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Sudden breaks in drift-independent volatility estimator based on multiple periods open, high, low, and close prices

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Abstract This paper investigates the superiority of the Yang and Zhang (YZ) estimator over the demeaned squared returns in detecting sudden breaks based on Inclan and Tiao (IT-ICSS) algorithm using Monte Carlo simulation experiments. Our findings indicate that the IT-ICSS algorithm exhibits desirable size and power properties when applied with the YZ estimator in comparison to its use with the demeaned squared returns. Empirically, we validate the superiority of the YZ estimator by relating the detected breaks with the major macroeconomic events using various US dollar exchange rates. We find that the demeaned squared returns detect many spurious breaks.

Introduction

This paper compares the performance of the Yang and Zhang (2000) (YZ) estimator and demeaned squared returns when applied with Inclan and Tiao's (1994) iterated cumulative sum of squares (IT-ICSS) algorithm to detect the sudden changes in the volatility of a random process. Analysis of market risk plays a crucial role in the financial markets literature. Volatility is known to be a popular measure in evaluating financial risks, leverage effects and to examine the impact of asymmetric shocks on markets. Volatility plays an important role in financial markets due to its application in designing investment decisions and in portfolio rebalancing and management (Aizenman & Marion, 1999), in pricing derivatives securities (Hull & White, 1987), in quantifying risk (based on value at risk and expected shortfall) (Granger, 2002) and in implementing trading strategies (Poon & Granger, 2003). It is well known in the literature that the unconditional volatility of tradable securities and portfolios may be significantly affected by infrequent structural breaks or regime shifts, which may arise due to various domestic or global macroeconomic and political events (see Aggarwal, Inclan, & Leal, 1999; Kumar & Maheswaran, 2012) including terrorist attacks, wars, sudden hike in interest rates, changes in investors' perception, crashes and crises in a market, or recession in an economy. Hence, it is important to consider the impact of sudden changes in volatility in the model for generating more accurate forecasts of volatility. This can be helpful for fund managers and investors to design investment strategies, to rebalance their portfolios and to hedge their positions based on an anticipation of future movements of the market. Regulators, policy makers and central banks also have an interest in volatility analysis to implement policy

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measures effectively based on changes taking place in markets. This would enable them to maintain stability in financial markets and to assess the effectiveness of these policies depending on the required goals (Poon & Granger, 2003).

There exist different methods to estimate daily unconditional volatility. The most popular method involves the use of square of close to close returns. The returns based volatility measures are well established in literature and also act as inputs to generalised autoregressive conditional heteroskedasticity (GARCH) class of models. However, the squared daily return is a noisy estimate of volatility and informational inefficiency (Alizadeh, Brandt, & Diebold, 2002). Another method involves the use of high frequency intraday data. This measure of volatility is also known as realised volatility which involves summing the squares of returns sampled at shorter intervals (for example, 5 minutes or 10 minutes) for a given day. However, the high frequency data exhibit non negligible microstructure issues, which may prevent the researchers in analysing its informational contents. On the other hand, high frequency data for many assets may not be available or may be available for a shorter duration. In addition, high frequency data are generally expensive and require substantial computational resources.

The literature that started with Parkinson (1980) and Garman and Klass (1980), and extended by Rogers and Satchell (1991) and Yang and Zhang (2000), has highlighted the importance of using opening, high, low and closing prices of an asset for the efficient estimation of volatility. Alizadeh et al. (2002) highlighted that range based volatility estimates are highly efficient and are robust in terms of the non negligible market microstructure issues. Among all these range based volatility estimators, the YZ estimator proposed by Yang and Zhang (2000) is based on multi-period open, high, low, and close prices, is unbiased in the continuous limit, independent of any non-zero drift, and incorporates the impact of opening price jumps. However, the RS estimator proposed by Rogers and Satchell (1991) is also unbiased regardless of non-zero drift. The YZ estimator also makes use the of RS estimator for volatility estimation (see equation (5) in the section on *Methodology*). The other range based volatility estimators are biased in some way if the mean return (drift) is non-zero. The open, high, low, and close prices are also available for most of the traded assets, indices and commodities, and contain more information for efficient estimation of volatility.

Literature provides evidence that the volatility models, which incorporate the impact of sudden changes in unconditional volatility provide better volatility forecasts (Kumar & Maheswaran, 2012). The IT-ICSS test assumes that the zero mean returns are independent over time and normally distributed. The IT-ICSS test detects both a significant increase and decrease in the unconditional volatility and, hence, can help in identifying both the beginning and the ending of volatility regimes. The IT-ICSS test has been extensively used in detecting sudden changes in the unconditional volatility of time series based on close-to-close returns (Aggarwal et al., 1999; Fernandez & Arago, 2003; Hammoudeh & Li, 2008; Malik, 2003; Malik, Ewing, & Payne, 2005). However, Aggarwal et al. (1999), Hammoudeh and Li (2008), Malik (2003), Malik et al. (2005), and Wang and Moore (2009) use demeaned squared returns with IT-ICSS algorithm to detect sudden changes in the unconditional variance.

In this study, we compare the size and power properties of IT-ICSS test with respect to both the volatility proxies (the YZ estimator and the demeaned squared returns) for various data generating processes like the independently and identically distributed (i.i.d.) random numbers from the Gaussian, Student's t, double exponential, gamma-mixture and generalised error distributions, the GARCH model, the stochastic volatility (SV) model and the fractionally integrated GARCH (FIGARCH) model. For the GARCH, the SV and the FIGARCH models, the innovations have been taken from the normal, the Student's t and the generalised error distribution (GED) distributions. The power properties are studied by incorporating sudden breaks at 25th percentile, 50th percentile and 75th percentile of the data series from i.i.d. normal, the GARCH and the SV data generating processes. The findings of this study indicate that YZ estimator exhibits more desirable size and power characteristics when applied with IT-ICSS algorithm than the demeaned squared returns. Hence, this study proposes the use of the YZ estimator with IT-ICSS test to detect sudden changes in volatility. On the application side, this study detects sudden breaks in the YZ estimator and the demeaned squared returns of three major exchange rates (USD/Euro, USD/Japanese Yen and USD/GBP).

The remainder of this paper is organised as follows: Section 2 introduces the IT-ICSS algorithm and the procedure for implementing the YZ estimator based extension of the IT-ICSS algorithm. Section 3 presents the results of the Monte Carlo simulation experiments to assess the performance of the IT-ICSS algorithm based on the YZ estimator and demeaned squared returns. Section 4 describes the application of the YZ estimator in detecting sudden breaks in USD/Euro, USD/Japanese Yen and USD/GBP exchange rates and section 5 concludes with a summary of the main findings.

Methodology

Inclan and Tiao's (1994) (IT) ICSS algorithm

The IT-ICSS algorithm is helpful in detecting multiple sudden changes in the volatility of time series. The IT-ICSS algorithm assumes stationary unconditional variance in a time series for a particular regime. This algorithm is simple to implement and is not affected by the long memory characteristics of the volatility.

Suppose ε_t ~ i.i.d. $(0, \sigma^2)$, where i.i.d. means independent and identically distributed. Suppose there are T_N change points in the volatility series with change points given as $1 < k_1 < k_2 < \ldots < k_{TN} < N$, where N is the number of observations in the time series. Suppose the variance within each regime is given by τ_j^2, where $j = 0, 1, \ldots\ldots, T_N$. Then,

$$\sigma_t^2 = \tau_0^2 \quad for \quad 1 < t < \kappa_1 \tag{1a}$$

$$\sigma_t^2 = \tau_1^2 \quad for \quad \kappa_1 < t < \kappa_2 \tag{1b}$$

$$\sigma_t^2 = \tau_{TN}^2 \quad for \quad \kappa_{TN} < t < N \tag{1c}$$

Inclan and Tiao (1994) applied the cumulative sum of squares approach to detect the number of sudden changes in the variance. The cumulative sum of the squared