Prediction of Individual Bond Prices via a Dynamic Bond Pricing Model: Application to Japanese Government Bond Price Data

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Abstract. In this paper, we propose a dynamic bond pricing model and report the usefulness of our bond pricing model based on analysis of Japanese Government bond price data. We extend the concept of the time dependent Markov (TDM) model proposed by Kariya and Tsuda (Financial Engineering and the Japanese Markets, Kluwer Academic Publishers, Dordrecht, The Netherlands, Vol. 1, pp. 1–20) to a dynamic model, which can obtain information for future bond prices. A main feature of the extended model is that the whole stochastic process of the random cash-flow discount functions of each individual bond has a time series structure. We express the dynamic structure for the models by using a Bayesian state space representation. The state space approach integrates cross-sectional and time series aspects of individual bond prices. From the empirical results, we find useful evidence that our model performs well for the prediction of the patterns of the term structure of the individual bond returns.

Key words: Bayesian state space representation, dynamic bond pricing model, Kalman filter, random cash-flow discount function

1. Introduction

We propose a dynamic bond pricing model to express the time series and cross-sectional structure of individual bond prices. The framework of our model includes the time dependent Markov (TDM) model proposed by Kariya and Tsuda (1994), which is a cross-sectional model of individual bond prices, but which does not include a time series structure to predict individual future bond prices. Our model is different from the TDM model in that we employ both of a time series and cross-sectional structure of individual bond price movements. On the other hand, our model is also quite different from many other normative bond pricing models modified for interest rate derivatives in that it directly models the random feature of coupon bond prices by the process of a random discount function (not by the formulation of spot and forward rate processes), and also prices all individual bonds having different attributes.

In addition, we propose a Kalman filtering approach based on a Bayesian state space model to estimate our dynamic bond pricing model and to predict individual bond prices. While the Kalman filtering approach is already traditional in
econometrics, it is still relatively new but growing in finance. In the literature, Babbs and Nowman (1999), and Geyer and Pichler (1999) employ the Kalman filtering approach for the estimation of the generalized Vasicek model and the K-factor’s Cox-Ingersoll-Ross model on interest rates, respectively.

We empirically tested our model with Japanese Government bond (JGB) data to investigate its usefulness. Our model performs very well as it stands. Our model is firstly estimated with the data sample period from January 1980 to December 1989 of monthly individual bond prices and predicts their prices at the end of January 1990, after which the data sample period is extended monthly until November 2002. In fact, the standard deviation of predicted price errors for the period 1990.1 through 2002.12 is 0.96 yen on the average, where the face value of a JGB is around 100 yen. Among 156 (12 month \times 13 years) months tested from 1990.1 through 2002.12, there were only 6 months with standard deviations of predicted price errors greater than 3.0 yen. In particular, our model well captures the patterns of the term structure of the realized returns of individual bonds. Moreover, we compare the predictive performance of our model with an approach based on the TDM model as follows. First, we estimate the parameters of the TDM model at each time \( t \). Next, we calculate individual bond prices of time \( t + 1 \) by predicting the parameters for which the model is assumed to have the same time series structure as our model. We found that the cumulative investment profit of the portfolio consisting of bonds chosen by our model was larger than the one chosen by the approach based on the TDM model. Hence, the information of our model has practical benefits for the construction of bond portfolios and bond trading.

The paper is organized as follows. In Section 2, we first summarize the concept of the TDM models proposed by Kariya and Tsuda (1994). Then we propose a dynamic bond pricing model to express the time series and cross-sectional structure of individual bond prices. Next, we present the estimation method of our model based on a Bayesian state space representation by using a Kalman filtering approach. In Section 3, we report the empirical results of the predictive performance of the models, where the usefulness of our model based on analysis of JGB price data is shown. In Section 4, we present our conclusion.

2. Bond Pricing Model

2.1. THE CONCEPT OF TIME DEPENDENT MARKOV MODEL

First, we provide a brief description of the concept of TDM model proposed by Kariya and Tsuda (1994), from which our model is derived. Individual bond prices are generated by investor preferences for various bond characteristics. The bond characteristics include not only directly observable prior issue attributes such as coupon rate and term to maturity but also unknown issue attributes which are impossible to identify in advance. The TDM model uses the past characteristics of the discount function as the proxy variables of the unknown issue attributes.