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Estimation of spot volatility with superposed noisy data

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ABSTRACT

By using high frequency financial data, we nonparametrically estimate the spot volatility at any given time point, while the simultaneous presence of multiple transactions and market microstructure noise in the observation procedure are considered. Our estimator is based on the summation of the locally ranged increments, while kernel smoothing give us spot volatility. Besides, the microstructure noise can be estimated and removed, if it is modeled as bid-ask spread, which is a frequently used assumption. The consistency and asymptotic normality of the estimator are established. We do some simulation studies to assess the finite sample performance of our estimator. The estimator is also applied to some real data sets, further, the relationship between multiple records and spot volatility is also explored.

1. Introduction

The large availability of high frequency financial data has not only provided considerable materials, but also brought some challenges to the research on volatility. The phenomenon of multiple records is one of these challenges, the one has been studied from just last several years (Jing, Liu, & Kong, 2017; Liu, Kong, & Jing, 2015). For high frequency financial data, the multiple records phenomenon refers to the possible presence of more than one observations at the same recording time, without any order information. In fact, such a phenomenon occurs commonly, due to the heavy tradings in the market and the limitation of the recording mechanism. To illustrate, Liu, Liu, Liu, and Ding (2017) showed that for some stocks traded frequently in a day, such as Microsoft, the percentage of the recording time intervals with multiple different observations can be as high as 15%. We find that the frequency of multiple records may be even much larger during some time intervals in a day, by analyzing the stocks during the financial crisis in 2008. We divide the intraday recording time points into grids, with 100 recording time points in each grid, and then compute the frequencies of recording time points with multiple different observations in these grids. We obtain the maximum frequency in a day for the following three stocks (the real financial data we used in this paper is from the LOBSTER database): 42% for Bear Stearns Cos (BSC) on March 14, 2008, 41% for Goldman Sachs (GS) on September 18, 2008 and 35% for Morgan Stanley (MS) on September 18, 2008. The results inspire us that there would exists multiple records clustering in some intervals, and we wonder if the volatility during the intervals with high multiple records frequency have a distinct rise in relative to the ones with low multiple records frequency.

Spot volatility measures the strength of return variation at a certain time point. Estimating spot volatility is relevant to studying the intraday pattern of the volatility process and a crucial ingredient in option pricing with stochastic volatility, it is also used for

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testing the presence of jumps (Lee & Mykland, 2007; Ait-Sahalia & Jacod, 2009; Veraart, 2010), or co-jumps (Jacod & Todorov, 2009), and estimating parametric stochastic volatility models (Bandi & Reno, 2009; Kanaya & Kristensen, 2016). In recent years, there are many papers on spot volatility estimation under different scenarios. Among them, nonparametric estimation of spot volatility in the context of diffusion model serves as the basement, examples are Foster and Nelson (1996), Fan and Wang (2008) and Kristensen (2010), etc.

As a stylized effect of high frequency financial data, the presence of market microstructure noise is necessarily to be considered, but it brings in bias to the estimation procedure of volatility. To tackle this, many researchers proposed their own schemes to extract spot volatility from noisy data, see Zu and Boswijk (2014), Hoffmann, Munk, and Schmidt-Hieber (2012), Ogawa and Sanfelici (2011), Kanaya and Kristensen (2016) and Mancini, Mattiussi, and Reno (2015). Market microstructure noise is caused by a variety of frictions inherent in the trading process, such as, bid-ask bounces, discreteness of price process, differences in trade sizes or informational content of price change, etc. Many researchers have worked on the problem that which factor has main contribution to microstructure noise. Bandi and Russell (2003) pointed out "In fact, actual transaction prices suffer from well-known bid-ask bounce effects ……", and Ait-Sahalia and Yu (2009) said "Bid-ask bounces are a well-recognized phenomenon in transaction price data – indeed, the only source of noise in the model of Roll (1984)". Namely, they think that bid-ask bounces represent the leading cause of market microstructure noise in most of transaction-based price data, especially, in an efficient market. In this paper, we follow their sayings and model the market microstructure noise as bid-ask bounces.

In this paper, our aim is to extract spot volatility from high-frequency financial data, in the consideration of the presence of multiple records phenomenon and market microstructure noise. As we know, the common estimation of spot volatility employ the local information about returns, and the precondition is that ones know the order of the observed prices. However, the occurrence of multiple records makes the condition unsatisfied. In practice, the phenomenon would appear frequently in a specific period, thus makes it very necessary and meaningful to propose an estimator of spot volatility immune from multiple records. In the presence of multiple records, there are only several papers tackling the estimation of integrated volatility, see, Jing et al. (2017), Liu et al. (2015), Liu et al. (2017) and Liu, Wang, and Liu (2016). Among them, the range-based method of Liu et al. (2016) has smaller asymptotic variance in contrast to the other existing estimators. This motivates us to construct our estimation based on the range-based method. In the absence of multiple records but the presence of microstructure noise, the range-based estimation of integrated volatility has been studied by Christensen and Podolskij (2007), Christensen, Podolskij, and Vetter (2009) and Bannouh, Martens, and Dijk (2013). Christensen and Podolskij (2006) and Christensen and Podolskij (2012) extend the estimation to the case of no multiple records but with jumps. Regarding to the estimation of spot volatility, using kernel functions is one of the most popular methods, see Fan and Wang (2008) and Kristensen (2010), Mancini et al. (2015), Ye, Lin, Zhao, and Hao (2015) and Liu, Liu, and Liu (2017). Based on the works above, our estimator combines the range method and the kernel method. We also study the problems of bandwidth setting and scale parameters selection, which are important for practical implementation. In Monte Carlo simulations, we display the finite sample performance of the estimator by two stochastic volatility models, to verify the asymptotic properties of the estimator. As an application, we apply our estimator to real high frequency financial data. We select several sets of intraday data during the 2008 financial crisis, and employ our estimator to gain their spot volatilities in a day. Then we extract the information of multiple records clustering from the data, and discuss the relationship between spot volatility and multiple records by computing their correlation coefficient.

The rest of the paper is organized as follows. Section 2 introduces the model we consider, and some basic assumptions. Then by using two-sided kernel function and one-sided kernel function, we present two corresponding estimators of spot volatility in the presence of multiple records and microstructure noise. In Section 3, we study their asymptotic properties and the selections of scale and bandwidth. Two commonly used models in financial literature are employed in the simulation experiments to assess the finite sample performance of our estimators in Section 4. In Section 5, the estimators are applied to the real financial data, and the empirical results are analyzed. Section 6 summarize our paper. The technical proofs are given in Appendix.

2. Setup

In what follows, we describe the underlying structure of high frequency data, explain the mechanism of multiple records phenomenon, and model the observed transaction prices with microstructure noise. After that, an estimation of spot volatility in the presence of multiple records and microstructure noise is proposed.

2.1. Model description

The log price process $\{X_t\}$, which is defined on a filtered probability space $(\Omega,\mathscr{F},(\mathscr{F}_t)_{t\geqslant 0},P)$, is adapted to the filtration $(\mathscr{F}_t)_{t\geqslant 0}$. We assume that X_t satisfies,

$$\mathrm{d}X_t = \mu_t\mathrm{d}t + \sigma_t\mathrm{d}W_t, t \in [0,1], \tag{1}$$

where $\{W_t\}$ is a standard Brownian motion, $\{\mu_t\}$ is locally bounded and predictable, and the spot volatility process $\{\sigma_t\}$ is a càdlàg process. We further assume that $\{\sigma_t\}$ is positive and locally bounded almost surely. A specific stochastic structure can be imposed on σ, which is widely used in financial econometrics:

Assumption 1. σ_t satisfies

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