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Bayesian inference for issuer heterogeneity in credit ratings migration ☆

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Abstract

Rating transition matrices for corporate bond issuers are often based on fitting a discrete time Markov chain model to homogeneous cohorts. Literature has documented that rating migration matrices can differ considerably depending on the characteristics of the issuers in the pool used for estimation. However, it is also well known in the literature that a continuous time Markov chain gives statistically superior estimates of the rating migration process. It remains to verify and quantify the issuer heterogeneity in rating migration behavior using a continuous time Markov chain. We fill this gap in the literature. We provide Bayesian estimates to mitigate the problem of data sparsity. Default data, especially when narrowing down to issuers with specific characteristics, can be highly sparse. Using classical estimation tools in such a situation can result in large estimation errors. Hence we adopt Bayesian estimation techniques. We apply them to the Moodys corporate bond default database. Our results indicate strong country and industry effects on the determination of rating migration behavior. Using the CreditRisk+ framework, and a sample credit portfolio, we show that ignoring issuer heterogeneity can give erroneous estimates of Value-at-Risk and a misleading picture of the risk capital. This insight is consistent with some recent findings in the literature. Therefore, given the upcoming Basel II implementation, understanding issuer heterogeneity has important policy implications.

JEL classification: C11; C13; C41; G12

Keywords: Credit risk; Risk capital; Markov chains; Bayesian inference; Heterogeneity

1. Introduction

Markov chains (c.f. Norris, 1997), and more specifically, a time-homogenous, discrete time Markov chain has been extensively used to model the ratings migration process for corporate bonds and bond issuers. Having accepted this model, the actual reported transition probability matrices can vary considerably depending on the actual data and estimation methodology used (c.f. Altman, 1998). Such modelling has often further assumed that the rated entities are homogeneous with respect to their rating migration behavior. Deviation from this added assumption has been the subject of several studies that highlight latent and observable sources of heterogeneity such as the issuer's age, country of domicile, stage in the business cycle, etc. (c.f. Frydman and Schuermann, 2007; Chava et al., 2006, Frydman and Kadam, 2004; Bangia et al., 2002; Nickell et al., 2000; Lucas and Lonski, 1992; Asquith et al., 1989 and research summary reports published by rating agencies such as Moody's KMV, Standard & Poor's and Fitch on their web-sites). However, it is well known in the literature that a continous time Markov chain gives statistically superior estimates of the rating migration process (c.f. Jarrow et al., 1997; Lando and Skodeberg, 2002; Christensen et al., 2004). It remains to verify and quantify the issuer heterogeneity in rating migration behavior using a contin-

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ous time Markov chain. We fill this gap in the literature. Such an exercise would be redundant if every observed rating transition matrix of a discrete time Markov chain could result unambiguously from a continuous time Markov chain rating migration process. However, in general, neither existence nor uniqueness of solution to this embedding problem is assured (c.f. Schonbucher, 2003; Bluhm et al., 2002 or Israel et al., 2001).

In some sense our modelling framework is similar to Frydman and Kadam (2004) and Frydman and Schuermann (2007). Both of these apply continuous time Markov chain based mixture models to ratings data. The discrete time model of Chava et al. (2006), explicitly addressing issuer heterogeneity, has a similar motivation. However, all of these use maximum likelihood estimation for model calibration.

We provide Bayesian estimates to mitigate the problem of data sparsity. Default data, especially when narrowing down to issuers with specific characteristics, can be highly sparse. Using classical estimation tools in such a situation can result in large estimation errors. In contrast, Bayesian methods have two major advantages.

The first advantage of Bayesian methods in this context is that of estimation accuracy. Stefanescu et al. (2007), who also advocate Bayesian methodology for calibrating models for rating transition probabilities using historical data, assert "Model calibration for this type of application is difficult in a classical frequentist estimation framework, because the sparsity of data often leads to unrealistic transition probabilities". Because of the nature of estimation procedure, we are able to provide estimates for an arbitrary issuer profile even if data on that profile may be a very small part of the sample we use for estimation. For instance the rating evolution for Japanese issuers in the Utility sector can be estimated although this type of issuers comprise only 0.1% of the data. This is made possible by combining the information on Japanese issuer transitions (3% of the sample) and on Utility sector issuer transitions (10% of the sample). The estimation error in doing this using a frequentist approach may be quite large.

The second advantage of Bayesian estimation is the incorporation of expert opinion or subjective beliefs (such as for instance those imposed during stress-tests for models) via prior distributions for rare events (such as rating transitions or defaults). As pointed out by McNeil and Wendin (2007), who also advocate Bayesian estimation for portfolio credit risk applications, this "could, in a sense, allow us to draw stronger conclusions about default risk than is possible from an analysis of empirical defaults alone". In our empirical analysis, we used highly noninformative priors but given default data sparsity, incorporating prior beliefs is a valuable tool that can be potentially prove quite useful.

A third side-benefit of using Bayesian inference is also that it becomes straightforward to compute the transition or default probability interval estimates which are becoming increasingly popular; see for instance Christensen et al. (2004). We do not provide such estimates here so as not to distract from our primary focus viz. heterogeneity which can be demonstrated with point estimates.

Our empirical results build upon the work of Nickell et al. (2000), who made a significant contribution to the literature by fitting a probit model to discrete rating data. Their model-based approach allows for each qualifier of interest (e.g. country of domicile), a conditional transition matrix (over a given time period), estimated by conditioning on values taken by that variable (e.g. USA, UK and Japan), having controlled for other sources of variation (e.g. industry type). Their ordered-probit model assumes that rating changes when an unobserved, latent measurement falls into disjoint, adjacent intervals. An advantage of this approach is that a common set of parameters for the latent measure is used for each rating state. In our model, the transition parameters depend on the current state of the process, which provides a more flexible model than the ordered-probit at the cost of a significantly larger parameter space. Fortunately, the issuer rating dataset we use is large, and Bayesian inference enables the estimation of a large number of parameters. Furthermore, we explicitly model duration viz. the time spent by an issuer in the current rating before making a transition to the future rating. Modelling the duration explicitly allows us to provide a richer understanding of rating stability. The variability in duration times for the dataset we used is quite high both within and across rating categories. This suggests that the average stay period in any given rating is not a reliable summary statistic. A key feature of this paper vs. other discrete time Markov chain model-based papers (such as Nickell et al., 2000) is that duration times have a model that captures this large variability.

Given the use of Bayesian techniques in ratings migration context, our work shares some similarities with McNeil and Wendin (2006). Their model, however, is quite different. It is set in discrete time, and not Markov chain based. In particular, it allows for serially correlated unobserved risk factors that affect the rating migrations process. This serial correlation gives joint migration distributions in terms of high dimensional integrals, which are awkward for standard maximum likelihood procedures; Bayesian estimation circumvents this problem.

Our results indicate strong country and industry effects on the determination of rating migration behavior. For instance, issuer default probability shows a clear ordering across countries: UK > Canada > US > EU > Japan. Utility sector issuer ratings are generally more stable and whereas Banking sector issuer ratings are generally less stable; Industrial sector issuer ratings lie somewhere in between. A possible explanation for country heterogeneity is the cross-country variation in bankruptcy codes, corporate governance and accounting standards. A possible explanation for sector heterogeneity is the cross-sector variation in the uncertainty of future revenue streams.