行政院國家科學委員會專題研究計畫成果報告

長記憶波動性之研究及其對選擇權定價之運用

An Investigation of Long Memory in Volatility with Applications to Option Pricing

計畫編號：NSC 89-2416-H-032-006
執行期限：88 年 8 月 1 日至 89 年 7 月 31 日

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一、中文摘要

本研究以蒙地卡羅模擬分析的方法首先討論如何驗證股票報酬與波動的長記憶性，比較在有限樣本下不同的檢定方法在驗證長記憶波動性的績效。實證分析結果發現，在檢驗波動度之長記憶性時 Lo (1991)之 MRS test 在使用 Date-dependent rule 以建立核定量之變異數值時，有很大的 size distortion 。其次對美國與亞太股票市場進行長記憶波動模型檢定及分析並進行比較，以驗證長記憶波動現象是否存在及此類模型在這些資本市場之適用性。研究發現除新加坡外，亞太地區股市具有長記憶波動現象，進一步分析長記憶波動性是否是因結構不穩定性(structure break)或加總(aggregation)的原因而衍生的虛假性(spurious)現象時發現，加總因素並非導致指數報酬有長記憶現象之主因。而波動度的結構性改變則是重要原因。其中虛假性長記憶波動度現象存在於泰國、香港及日本股價指數。此外以 Andersen and Bollerslev (1997b)的模式為基礎提出一個可以解釋長記憶波動現象的財務理論模型。最後此類長記憶波動模型如 FIGARCH 與 FIEGARCH 模式運用於衍生性金融商品如 S&P100 指數選擇權的訂價，研究發現忽略此長記憶波動性特性時所造成選擇權訂價偏誤大小受波動度的持續性大小影響很大，即波動度的持續性大則選擇權訂價偏誤較大，但其關係並非線性。

Abstract

One of the important questions in studies of asset return and volatility has been how long the effects of shocks persist. In this research, the modified R/S statistic of Lo (1991) and the robust semiparametric method of Lobato and Robinson (1997) are applied to investigate the long memory properties in return and volatility of Asian financial markets. For the return series, we find little evidence of long memory, while the empirical results support the hypothesis of long memory in volatility for Asia-Pacific stock markets. We also discuss the possible causes of spurious long memory effect in volatility, namely aggregation, size distortion, and shifts in variance. Monte Carlo Simulation is conducted to investigate the test size of MRS test, GPH test and LM test. The simulation evidence shows that size distortion is more severe when the data-dependent rule for calculating the variance of test statistics is applied. Our empirical evidence shows that spurious long memory effect in volatility might occur as a result of shifts in variance for Thailand, Hong Kong, and Japan stock markets. This research then provides simulation results to investigate the bias in the option pricing when the true DGP of conditional volatility is long memory process, but use the simple GARCH option pricing model to price.

二、緣由與目的

Understanding volatility in emerging capital markets is important for evaluating investment and asset allocation decision, for pricing derivative assets and for determining the cost of capital. This research investigates the long memory properties in volatility for emerging Asian stock markets. Stationary processes exhibiting long-term, persistent fluctuations are termed long-range dependent. A key feature of these processes is that their autocovariance function decays hyperbolically, rather than

exponentially. Empirical results generally find no evidence of long memory in stock return series. The work of Ding, Granger, and Engle (1993) has motivated a variety of studies on the long memory property in volatility. Based on the evidence of strong persistent autocorrelation in the squared and absolute value of returns, one might be interested in applying long memory tests to the squared observations or other pertinent variables. However, the squared observation and other variables are only proxies for the conditional variances. Implementation of the long memory tests to volatility remains an important issue.

The empirical regularity of long memory in volatility has been criticized as lack of theoretical justification. Andersen and Bollerslev (1997) provide a theoretical justification of long memory in volatility. They formulate a version of the mixture of distributions hypothesis (MDH) for return and interpret the volatility as resulting from the aggregation of numerous components that include some short-run decay components and others possessing long-run dependence.

An important issue in the studies of long memory effect is the possible causes of spurious long memory effect. Spurious long memory effect might be caused by aggregation and shifts in variance[1]. Lobato and Savin (1998) have empirically tested whether the long memory effect in volatility is a spurious effect due to structural changes in variance. They conclude that for the U.S. stock market data the long memory volatility appears to be real, not spurious. However, their testing results are misleading because their investigation is based on arbitrarily selected sub-samples.

This reseach extends previous studies by providing a more extensive and systematic study of stock market dynamics in several respects. First, international evidence concerning long memory in stock returns and volatility is explored. This task is particularly important for the Asian Pacific financial markets, because many would believe that the recent Asian financial crisis has a long run effect on the market's perception of volatility. Second, we applied both the modified R/S test and the robust semiparametric procedure of Lobato and Robinson (1997) to detect long memory in stock returns and volatility. Third, the possible causes of spurious long memory effect are investigated. Emerging market is marked by frequent, sudden changes in variance. This research then provides simulation results to investigate the bias in the option pricing when the true DGP of conditional volatility is long memory process, but use the simple GARCH option pricing model to price.

三、結果與討論

Empirical tests of long memory in volatility are usually conducted by applying long memory test methods to the squared observations or other pertinent variables. However, the squared observation and other variables are only proxies for the conditional variance. Implementation of the long memory tests to the volatility remains an interesting task.

Two useful tests for long memory are the methods of Geweke and Porter-Hudak (1983), henceforth GPH and the rescaled range (R/S) statistic proposed by Hurst (1951) and modified by Lo (1991). Robinson (1994) argued that despite being robust, the efficiency properties of modified R/S test are questionable. Lobato and Robinson (1997) proposed a robust semiparametric procedure. The null hypothesis of Lobato and Robinson's test is that of weak dependence or short memory. The sample data are daily returns of stock market indexes and they cover the sample period from Jan 8, 1978 to September 22, 1998. The return series of stock market data are first filtered to remove serial correlation. The data consist of daily closing index values for the Nikkei Average (Japan), Hang Seng (Hong Kong), Singapore Straits Industrial (Singapore), Seoul Composite Index (Korea), Taipei Weighted Price Index (Taiwan), and Bangkok S.E.T. Index (Thailand).

Strong evidence of persistence in volatility is observed as the lag 1 through 300 sample autocorrelation of the daily squared returns on the Hang Seng index and Korea stock index demonstrate. The volatility-clustering phenomenon is significantly evident from this figure. The first order sample autocorrelation is close to 40%, while the sample autocorrelation at lag 150 is around 10%. The return series is fist filter by an ARMA model. We then use the conditional MLE of Chung and Baillie (1993) to estimate the GARCH model and Fractional Integrated GARCH (FIGARCH) model of Baillie, Bollerslev and Mikkelson (1996) and Chung (1998) for the filtered return series. To compare the performance of short memory and long memory volatility model in modeling the data series, the theoretical autocorrelation of squared return implied by the FIGARCH estimates for each data series are also calculated, while the results of the simple short memory volatility model such as GARCH(1,1) are also presented as

a comparison. It is clear that long memory volatility model appears to provide a better description of the data series than the GARCH model.

We also apply the modified R/S test to the squared and absolute returns of each data series. Andrews' (1991) data-dependent formula is applied to choose the number of lags in calculating the sample variance of the modified R/S. For the return series, the results show that none of the market exhibits long memory in returns itself except that of Thailand. The results of the LM test show no evidence of long memory in returns. It is found that the LM test of Lobato and Robinson (1997) and modified R/S test confirm the long memory in the absolute returns and squared returns of the sample data. Similar to that of Ding, Granger and Engle (1993), we find that the evidence of long memory is stronger for absolute returns than for squared returns.

If volatility exhibits long memory, economic events might have long run effects on the future volatility of assets and standard option pricing models assuming a short-memory conditional volatility model, such as GARCH or stochastic volatility model, are misleading. However, it is important to note that spurious long memory effect in volatility might be produced under certain circumstances.

Investigation of real or spurious long memory in volatility

Since stock market index is a weighted average of many individual stocks. It is argued that spurious long memory in stock index may be due to the effect of aggregation. Using a result given in Granger (1980), Andersen and Bollerslev (1997) provide a theoretical justification for the result that index return volatility can display long memory property, even though condition volatility of individual stocks exhibits short memory property.

Hence, it might be interesting to investigate whether the long memory exists in the volatility of individual stocks. If individual stock volatility indeed behaves like a short memory volatility process, it is obvious that the long memory property in stock index volatility is an artifact of aggregation. We apply the LM test of Lobato and Robinson (1997) and modified R/S test to the absolute return series of each individual stock. We also examined whether there is a long memory effect in returns and squared returns for 43 major individual stocks listed in Taiwan Stock Exchange. The results show that the long memory in volatility is also found in many individual stocks. The sample autocorrelations for squared and absolute returns for the individual stocks are also calculated. It is found that the sample autocorrelation of absolute returns tend to be higher than those of squared returns.

One interesting implication of the heterogeneous information hypothesis of Andersen and Bollerslev (1997) is that transaction volume will also be affected by the aggregated information process. According to Tauchen and Pitt (1983), the trading volume is driven by the arrival of new information to the market. Hence, one might assert that the volume series might be better characterized as fractional integrated process. Although the trading volume data is not observable in the foreign exchange market, the data is available in the stock market. The empirical results cannot reject that daily trading volume exhibits long memory.

Geweke (1998) argues that a critical question in the applications of the LM test of Lobato and Robinson (1997) is the choice for the bandwidth parameter (m). His Monte Carlo evidence shows that no choices of the bandwidth parameter for which the properties of the LM test are satisfactory for all values of the autoregressive parameter. In particular, for the DGP being an AR(1) process with AR coefficient greater than 0.5, the probability of rejecting a short memory alternative is close to 100% if the number of bandwidth is greater than 100. Monte Carlo simulation is conducted to examine the importance of size distortion as a cause of spurious long memory effect. The true data generating process is the martingale GARCH (1,1) process, i.e., $r_t = \sigma_t u_t$, with $\sigma_t^2 = \omega + a r_{t-1}^2 + b\sigma_{t-1}^2$; $u_t \sim$ iid (0,1). We find that the MRS with a data-dependent rule in choosing the bandwidth has serious size distortion problem. The sizes of the LM test decrease with sample size. In general, the optimal number of bandwidth depends on the sample size and true parameter values of the underlying DGP. It appears that the distribution of the LM test statistics very much depends on the short-memory model entertained under the null hypothesis. Spurious evidence of long memory is clearly observed for the cases that $a+b$ close to 1 and particularly serious if m is too large.

We also examine whether there is a long memory effect in volatility for each variance shift sub-sample period found in Aggarwal, Inclan and Leal. Because volatility shift in emerging markets are likely be affected by local political

and economic events, our testing method is better than that of Lobato and Savin, where arbitrarily selected sub-samples of before and after oil-price shock periods are tested. The results seem to favor the result that spurious long memory effect did occur in many of the data series. Indeed, for the data series of Singapore, MRS test results show no evidence of long memory in volatility for each sub-sample period. For Hong Kong and Japan, the MRS tests for the squared and absolute return are only significant for one sub-sample period. Similar results are found using the LM tests. Lobato and Savin (1998) argue that for the U.S stock market data the long memory effect in squared returns appears to be real, not spurious. However, our empirical evidence show that spurious effect of long memory volatility due to shifts in variance is observed for many Asian stock markets. Our results support the hypothesis that misleading persistent effect in volatility can occur as a result of structural shift in variance.

This research also provides simulation results to investigate the bias in the option pricing when the true DGP of conditional volatility is long memory process, but use the simple GARCH option pricing model to price. Simulation evidence shows that the percentage of bias in option pricing increases as the persistence in volatility (the fractional integration parameter) increases.

四. 成果自評

The findings in this research have contributed to the evidence that spurious long memory effect in volatility might occur as a result of shifts in variance in stock markets. This research also provides simulation results for investigating the bias in the option pricing when the true DGP of conditional volatility is long memory process, but the simple GARCH option pricing model to price are employed. Participants in this research successfully understand the Monte Carlo approach of option pricing and Monte Carlo approach for investigation of test sizes of long memory tests in volatility. Research assistant's programming ability in MATLAB and GAUSS are enhanced.

The main results of this research have been revised in an academic paper, which has been presented at two conferences and was accepted for publication by a refereed U.S. academic journal.

五. 參考文獻

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