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Estimation for factor models of term structure of interest rates with jumps: the case of the Taiwanese government bond market

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Abstract

This paper examines the Ornstein–Uhlenbeck (O–U) process used by Vasicek, J. Financial Econ. 5 (1977) 177, and a jump-diffusion process used by Baz and Das, J. Fixed Income (Jnue, 1996) 78, for the Taiwanese Government Bond (TGB) term structure of interest rates. We first obtain the TGB term structures by applying the B-spline approximation, and then use the estimated interest rates to estimate parameters for the one-factor and two-factor Vasicek and jump-diffusion models. The results show that both the one-factor and two-factor Vasicek and jump-diffusion models are statistically significant, with the two-factor models fitting better. For two-factor models, compared with the second factor, the first factor exhibits characteristics of stronger mean reversion, higher volatility, and more frequent and significant jumps in the case of the jump-diffusion process. This is because the first factor is more associated with short-term interest rates, and the second factor is associated with both short-term and long-term interest rates. The jump-diffusion model, which can incorporate jump risks, provides more insight in explaining the term structure as well as the pricing of interest rate derivatives. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Financial variables such as stock prices, foreign exchange rates, and interest rates are conventionally assumed to follow a diffusion process with continuous time paths when pricing financial assets. Despite their attractive statistical properties and computation convenience, more and more empirical evidence has shown that pure diffusion models are not appropriate for these financial variables. For example, Ball and Torous (1983), Jarrow and Rosenfeld (1984), Ball and Torous (1985a,b), Akgiray and Booth (1986), Lin and Yeh (1997), Jorion (1988) all found evidence indicating the presence of jumps in the stock price process. Akgiray and Booth (1988), Tucker and Pond (1988), Park et al. (1993) studied foreign exchange markets and concluded that the jump-diffusion process is more appropriate for foreign exchange rates. In pricing and hedging with financial derivatives, jump-diffusion models are particularly important, since ignoring jumps in financial prices will cause pricing and hedging risks.

The jump-diffusion process is particularly meaningful for interest rates, since the interest rate is an important economic variable, which is, to some extent, controlled by the government as an instrument for its financial policy. Hamilton (1988) investigated US interest rates and found changes in regime for the interest rate process. Das (1994) found movements in interest rates display both continuous and discontinuous jump behavior. Presumably, jumps in interest rates are caused by several market phenomena, such as money market interventions by the Fed, news surprises, shocks in the foreign exchange markets, and so on.

Classical term structure of interest rate models, such as the Vasicek (1977) model, the Cox et al., 1985 model, the Brennan and Schwartz (1978) model, and other extended models all assume that processes of state variables (such as the short-term interest rate, the long-term interest rate, or others), which drive interest rate fluctuations, follow various diffusion processes. Their assumptions are inconsistent with the a priori belief and empirical evidence regarding the existence of discontinuous jumps in interest rates. At a cost of additional complexity, Ahn and Thompson (1988) extended the CIR model by adding a jump component to the square root interest rate process. Using a linearization technique, they obtained closed-form approximations for discount bond prices. Similarly, Baz and Das (1996) extended the Vasicek model by adding a jump component to the Ornstein–Uhlenbeck (O–U) interest rate process, and obtained closed-form approximate solutions for bond prices by the same linearization technique. They also showed that the approximate formula is quite accurate.

Although theoretical derivations for the jump-diffusion term structure models have been developed, the associated empirical work is quite limited. A formal model of the term structure of interest rates is necessary for the valuation of bonds and various interest rate options. More importantly, parameter values or estimates are required for the implementation of a specific model. To price interest rate options, with closed-form solutions or by numerical methods, one must have values of the parameters in the stochastic processes that determine interest rate dynamics.