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Multifractal analysis of Asian markets during 2007–2008 financial crisis

Rashid Hasan *, Mohammad Salim M.

Department of Physics, Aligarh Muslim University, Aligarh-202002, India

HIGHLIGHTS

- We study the US and Asian markets during 2007–2008 crisis triggered by the US subprime loans.
- A study of markets during a crisis could reveal important information about their dynamics.
- Markets of the US, Japan, Hong Kong, Korea and Indonesia show strong nonlinearities for positive q.
- These nonlinearities are due to long range correlations of large fluctuations in returns.
- The tail exponent of the cumulative log return distribution decreases during the crisis period.

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ABSTRACT

2007–2008 US financial crisis adversely affected the stock markets all over the world. Asian markets also came under pressure and were differently affected. As markets under stress could reveal features that remain hidden under normal conditions, we use MF-DFA technique to investigate the multifractal structure of the US and seven Asian stock markets during the crisis period. The overall period of study, from 01 July 2002 to 31 December 2013, is divided into three sub-periods: pre-crisis period, crisis period and post-crisis period. We find during the crisis period markets of the US, Japan, Hong Kong, S. Korea and Indonesia show very strong non-linearity for positive values of the moment q. We calculate the singularity spectra, $f(\alpha)$ for the three sub-periods for all markets. During the crisis period, we observe that the peaks of the $f(\alpha)$ spectra shift to lower values of α and markets of the US, Japan, Hong Kong, Korea and Indonesia exhibit increased long range correlations of large fluctuations in index returns. We also study the impact of the crisis on the power law exponent in the tail region of the cumulative return distribution and find that by excluding the crisis period from the overall data sets, the tail exponent increases across all markets.

1. Introduction

Financial markets are complex dynamical systems with a large number of interacting elements such as traders, brokerage firms, banks, mutual funds and assets. The dynamics of financial markets is difficult to understand because interactions between different elements and the manner in which the external factors affect the market are not known.

The interactions between different elements of the financial market generate a lot of data such as time series of asset prices and time series of index values, among others. These time series have complicated structures. But despite the complexity, analysis of large amount of high quality financial data has revealed very rich and non trivial features such as volatility

* Corresponding author.
E-mail address: rhasan1948@yahoo.com (R. Hasan).

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clustering [1,2], fat-tails of the probability density function of logarithmic returns [3,4] and multifractal characteristics [5,6]. These features which are referred to as the 'stylized facts' seem to be universal as they are invariant across different markets, types of assets and period of observation. The fat tails of the probability density function of logarithmic returns have been observed to follow a power law [7,8]. The existence of power law has implications for the risk management strategies for financial investments and it also suggests analogies to critical phenomena and non-equilibrium behaviour in the processes that generate financial returns.

Multifractality is now a well known feature of complex systems and it has been observed in systems ranging from DNA sequences [9,10] through heart beat rate [11], long time weather records [12], relativistic nuclear collisions [13,14] to financial markets [15,16]. Ivanov et al. [17] found evidence for a relationship between the complexity of a system and its degree of multifractality.

Multifractality in financial time series has been studied using several methods. Some of these methods are: generalized Hurst exponent method [18,19], partition function method [20,21] wavelet transform method [22,23], height–height correlation method [24,25] and multifractal detrended fluctuation analysis (MF-DFA) method [26,27] which is a multifractal generalization of the detrended fluctuation analysis (DFA) method [28,29]. Matteo et al. [30,31]used the generalized Hurst exponent method to study multifractality (multiscaling) in differently developed markets in order to find out if it could serve to characterize and measure the degree of development of the markets. They found that the emerging markets have Hurst exponent $H > 0.5$ while well-developed ones have $H < 0.5$. Zunino et al. [32] used the multifractal detrended fluctuation analysis (MF-DFA) method to study multifractality in a number of developed and emerging markets and found that the multifractality degree could be used as a measure to characterize the stage of market development. Jiang et al. [33] used the detrended fluctuation analysis (DFA) method to investigate the long range correlations of volatility in Asian stock markets. Eom et al. [34] investigated the relationship between the degree of efficiency and the predictability in the financial time series of markets of various countries and suggested that the Hurst exponent could be useful in predicting future price changes. Kumar and Deo [35] investigated the multifractal properties of logarithmic returns of indices of Indian stock market using the multifractal detrended fluctuation analysis (MF-DFA) method and found evidence of multifractality. Su et al. [36] investigated the minute by minute TAIEX return data and tick by tick LPI signals of 150 highly capitalized Taiwanese companies and found these data possess significant multifractal structures.

It has been argued by Sornette [37] that complex systems when under stress reveal features which remain hidden under normal conditions. So study of multifractality in the financial time series during periods of financial crisis could reveal critical information about the dynamics and complexity of the financial markets. Such information would be very useful for investors, especially the institutional investors, to correctly assess the risk in investments and also for policy makers to put in place a mechanism to deal with financial crises.

A number of studies have attempted to study the behaviour of the European and American stock markets during periods of financial crisis. Morales et al. [38] investigated the scaling behaviour in time of log-returns of the companies listed in the New York Stock Exchange which were more severely affected by 2008–2009 'credit crunch' crisis. They found these companies revealing multiscaling behaviour, with multifractality increasing when the crisis occurred. Kristoufek [39] investigated use of the Hurst exponent, dynamically computed over a moving time window as a crash detection tool. Podobnik et al. [40] studied long range magnitude cross-correlations in 1340 composite members of the New York Stock Exchange using Time Lag Random Matrix Theory (TLRMT) and reported that the largest singular values and their vectors substantially changed after the Dot-Com Bubble crash in 2001. Caraiani [41] studied multifractality in the daily returns for the indices of three emerging European stock markets, Czech PX, Hungarian BUX and Polish WIG and found multifractality in the markets increasing during 2007–2008 crisis period. Recently, Siokis [42] studied the multifractal properties of the Dow Jones Industrial Average (DJIA) index during 1927 and 1987 crashes and found that multifractality changed significantly after the crashes. More recently Siokis [43] also studied the effect of financial assistance on the multifractal properties of three troubled European economies and found that financial packages changed the multifractal properties of the markets.

However, only a few studies have attempted to study the Asian markets during periods of financial crisis: Yalamova [44] examined the multifractality of index price series of the daily data of Nikkei 225, All Ordinaries, Hang Seng, KLSE Composite and Straits Times index and found these markets exhibiting increased risks after 1997 Asian financial crisis. Lim et al. [45] studied the impact of 1997 Asian financial crisis on the efficiency of eight Asian stock markets. They found that the crisis adversely affected the efficiency of most Asian markets, with Hong Kong being the hardest hit followed by Philippines, Malaysia, Singapore, Thailand and S. Korea. Recently, Oh et al. [46] studied the influence of 1997 Asian currency crisis on the foreign exchange markets in Japan, Hong Kong, Korea and Thailand. They found that in FX markets in S. Korea and Thailand, the degree of multifractality significantly increased after the currency crisis, whereas FX markets in Japan and Hong Kong remained almost unaffected.

In this paper, we empirically investigate the influence of 2007–2008 US financial crisis on the multifractal structure of two developed (Japan and Hong Kong) and five emerging (S. Korea, China, India, Indonesia and Malaysia) stock markets in Asia. We also include the US market in the analysis for the sake of comparison. The aim is to study these markets when they are under stress during the financial crisis and are expected to reveal some critical information about their dynamics. For this, we divide the period of study (01 July 2002 to 31 December 2013) into three sub-periods: pre-crisis period (01 July 2002 to 31 December 2006), crisis period (01 January 2007 to 31 December 2008) and post-crisis period (01 January 2009 to 31 December 2013) and use the multifractal detrended fluctuation analysis (MF-DFA) technique to extract some useful information about the dynamics and complexity of these markets during the financial crisis.