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Long memory and regime switching: A simulation study on the Markov Regime-Switching ARFIMA model

Yanlin Shi [a,b,*], Kin-Yip Ho [a]

[a] Research School of Finance, Actuarial Studies and Statistics, The Australian National University, Canberra, ACTON 2601, Australia
[b] Australian Demographic and Social Research Institute, The Australian National University, Canberra, ACTON 2601, Australia

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ABSTRACT

Recent research argues that if the cause of confusion between long memory and regime switching were properly controlled for, they could be effectively distinguished. Motivated by this idea, our study aims to distinguish between them of financial series. We firstly model long memory and regime switching via the Autoregressive Fractionally Integrated Moving Average (ARFIMA) and Markov Regime-Switching (MRS) models, respectively. Their finite-sample properties and the confusion are investigated via simulations. To control for the cause of this confusion, we propose the MRS–ARFIMA model. A Monte Carlo study shows that this framework can effectively distinguish between the pure ARFIMA and pure MRS processes. Furthermore, MRS–ARFIMA outperforms the ordinary ARFIMA model for data simulated from the MRS–ARFIMA process. Finally, empirical studies of hourly and five-minute Garman–Klass and realized volatility of the FTSE index is conducted to demonstrate the advantages and usefulness of the proposed MRS–ARFIMA framework compared with the ARFIMA and MRS models in practice.

1. Introduction

Long memory describes the property of financial series, whose sample autocorrelations are significantly different from zero, even for large lags (Baillie et al., 1996; Bollerslev and Mikkelsen, 1996; Diebold and Inoue, 2001). In many recent studies, long memory is extensively observed, especially for the high-frequency financial series (Chortareas et al., 2011; Fleming and Kirby, 2011; Degiannakis et al., 2013; Caporale and Gil-Alana, 2013; Ho et al., 2013). In Fig. 3, the autocorrelation functions (ACFs) of hourly log Garman–Klass and realized volatility of London Stock Exchange (FTSE) index ranging from 1/1/2001 to 31/12/2012 are plotted. It can be observed that even at the very large lags (up to 30), their ACFs are still significant, indicating the possible presence of long memory in the hourly volatility. This is also true for the five-minute log Garman–Klass and realized volatility cases, the ACFs of which are plotted in Fig. 5.

Apart from the actual persistent effects in ACFs, it is well known that regime switching can also induce long memory (Diebold and Inoue, 2001; Choi et al., 2010; Arouri et al., 2012; Charfeddine and Guégan, 2012; Yalama and Celik, 2013; Wang and Vasilakis, 2012). To illustrate that, we simulate 5000 long-memory and 5000 regime-switching data,[1] ACFs of which are both plotted in Fig. 1. For the long-memory simulation, it is not surprising that the significant ACFs exist for large lags. Turning to the regime-switching simulation, however, even no autocorrelation is allowed in the original data generation process (DGP), ACFs also show the similar pattern as those of long memory. Diebold and Inoue (2001) give a theoretical explanation of this phenomenon, and their simulation study further demonstrates that when structural change or stochastic regime switching exists, they are related to long memory and are easily confused with it. Therefore, the results of FTSE volatility in Figs. 3 and 5 could be "spurious", since it can be caused by long memory, regime switching or even both. Hence, Diebold and

Abbreviations: ARFIMA, Autoregressive Fractionally Integrated Moving Average; MRS, Markov Regime-Switching; ACFs, autocorrelation functions; FTSE, London Stock Exchange; DGP, data generation process; QMLE, Quasi Maximum Likelihood Estimation; RMSE, mean square error; TRTH, Thomson Reuters Tick History; SIRCA, Securities Industry Research Center of Australasia; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion.

* Corresponding author at: Research School of Finance, Actuarial Studies and Statistics, The Australian National University, Canberra, ACTON 2601, Australia. Tel.: +61 2 6125 7318; fax: +61 2 6125 0087.
E-mail address: yanlin.shi@anu.edu.au (Y. Shi).

[1] The data generation processes (DGPs) to simulate the long-memory and regime-switching data are discussed in Sections 2 and 3, respectively.

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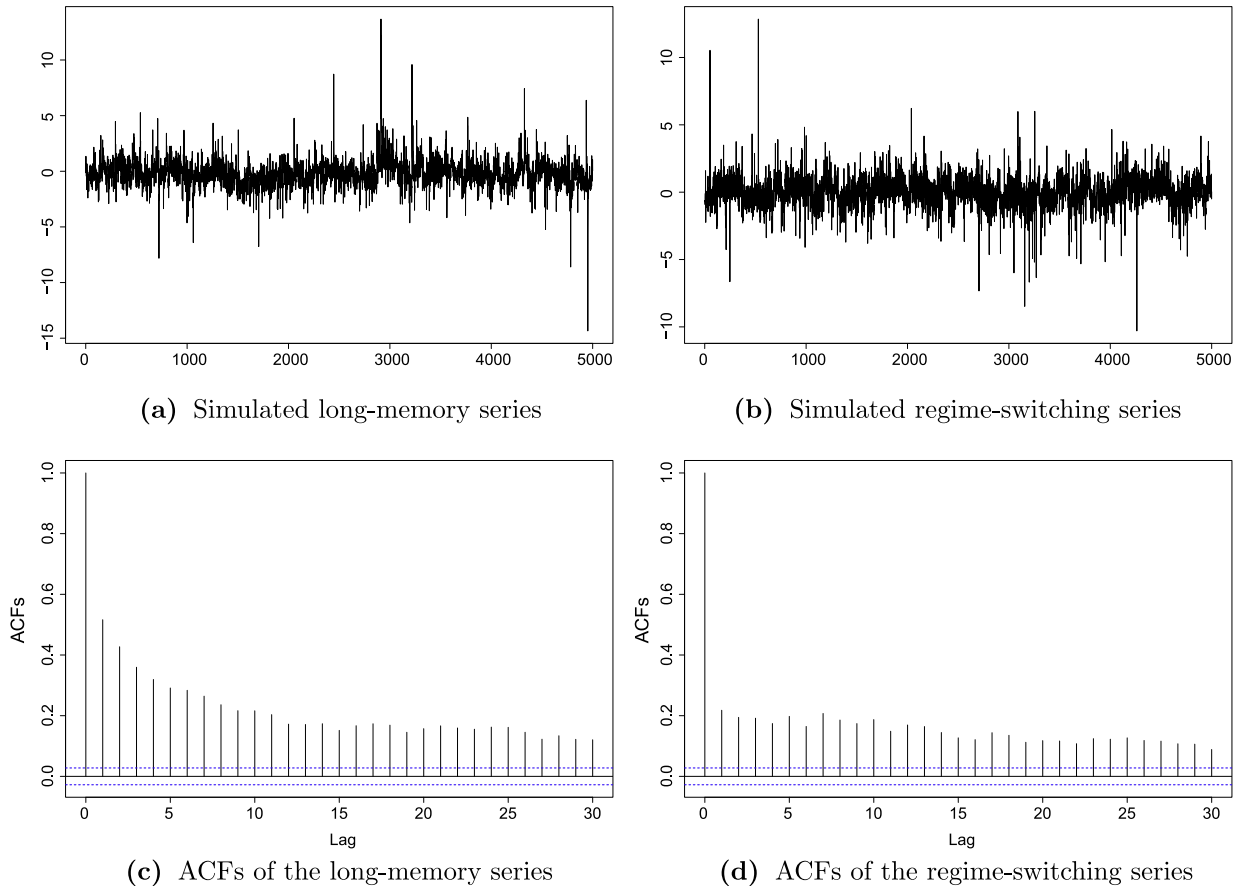

Fig. 1. Simulated series with autocorrelation functions. This figure presents the simulated long memory and regime-switching series with their autocorrelation functions (ACF). The long-memory parameter of the simulated long-memory series is 0.35. The transition probabilities of the regime-switching simulation are both 0.99. The sample sizes of both series are 5000. The lags of ACFs range from 0 to 30.

Inoue (2001) further argue that long memory and regime switching are interchangeable concepts and should not be studied separately. However, since regime switching is more closely related to the concept "business cycle" (Hamilton, 1989), to distinguish it from long memory is of great financial and economic importance.

In a recent study, Perron and Qu (2010) propose a test to effectively distinguish between the long- and short-memory processes with mean shifts at the first moment of financial series. Motivated by their work, it is expected that if the effects of regime switching can be appropriately controlled for, pure long-memory process should be distinguished from pure regime-switching process.

This paper aims to distinguish between the long memory and regime switching at the first moment of financial series. Autoregressive Fractionally Integrated Moving Average (ARFIMA) (Hosking, 1981) and Markov Regime-Switching (MRS) models (Hamilton, 1988, 1989, 1994) are widely used to model the long memory and regime switching characteristics for the first moment of financial data, respectively (Hamilton, 1989; Charfeddine and Guégan, 2012; Raggi and Bordignon, 2012; Yalama and Celik, 2013; Wang and Vasilakis, 2012). Regarding the distribution of innovations, in both standard ARFIMA and MRS models, they are originally assumed to be Normal. However, significant evidence suggests that financial series is rarely Normal but typically leptokurtic and exhibits heavy-tail behavior (Bollerslev, 1987; Susmel and Engle, 1994; Stanley et al., 2008; Podobnika et al., 2009). In terms of the ARFIMA model, it is argued that even if the true innovation does not follow a Normal distribution, estimators of Quasi Maximum Likelihood Estimation (QMLE) based on the Normal distribution are still asymptotically consistent. Nevertheless, MLE based on the true distribution is expected to be more efficient than its QMLE counterpart. With respect to the MRS-type model, however, Klaassen (2002), Ardia (2009) and Haas (2009) notice that if regimes (states) are not Normal but leptokurtic, the use of within-regime normality can seriously affect the identification of the regime process. The details can be found in Haas and Paolella (2012), who further argue that QMLE based on Normal components does not provide a consistent estimator of the MRS-type model, if the true distribution of innovations is not Normal. We therefore perform a Monte Carlo study on the standard ARFIMA and MRS models, where simulated data actually follow the Student-t distribution. Our results suggest that, for the non-Normally distributed data, estimators of the standard ARFIMA model are consistent but not efficient, and estimators of the standard MRS model are neither consistent nor efficient. Those results are consistent with the existing literature. As a result, we argue that a non-Normal distribution of innovations should always be used to model long memory and regime switching of financial data.

To demonstrate the confusion between the ARFIMA and MRS DGPs, we perform a simulation study and conduct long-memory tests. Similar to Diebold and Inoue (2001), it is found that MRS DGP can lead to significant presence of long memory. In addition, both the widely used R/S (Lo, 1991) and V/S (Giraitis et al., 2003) long-memory tests cannot distinguish between them. We also fit simulations of MRS (ARFIMA) DGP into the ARFIMA (MRS) model, but the estimates still suggest a confusion between the two DGPs.

Diebold and Inoue (2001) theoretically analyze the causality of long memory in regime switching DGP based on the assumption that transition probability is time-varying. However, in the standard MRS model, it is actually constant over time (Hamilton, 1988, 1989, 1994). Thus, a recent study by Shi (2015) gives an improved

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