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# Are developed and emerging agricultural futures markets multifractal? A comparative perspective

Ling-Yun He *, Shu-Peng Chen

*Center for Futures and Financial Derivatives, College of Economics and Management, China Agricultural University, Beijing 100083, China*

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ABSTRACT

Although there are many reports on the empirical evidence of the existence of multifractality in various financial or commodity markets in current literature, few can be found to compare the multifractal properties of emerging and developed economies, especially for agricultural futures markets in those countries (regions). We therefore chose China as the representative of the transition and emerging economies, and USA as the representative of developed ones. We attempt to find the answers to the following questions: (1) Are all those different markets multifractal? (2) What are the dynamical causes for multifractality in those markets (if any)? (3) Are the multifractality strengths in those markets of the transition and emerging economies weaker (or stronger) than those of the developed ones? To answer these questions, Multifractal Detrended Fluctuation Analysis (MF-DFA) are applied to study some of the representative agricultural futures markets in China and USA, namely, wheat, soy meal, soybean and corn. Our results suggest that all the markets of China and USA exhibit multifractal properties except US soybean market, which is much closer to mono-fractal comparing with China's soybean market. To investigate the sources of multifractality, shuffling and phase randomization procedures are applied to destroy the temporal correlations and non-Gaussian distributions respectively. We found that multifractality can be mainly attributed to the non-Gaussian probability distribution and secondarily to the nonlinear temporal correlation mechanism for all the markets, except US soybean and soy meal, which derives from some other unknown factors. Furthermore, the average of $\tau(q)$ are applied to obtain the multifractal spectra of the two markets as a whole. The results show that the width of the multifractal spectrum of US agricultural futures markets is significantly narrower than that of China's. Based on our findings, we proposed a hypothesis that the strength of multifractality in developed economies may be weaker than that in emerging and transition ones.



## 1. Introduction

As an important representative of transition and emerging economies, China's economy is rapidly growing and getting more globally influential in recent decades. At the same time, although USA is still enduring the ongoing financial tsunami, it is still the most important developed economy in the world. As for the two economic giants, the following questions are waiting to be answered: (1) Are all those completely different economies multifractal? (2) What are the causes for the multifractality in the economies (if any)? (3) Are the multifractality strengths in the transition and emerging economies stronger (or weaker) than those in the developed ones? Focusing on agricultural futures markets, we try to answer those questions from a comparative perspective.

* Corresponding address: Campus Mailbox #108, China Agricultural University (East campus), Qinghuadonglu Street, Beijing 100083, China. Tel.: +86 13522821703.
*E-mail addresses:* lyhe@amss.ac.cn, lyhe@yahoo.cn (L.-Y. He).

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The study of financial or commodity prices is largely based on current main stream literature, whose fundamental assumption is that stock price (or returns) follows a normal distribution and price behavior obeys 'random-walk' hypothesis (RWH), which was first introduced by Bachelier in 1900 [1], since then it has been adopted as the essence of many asset pricing models. However, some important results in econophysics suggest that price (or returns) in financial or commodity markets have fundamentally different properties that contradict or reject RWH. These ubiquitous properties identified are: fat tails [2], long-term correlation [3], volatility clustering [4], fractals and multifractals [5–8], chaos [9], etc. Nowadays, RWH has been widely criticized in the finance and econophysics literatures as this hypothesis fails to explain the market phenomena.

After investigating the prices of cotton, wheat and so on, Mandelbrot provided earliest empirical evidence that agricultural commodity spot prices do not obey RWH by means of fractal geometry [10,11]. Since then, fractal geometry has been widely applied in finance and market research domains. Peters introduced fractal theory into the capital market research, and provided empirical evidence of the mono-fractal properties in many financial markets by means of R/S analysis [12,13]. In order to study the mono-fractal properties of nonstationary series, Detrended Fluctuation Analysis (DFA) [14] and Detrended Moving Average Analysis (DMA) proposed by Carbone et al. [15–20] were introduced for the analysis of average and time-dependent long-range correlation. As Mono-fractals cannot describe the multiscale and subtle substructures of fractals in complex systems, many measures are applied to investigate the multifractality, such as height–height correlation function [21], Multifractal Detrended Fluctuation Analysis (MF-DFA) [22–31], the partition function method [32–34], etc. Empirical evidence shows that many financial markets are multifractal. Norouzzadeh et al. found the multifractal properties and scaling behaviors of the exchange rate variations of the Iranian rial against the US dollar, and found that the contributions of two major sources of multifractality are fat-tailed probability distributions and nonlinear temporal correlations [26]; Kumar and Deo studied the multifractal properties of the logarithmic returns of the Indian financial indices, and found that the multifractality is due to the contributions of nonlinear temporal correlations as well as the broad probability density function [31]; Oświęcimka et al. investigated the different multifractal properties between the time series of logarithmic price increments and the inter-trade intervals of time by high-frequency tick-by-tick data, and found that the multifractals come from the nonlinear temporal correlations as well as the non-Gaussian distributions of the fluctuations [24]. Similar results are found in commodity markets. Alvarez-Ramirez et al. investigated the multifractal properties of international crude oil prices and their dynamical properties [6]; Matia et al. analyzed daily price of 29 commodities (and 2449 stocks as well), and found that the price returns for commodities have a significantly broader multifractal spectrum than for stocks, and both of the multifractal properties can be attributed mainly to the broad probability distribution of price fluctuations and secondly to their temporal organization [23]; Lim et al. investigated the multifractal properties of price increments in the cases of derivative and spot markets, and found that multifractality due to a fat-tailed distribution is significant [27].

In agricultural futures markets domain, Chatrath et al. studied four futures as the representatives of US agricultural futures and found low-dimensional chaotic structures in the markets [35]; Corazza et al. studied six main US agricultural futures and found the existence of mono-fractals [36]. As for China's markets, although there are some results on multifractal properties in Shenzhen and Shanghai stock markets [29,32,33], few empirical evidence in current literature can offer the answer to the problem whether China's agricultural futures markets are multifractal or not.

Many scholars have compared many different markets and investigated their multifractal properties. K. Matia et al. investigated daily prices of 29 commodities and 2449 stocks, and found that the price returns for commodities have a significantly broader multifractal spectrum than for stocks [23]; L. Zunino et al. investigated the multifractality degree of developed and emerging stock market indices, and found that higher multifractality is associated with a less developed market [30]; Zhi-Qiang Jiang, Wei-Xing Zhou also investigated the emerging and developed stock markets, and found that there are not multifractality in the original series of the two markets [34], but their results on China's stock indices shows that there are multifractality properties in those markets [33]. Matos et al. use a new method of studying the Hurst exponent with time and scale dependency to recover the major events affecting worldwide markets which can measure and compare the behaviors in emergent/established markets [37]. Current studies focused on the commodity market, stock market and some other fields, but there is no report on comparative multifractal study between the emerging and developed agricultural futures markets.

Therefore, we chose wheat, soy meal, soybean and corn futures contracts from US and China's agricultural markets as the representatives of the emerging and developed markets, and applied MF-DFA to study the multifractal properties. Our results suggest that there are multifractal features in the two markets except US soybean market, which is much closer to mono-fractal comparing with its counterpart in China; furthermore, the dynamical resources of multifractality are investigated by means of shuffling and phase randomization procedures; finally, the average of $\tau(q)$ are applied to obtain the multifractal spectrum of whole markets, and the multifractal strengths of emerging and developed agricultural futures markets are compared.

## 2. Model

To keep our description as self-contained as possible, let us review briefly the model [38–40].
Let us suppose $P(i),\ i = 1, 2, \ldots, L$, to be a price series, where $L$ stands for the length of the analyzed series. Let us define the logarithmic returns as:

$$r(i) = |\ln\left(P\left(i + \Delta t\right)/P(i)\right)| \quad (i \le L - \Delta t) \tag{2.1}$$