



Modeling spot rate using a realized stochastic volatility model with level effect and dynamic drift



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ABSTRACT

This paper proposes a class of realized stochastic volatility model based on both various realized volatility measures and spot rate. It applies the realized stochastic volatility model (Takahashi, Omori, & Watanabe, 2009, and Koopman & Scharth, 2013) to the spot rate model with dynamic drift and level effect setups (RSVL). A jointly approximated maximum likelihood procedure is used to estimate this model. The simulation results show that the RSVL model can be consistently estimated and noise-and-jump-robust realized volatility measures improve the accuracy of the estimation. This study empirically investigates the Chinese interbank repo market with RSVL model, which manifested the advantage of taking the level effect and nonlinear drift into consideration. The noise-and-jump-robust realized volatility measures (e.g. subsample realized volatility and threshold pre-average realized volatility) decrease the volatility fitting error. The nonparametric testing suggests that the RSVL model with noise-and-jump-robust realized volatility measures has more power on forecasting excess kurtosis and fat tails and predicting dynamics of higher order autocorrelations.

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1. Introduction

In this paper, we attempt to investigate several popular spot rate models with realized stochastic volatility specification and various realized volatility measures, and examine the information implied in these models. Different from the ordinary realized volatility models applied to the stock and exchange rate data, our realized volatility model can adapt to the spot rate data by considering nonlinear drift and level effect.

Traditional ways to model the dynamics of spot rate relied on single factor diffusion model. A huge literature has contributed to model the dynamics of spot rates with several kinds of spot rate models, e.g., Vasicek (1977, VASICEK), Cox, Ingersoll, and Ross (1985, CIR), Brennan and Schwartz (1980, BS), Chan, Karolyi, Longstaff, and Sanders (1992, CKLS), and Ait-Sahalia (1996, CEV), etc. These studies characterized some important features of spot rate in mature market such as that the U.S. market, but were found that they failed to capture volatility clustering, fat tails, and excess kurtosis of spot rates.

To cover the shortages, some literature extended the spot rate models with the specification of GARCH, regime switching, jump, and stochastic volatility, based on daily data of spot rate (Andersen & Lund, 1997; Fan & Zhang, 2007; Hong, Lin, & Wang, 2010; Johannes, 2004; Zheng & Song, 2011). Andersen and Lund (1997) and Ball and Torous (1999) found that a

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two-factor interest rate model with level interest rate and its stochastic volatility (SV) factor outperforms the GARCH volatility models, so the stochastic volatility model is a better choice to model the short-term spot rate. However, as pointed out by Alizadeh, Brandt, and Diebold (2002), Chou (2005), Brandt and Diebold (2006), and other authors, the return-based stochastic volatility models are inaccurate and inefficient, because they failed to use the information inside the reference period. Barndorff-Nielsen and Shephard (2002a) studied the use of realized volatility in estimating stochastic volatility model, and showed that the model-based methods may be particularly helpful in estimating historical records of actual volatility. Andersen, Bollerslev, Frederiksen, and Nielsen (2010) and Thomakos and Wang (2003) found that the empirical density of returns standardized by realized volatility (RV) was closer to normal than that of the standardized residuals from parametric stochastic volatility (SV) models estimated at the daily frequency. Therefore, the recent advent of readily available high-frequency data has spurred our interest to study the spot rate models by using stochastic volatility and realized volatility measures.

Problems, such as market microstructure noise and jump effect, will inevitably occur when estimating realized volatility measures from high-frequency data. Any remaining deviation from normality may induce a bias in realized volatility measures stemming from microstructure noise as well as model misspecification. In particular, when returns jump and the asymmetric return volatility relation, such as level effect, exists. Set against that background, adding the realized volatility measurement directly to the stochastic volatility process may cause huge bias on estimating results, so traditional realized stochastic volatility model (RSV), e.g., Takahashi, Omori, & Watanabe (2009), Dobrev and Szerszen (2010), Zheng and Song (2014), cannot successfully fit this stylized fact. Koopman and Scharth (2013) considered a fixed bias setup in the volatility dynamics, and the proposed RSV model provided a useful framework for modeling the securities' dynamics. However, in their model, the specifications of the dynamic drift (linear mean-reverted drift and nonlinear drift) and the level effect, which are two stylized facts for spot rate dynamics in many spot rate markets, are not considered nor applied in empirical estimation.

Our realized stochastic volatility model was developed from Takahashi et al. (2009) and Koopman and Scharth (2013). It may improve volatility fitting via incorporating the level effect and dynamic drift in the realized stochastic volatility model (RSVL). Under the level effect and nonlinear drift setups, the popular spot rate models, such as CEV, CKLS, BS, CIR, and VASICEK, can be easily estimated by the RSVL framework, and facilitate the empirical application of the realized stochastic volatility model on the spot rate markets. A simulation study of the RSVL model was carried out and suggested the consistency of the approximated maximum likelihood estimation. The non-parametric specification tests, which are more suitable to examine the predictive powers of the spot rate models (e.g., Hong and Li (2005), Hong, Li, and Zhao (2004), and Hong et al. (2010)), were applied to the empirical study of spot rate markets.

As the development of Chinese bond markets and their derivative products, it becomes necessary to model the dynamics of Chinese spot rate in derivative pricing and risk management. The information embodied in the spot rate models is multi-applicable. For example, the model-implied marginal distribution can be used to forecast the distribution and calculate the value-at-risk, and the model dynamics are often applied to price interest rate derivative, such as Chinese interest rate swap with repo rate as underlying asset. It is, therefore, important to figure out whether a complicate spot rate model can improve model dynamics or marginal distribution.

This study also carried out a detailed empirical study of the RSVL model using the spot rate data in the period between 2006 and 2013. It used the one-day and one-week repo rate of the interbank market as the proxy of spot rate respectively, and made sure that the time duration of which covers the latest dynamics in Chinese monetary market. This article calculated various kinds of realized volatility measures with high-frequency spot rate data following the methodology of Andersen and Benzoni (2010). As far as we know, this is the first literature calculating realized volatility measures by using repo rate, other than log bond price (Andersen, Bollerslev, Diebold, & Vega, 2007), log stock price or exchange rate (Barndorff-Nielsen & Shephard, 2002a; Barndorff-Nielsen & Shephard, 2002b; Barndorff-Nielsen & Shephard, 2004a; etc.), and it also verified the theoretical background of these realized volatility measures under the spot rate stochastic processes. In empirical application of RSVL model, our results complement the former volatility research of Fan and Zhang (2007) and Hong et al. (2010) on Chinese spot rate market, which suggested the usage of realized measure to improve the volatility forecasting of the spot rate dynamic and the application of noise-and-jump-robust realized volatility measures to increase the model's goodness-of-fit on marginal density and dynamics.

The rest of the paper is organized as follows: Section 2 discusses the theoretical background of realized volatility measures and their calculating methods under spot rate dynamics. Section 3 depicts spot rate models under the RSVL framework, and discusses the estimation method, simulation, and model specification test methods for the RSVL models; Section 4 draws the characteristics of Chinese interbank repo market; Section 5 presents the empirical illustration using the Chinese repo rate data; and the whole paper is summarized and concluded in Section 6.

2. Realized volatility measures for spot rate

Recent volatility measurement and forecasting literature have advocated using realized volatility measures as a way to approximate the daily realizations from the return quadratic variation process. The analysis of this study focuses on the volatility of spot rate, rather than the volatility of the bond return (Andersen et al., 2007) or bond yield (Andersen et al., 2010), so it is useful to verify whether ordinary statistics of realized volatility measures is applicable to spot rate, and clarify the link among them.

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