite mounting evidence to the contrary, credit migration matrices, used in many credit risk and pricing applications, are typically assumed to be generated by a simple Markov process. Based on empirical evidence, we propose a parsimonious model that is a mixture of (two) Markov chains, where the mixing is on the speed of movement among credit ratings. We estimate this model using credit rating histories and show that the mixture model statistically dominates the simple Markov model and that the differences between two models can be economically meaningful. The non-Markov property of our model implies that the future distribution of a firm's ratings depends not only on its current rating but also on its past rating history. Indeed we find that two firms with identical current credit ratings can have substantially different transition probability vectors. We also find that conditioning on the state of the business cycle or industry group does not remove the heterogeneity with respect to the rate of movement. We go on to compare the performance of mixture and Markov chain using out-of-sample predictions.

JEL classification: C13; C41; G12; G20

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1. Introduction

In the study of credit rating dynamics of firms, it is very convenient to assume that the ratings process is time homogeneous Markov. The credit migration or transition matrix, which characterizes past changes in credit quality of these firms, is then all that is needed to generate forecasts of the credit asset portfolio distribution in the future. Moreover, in the continuous time homogeneous Markov framework, the objective is to estimate a generator matrix which is used to compute the credit transition matrix, allowing for forecasts over any time horizon.

Against this convenience is mounting evidence of non-Markovian behavior of the rating process. Altman and Kao (1992), Carty and Fons (1993), Altman (1998), Nickell et al. (2000), Bangia et al. (2002), Lando and Skødeberg (2002), Hamilton and Cantor (2004) and others have shown the presence of non-Markovian behavior such as ratings drift and industry heterogeneity, and time variation due in particular to the business cycle. The literature is only recently beginning to propose modeling alternatives to address these departures from the Markov assumption. For example, Christensen et al. (2004) consider the possibility of latent "excited" states for certain downgrades in an effort to address serial correlation of ratings changes (or ratings drift). Giampieri et al. (2005) use a hidden Markov model to back out the state of the economy from ratings dynamics, although their model focuses just on default prediction, and Stefanescu et al. (2006) consider a

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* Corresponding author. Tel.: +1 212 720 5968; fax: +1 212 720 8363.
E-mail addresses: hfrydman@stern.nyu.edu (H. Frydman), til.schuermann@ny.frb.org (T. Schuermann).
[1] Tel.: +1 212 998 0453.

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simulation-based Bayesian approach which allows for some ratings momentum.

This paper considers a different type of non-Markov behavior than discussed in the extant literature and proposes a non-Markov model which is a generalization of a continuous time homogeneous Markov chain. A continuous time homogeneous Markov chain has the property that durations in states (spells) follow an exponential distribution. An exponential distribution has a constant hazard function which implies that the plot of the integrated hazard function against time is a straight line. We show that this property is violated for credit rating dynamics, albeit differently for different ratings. Firms with the same rating migrate at different speeds, a feature which is not admitted in the Markov model.

Motivated by these empirical findings, we propose a new model for the ratings migration process, namely a mixture of two independent continuous time homogeneous Markov chains. The two Markov chains differ only in their implied migration speed, specifically in the rates with which they exit the states; they have the same embedded transition probability matrix.[2] The model assumes that there are two subpopulations of firms, each moving according to its own Markov chain. It implies that a duration in a state is generated by one or the other of the two exponential distributions so that the observed durations in a given state come from a mixture of two exponential distributions.

This is a nontrivial generalization of the basic Markov migration model: instead of forcing all firms of a given rating to migrate at the same speed regardless of their rating experience to date, the mixture process allows for rich and nuanced migration behavior across firms which all have the same rating today (but arrived at that rating in different ways).

We estimate the mixture model with corporate credit rating histories from Standard & Poor's spanning 1981–2002 using an algorithm developed in Frydman (2005). We show that the mixture model not only statistically dominates the simple Markov model but that the differences between two models can be economically meaningful; for the $\mathscr{CCC}$ rating, pricing differences of the mixture model can range from 30% to 57% relative to the value implied by the Markov model. The non-Markov property of our model implies that the future distribution of a firm's ratings depends not only on its current rating but also on the past history of its ratings. Thus, unlike in a Markov model, all firms with a particular current rating are *not* assigned the same future distribution of ratings.

This paper's contribution is twofold, one methodological and the other empirical. Our methodological contribution to the approach developed in Frydman (2005) consists of deriving explicit expressions for a firm's future ratings distribution conditional on past information. We show how this distribution differs depending on the available information which has particular relevance for practitioners. One may know the entire history, only a subset (say the last five years), or just the current rating.

We find that, under our model, two firms with identical current credit ratings can have substantially different future distributions of ratings. We show that firm specific transition probabilities can vary a lot, a source of heterogeneity which is obscured by the Markov approach. This is further illustrated using a bond pricing example.

Despite this predicted variation, it remains an open question whether the simplicity of the Markov model results in markedly worse out-of-sample performance. With this in mind, we conduct out-of-sample forecast evaluations of the Markov against the mixture model. Although the literature has recently proposed and developed some alternatives to the standard Markov model, to our knowledge we are the first to conduct systematic out-of-sample forecast evaluations. We find that the one year out-of-sample average error rate is about 4% lower for the mixture than for the Markov model.[3] Our findings of the Markov model's robust performance is consistent with recent work by Kiefer and Larson (2006) who find that for typical forecast horizons, say one or two years, credit rating dynamics can be adequately modeled as a Markov chain, albeit based only on in-sample analysis. Conditioning on industry or state of the business cycle does not alter the basic results.

Credit ratings and consequently credit migrations find wide applications in finance. These include bond pricing models like Jarrow and Turnbull (1995) and Jarrow et al. (1997), credit derivative pricing models like Kijima and Komoribayashi (1998) and Acharya et al. (2002), as well as credit portfolio models such as CreditMetrics by Gupton et al. (1997). This topic also has significant policy relevance given the pending new banking regulation around the New Basel Capital Accord where capital requirements are driven in part by ratings migration (BIS, 2005).

The plan for the remainder of the paper is as follows: Section 2 defines a Markov mixture model, discusses its estimation from continuous credit ratings histories and derives some of its probabilistic properties. In Section 3, we provide a synopsis of the data set, discuss the estimation results, and compare a mixture model with a simple Markov model empirically, in and out-of-sample, and in terms of economic implications. Section 4 provides some concluding remarks.

2. Markov mixture modeling

Firms may take on one of 17 credit ratings, including +/− modifiers, as well as the default ($\mathscr{D}$) rating, and

[2] Given that the jump from state x occurs, the probability that it is to state y is the same for both chains. The proposed model captures observed heterogeneity in the rate of movement, but is not intended to capture ratings drift per se.

[3] Stefanescu et al. (2006) conduct an out-of-sample exercise focusing only on transitions to default rather than all transitions.