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# The long memory and the transaction cost in financial markets

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## HIGHLIGHTS

- We proposed a model to predict market trends using Hurst exponent.
- Market anomaly of the persisting long-term memory will be discussed.
- The transaction cost may cause of the long-term memory in financial markets

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## ABSTRACT

In the present work, we investigate the fractal dimensions of 30 important stock markets from 2006 to 2013; the analysis indicates that the Hurst exponent of emerging markets shifts significantly away from the standard Brownian motion. We propose a model based on the Hurst exponent to explore the considerable profits from the predictable long-term memory. We take the transaction cost into account to justify why the market inefficiency has not been arbitrated away in the majority of cases. The empirical evidence indicates that the majority of the markets are efficient with a certain transaction cost under the no-arbitrage assumption. Furthermore, we use the Monte Carlo simulation to display “the efficient frontier” of the Hurst exponent with different transaction costs.

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## 1. Introduction

The efficient market hypothesis (EMH) [1] has been widely accepted as a cornerstone of modern financial economics. It is defined as a random walk and leads to a Brownian motion of the asset prices. It is assumed that the financial market is “efficient informationally”, so no one can continuously earn returns in excess of average market returns on a risk-adjusted basis, with the information available at the time of the investment. However, researchers have found that a significant amount of empirical evidence indicates that the capital markets are not well described by the normal distribution and random walk [2–5]. The long memory in returns has been detected in many markets, and the trend of the market return has persisted for years and has not been eliminated by the arbitragers as described in the EMH [2,3,6,7].

Hurst [8] developed the rescaled range analysis (R/S Analysis) and the Hurst exponent, which is widely used as a measure of the long-term memory of time series. Fractal theory [9] demonstrated that much complexity in the financial market could be described by certain ubiquitous mathematical laws. Peters [6] proposed the fractal market hypothesis (FMH) based on Hurst [8] and Mandelbrot [9] and explored the application of chaos theory and fractals to finance. The theory is supported by the simulation based on the agent-based model [10].

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The standard complement of statistical techniques like R/S is used to identify the predictable market structure and is capable of identifying regular periodic cycles and the long memory, which reveals trends in financial markets. Since the acceptance of R/S analysis as a method to capture the long-memory properties in financial markets, new statistical methods have been developed, such as the modified R/S analysis [11] and detrended fluctuation analysis (DFA) [12]. DFA measures the scaling-behavior of the second moment fluctuations and multifractal DFA uses a variable moment and is proposed by Kantelhardt et al. [13,14] as a generalization of the classical Hurst exponent. Generalized Hurst exponent approach (GHE) is suitable to measure the fractal dimension re-explored for financial time series [15]. Detrended moving average method (DMA) [16,17] is another method developed and applied to non-stationary signals. The wavelet transform analysis is also utilized to obtain the wavelet power spectra and indicate the crucial information about the variance distribution across scales and its evolution in time [18,19].

These methods are suitable tools for investigating market efficiency and long memory, which are widely addressed by researchers with ample simulation [10] and empirical results provided. In general, the prediction performs most effectively in emerging markets and least effectively in developed countries. [20,21] adopts the Hurst exponent to test the logarithmic returns of the US S&P 500, and the null hypothesis of the use of Brownian motion to model the return cannot be rejected. Empirical evidences illustrate the dynamic behavior of US stock markets [21]. The Hurst exponent displays erratic dynamics with some episodes alternating between low and high persistent behavior; the major breakthrough of the long-term trend of the scaling behavior occurred in 1972 at the end of the Bretton Woods system, when the Hurst exponent shifted from a positive to a negative long-term trend.

Compared with the research of developed markets, the empirical studies of emerging markets have been examined using the scaling analysis and results indicate a very different result [22–24]. The long-term trend in emerging markets remains positive and more persistent the majority of the time. In the research of Ref. [25], 60 market indexes of various countries are examined. The empirical results indicate a positive relationship between the degree of efficiency and the predictability of the market. The Hurst exponent is useful to distinguish emerging capital markets from mature capital markets, which tend to have a smaller value. [3,26] present an empirical analysis across different markets and assets, including both mature and liquid markets and emerging and less liquid markets. The latter often has a significantly larger Hurst exponent value of above 0.5.<sup>1</sup> Researches [4,27] have also revealed that the stock and exchange market in China exhibits strong long-memory behavior, and the market reflected increasing efficiency with the application of time-varying Hurst exponents based on the volatility series. The detection of the long memory in energy markets are also studied by Refs. [28–33]. A vector measure for capital market efficiency containing long-term memory, short-term memory and fractal dimension measures, built on the martingale definition of EMH, has been introduced, and results indicate that the more efficient markets are dominated by European stock indices and the less efficient markets cover mainly the Latin America, Asia and Oceania [7,34]. Moreover, the local Hurst exponent or time-varying Hurst exponent has been adopted to describe the critical phenomenon in the equity markets and been used as an indicator for the early awareness of the major events affecting the world-wide markets [35–38].

These empirical results raise an additional straightforward question. Because such strong long-memory behavior in emerging markets would imply strong predictability of the price return and substantial profits, the no-arbitrage pricing principle appears to contradict the fact that the inefficiency holds for years and is not eliminated by arbitrageurs. There is one possible explanation for this phenomenon: the transaction cost [39]. The fluctuations in order signs are compensated for by the anti-correlated fluctuations in transaction size and liquidity, which are also long-memory processes that act to make the returns whiter.

In this paper, we use the empirical approach to examine what role the transaction cost plays in this phenomenon. Using the local Hurst exponent  $H(T)$  with a moving window [40–42],<sup>2</sup> we demonstrate that the time-varying fractal dimension of financial markets is connected with the transaction cost. The quantitative approach is used to illustrate how the arbitrageurs of different time-scale intervals are blocked from excessive market returns by the transaction cost, which keeps the market efficient. Moreover, we empirically investigate whether the width of the moving window affects the prediction based on the local Hurst exponent and how precise the prediction is on different scales.

The empirical research above indicates the statistical characteristics of the real markets. To obtain a broader picture of the relationship between the Hurst exponent and the transaction cost, we use the Monte Carlo simulation to display a finer-grained frontier of efficient markets with transaction costs, and various degrees of long memory from the simulating markets are examined. The simulation is able to illustrate that under the no-arbitrage assumption, the value of the Hurst exponent for efficient markets will be expanded from one point (the Hurst exponent is equal to 0.5 in the Brownian motion case) to a range that becomes wider when the transaction cost rises.

In Section 2, we present a brief summary of random midpoint displacement, adopted in this paper to generate the fBm, and the prediction method based on the local Hurst exponent. In Section 3, we indicate the level of the transaction cost required to keep the emerging market efficient under the no-arbitrage assumption and then use the Monte Carlo simulation to display “the efficient zone” of the Hurst exponent with different transaction costs.

<sup>1</sup> The Hurst exponent ( $H$ ) can be used as an estimate of the predictability of a series. The trend of the series can be persistent ( $0.5 < H < 1$ , and what happened in the past is likely to continue), anti-persistent ( $0 < H < 0.5$ , and what happened is likely to reverse), or random ( $H = 0.5$ , and it is likely to go in any direction).

<sup>2</sup> In the study by Grech [40], the Hurst exponent of an  $N$ -length subseries  $[T - N - 1, T]$  is used to describe the statistical properties and local fractal dimension of the series at the time  $T$ .

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