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Estimating stochastic volatility with jumps and asymmetry in Asian markets

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ABSTRACT

This study investigates the impact of stock market cycles on the volatility of Asian markets. It specifically addresses the combined effect of jumps, asymmetry and stochasticity while predicting the market volatility. Our results indicate that the stochastic volatility process is highly persistent across the countries. Leverage effect, size and frequency of jumps are found to be significant and play a prominent role in computing market volatility. The empirical results imply that the stochastic volatility model embedded with the jump and asymmetric component significantly helps in measuring volatility especially during the turbulent periods. Our results have major implications for policy makers, regulators, mutual funds, hedge funds as well for other institutional investors.

1. Introduction

Financial markets have undergone several economic drifts and turns over the last decade. Markets, the world over, witnessed abrupt changes in economic and fundamental factors leading to stock market cycles and fluctuations in volatility. Prior studies widely used GARCH family models to forecast volatility and found evidence in favor of in-sample estimates. However, their out of sample forecasts are poor due to their rigid linear structure (Tripathy and Gil-Alana, 2015).

Financial markets exhibit asymmetric conditional volatilities (Hafner and Franses, 2009) especially, in emerging markets. Also, the presence of asymmetry is most apparent during stock market crashes (Wu, 2001). Engle (2004) postulated that ignoring asymmetry in volatility leads to a significant under/ over estimation of the risk. Corsi et al. (2010) indicated that jumps, when included in the model, increase the predicting power for volatility.

Yet, all these contemporary studies modeled only one property of volatility i.e., either jumps or clustering or asymmetry or stochasticity. However, accurate volatility estimation requires the integrating all the properties. Moreover, forecasting stochastic volatility during the crisis periods requires contemporary investigation. Hence, this study investigates the individual and combined effect of these properties in volatility estimation. The study not only tests the empirical validity of the model but also explores out of sample validation in both turbulent and tranquil periods.

This study contributes to the literature in several aspects: First, the impact of stochasticity, jumps and asymmetry on volatility estimation was investigated for the period 2005–2014. This period was characterized by the occurrence of successive crises and turbulent episodes. These events had significant effect on volatility. Second, volatility was modeled for both emerging and developed countries in Asia. Empirical studies on stochastic volatility modeling predominantly in the context of emerging markets are minimal. Finally, the conditional volatilities were also forecasted, to establish the predictive ability of alternate stochastic volatility models.

Volatility of five Asian market indices (NIFTY, KOPSI, TWSE, FSSTI and Nikkei) over the period from 1 January 2005 to 31

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December 2014 was estimated using four models. First, standard stochastic volatility model (SV); second, stochastic volatility model with asymmetry (SVA); third, stochastic volatility model with jumps (SVJ) and the fourth, stochastic volatility with jumps and asymmetry model (SVAJ). The conditional volatilities have been forecasted at daily. The forecast performance is evaluated using Diebold Marino test (DM test).

The main results are summarized as follows. First, persistence and leverage effect is noted across the Asian markets. Second, volatility forecasts indicate that the SVJ model captures the volatility effectively during the tranquil periods. Third, during the turbulent periods the SVAJ model has better predictive ability. The study affirms the importance of incorporating the jump and asymmetric components in volatility estimation. Rest of the paper is organized as follows. Section 2 describes the empirical framework. Sections 3 and 4 presents the data and empirical results respectively. Section 5 concludes the study.

2. Methodology

This section describes the four stochastic volatility models that are employed in the study. The first model considered in the study is the basic stochastic volatility model (SV Model).

$$r_t = \mu + \varepsilon_t^r \varepsilon_t^r \sim N(0, e^{h_t}) \tag{1}$$

$$h_t = \mu_h + \varphi_h(h_{t-1} - \mu_h) + \epsilon_t^h \epsilon_t^h \sim N(0, \omega_h^2) \tag{2}$$

where φ_h is the persistent parameter and $|\varphi_h| < 1$ and ε_t^r, ϵ_t^h are independent. The conditional volatility follows the AR (1) process. As SV models have no closed form solution, we employed Monte Carlo Markov Chain (MCMC) method to estimate the model parameters.

The second model incorporates the jump component into SV model (SVJ model). The asset return and conditional volatility are modeled as follows:

$$r_t = \mu + k_t q_t + \varepsilon_t^r \varepsilon_t^r \sim N(0, e^{h_t}) \tag{3}$$

$$h_t = \mu_h + \varphi_h(h_{t-1} - \mu_h) + \epsilon_t^h \epsilon_t^h \sim N(0, \omega_h^2) \tag{4}$$

The jump component $k_t q_t$ is integrated in the return equation, where, '*k*' denotes the size of jump and '*q*' denotes the occurrence of jump. q_t is a binary variable that takes the value of 1 when a jump occurs, and 0 otherwise. k_t follows a normal distribution with mean μ_k and standard deviation σ_k^2. μ_k indicates the average size of the jump. The unconditional probability of a jump is denoted as *p*; and the conditional probability of a jump is:

$$P(q_t = 1/h_t, r_t) = \frac{P(r_t/q_t = 1)P(q_t = 1)}{P(r_t/q_t = 1)P(q_t = 1) + P(r_t/q_t = 0)P(q_t = 0)} \tag{5}$$

Our third volatility model incorporates asymmetry into the SV model (SVA model). Harvey and Shephard (1996) were the first to combine asymmetry with stochastic volatility using the quasi maximum likelihood method but this QML yielded poor estimates. Kim et al. (1998) indicated that MCMC method improves the estimation. SVA models the conditional volatility as follows:

$$r_t = \mu + \varepsilon_t^r \varepsilon_t^r \sim N(0, e^{h_t}) \tag{6}$$

$$h_t = \mu_h + \varphi_h(h_{t-1} - \mu_h) + \sigma_\eta \eta_t \, \eta_t \sim N(0, \sigma_\eta^2) \tag{7}$$

$$E(\varepsilon_t^r, \eta_t) = \rho \tag{8}$$

$$h_{t+1} = \mu_h + \varphi_h(h_t - \mu_h) + \rho\sigma_\eta r_t e^{h_t/2} + \sigma_\eta \sqrt{1-\rho^2}\, w_{t+1} \tag{9}$$

$$w_{t+1} = (\eta_{t+1} - \rho\varepsilon_t^r)/\sqrt{1-\rho^2} \tag{10}$$

Also η_t can be written as $\eta_t = \rho\varepsilon_t^r + \sqrt{(1-\rho^2)}\,\xi_t$, where ξ_t follows a standard normal distribution. Leverage effect is measured using ρ.

Our fourth model combines both jumps and asymmetry into the standard stochastic volatility equation (SVAJ Model). Malik and Pitt (2011) estimated the volatility of simulated data using SVAJ model. Our study not only analyzes the model fit but also forecasts the conditional volatility for the real time data.

$$r_t = \mu + k_t q_t + \varepsilon_t^r \varepsilon_t^r \sim N(0, e^{h_t}) \tag{11}$$

$$h_t = \mu_h + \varphi_h(h_{t-1} - \mu_h) + \sigma_\eta \eta_t \eta_t \sim N(0, \sigma_\eta^2) \tag{12}$$

$$E(\varepsilon_t^r, \eta_t) = \rho \tag{13}$$

$$h_{t+1} = \mu_h + \varphi_h(h_t - \mu_h) + \rho\sigma_\eta r_t e^{h_t/2} + \sigma_\eta \sqrt{1-\rho^2}\, w_{t+1} \tag{14}$$

$$w_{t+1} = (\eta_{t+1} - \rho\varepsilon_t^r)/\sqrt{1-\rho^2} \tag{15}$$