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The long-term memory of stock markets: unveiling patterns and predictability

Samuel Tabot Enow [(a)]*

[(a)] *Research associate, The IIE Vega school, 444 Jan Smuts Ave, Bordeaux, Randburg, 2194, South Africa*

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ABSTRACT

The efficient market hypothesis assumes that financial markets fully incorporate all available information, rendering past information irrelevant for predicting future prices. However, numerous studies challenge this notion and suggest the presence of long-term memory in market dynamics. Understanding long-term memory in financial markets has important implications for investors and policymakers. The aim of this study was to empirically investigate long term memory in financial markets. This study employed a Hurst model for a sample of 5 financial markets from June 1, 2018, to June 1, 2023. The findings revealed that four out of the five sampled financial market exhibits long term memory which challenges the efficient market hypothesis concept. Therefore, portfolio managers and active market participants can utilize long-term memory to optimize asset allocation decisions by considering the persistent effects of past returns and adjust portfolio weights to take advantage of potential return predictability and manage risk.

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Introduction

The concept of the long-term memory of stock markets has garnered significant attention in financial economics. It challenges the notion of market efficiency and random price movements by suggesting that past price patterns and trends have a persistent influence on future stock returns. Efficient market theory posits that stock prices fully and immediately reflect all available information, making it impossible to consistently outperform the market (Fama, 1965). However, empirical studies have uncovered evidence of predictable patterns and dependencies in stock returns that extend beyond short-term horizons. This phenomenon, known as long-term memory, suggests that past stock prices contain information that is not fully incorporated into current prices, providing potential opportunities for investors (Li & Wang, 2020).

The empirical evidence supporting the existence of long-term memory in stock markets is substantial. Researchers have employed various statistical techniques, such as autoregressive models, fractional integration models, or wavelet analysis, to measure the degree of persistence in stock returns (Tan, Galagedera & Ann Maharaj, 2012; Caporale, Gil-Alana & Plastun, 2022). These studies consistently find that past returns continue to have an influence on future returns over extended time horizons, indicating a slow decay or persistence in stock price dynamics.

The presence of long-term memory in stock markets has important implications for market participants. Investors can exploit the predictability in stock returns to develop investment strategies such as momentum or contrarian approaches that capitalize on the persistence of past price movements. Portfolio managers can incorporate long-term memory into their asset allocation decisions, adjusting portfolio weights based on historical trends to enhance performance and manage risk. Also, the existence of long-term memory suggests that there may be informational inefficiencies or behavioural biases in the market that can be exploited by astute investors (Weixiang, Qamruzzaman, Rui & Kler, 2022).

* *Corresponding author. ORCID ID: 0000-0003-4178-4123*
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Understanding the mechanisms behind long-term memory in stock markets is an area of ongoing research. Theoretical explanations for long term memory in financial markets include investor sentiment, herding behaviour and the presence of fundamental factors that change gradually over time.

Therefore, the aim of this study was to empirically investigate long term memory in financial markets using the most recent data. Specifically, this study investigates the following research question; Are there any empirical evidence for long term memory in financial markets? What is the implication of this study for the concept of market efficiency? Recognizing and understanding the long-term memory in stock markets can help market participants make informed investment decisions and develop strategies that capitalize on predictable patterns in stock price dynamics. Therefore, this study makes a noteworthy contribution.

Literature Review

The literature on long-term memory in financial markets encompasses studies from different subfields, including stock markets, bond markets, foreign exchange markets, and commodity markets. The long-term memory of stock markets refers to the phenomenon where past price movements and patterns have a persistent influence on future price dynamics. It suggests that stock returns exhibit a certain degree of dependence on historical data over an extended period, challenging the notion of efficient markets and random price movements. Researchers have employed various statistical techniques, such as autoregressive models, fractional integration models, wavelet analysis, and multifractal approaches, to capture and measure the presence of long-term memory. Some researchers (Kelly, Moskowitz & Pruitt, 2021; Enow, 2023) have demonstrated that past stock returns exhibit persistence, suggesting that historical price patterns and trends influence future returns. This persistence can be observed over extended time horizons, challenging the assumption of random price movements and providing opportunities for investors to exploit predictable patterns. Theoretical explanations for these long-term memory in financial markets include investor sentiment, herding behaviour and the presence of fundamental factors that change gradually over time. These factors contribute to the patterns observed in stock market returns and suggest the presence of informational inefficiencies or behavioural biases in the market.

Numerous empirical studies (Lo, 1991; Cutler, Poterba, and Summers, 1991; Bouchaud, Matacz, and Potters, 2001; Preis, Golke, and Paul, 2006; Cont and Bouchaud, 2008; Zunino et al. 2012; Wang, Xie & Yang, 2018) have provided evidence of long-term memory in stock markets. These studies employ statistical techniques such as autoregressive models, fractional integration models and wavelet analysis to estimate the presence of long-term memory in financial markets. The findings consistently indicate that stock returns exhibit slow decay or persistence, meaning that past returns continue to influence future returns over extended time horizons. This persistence suggests that information contained in past stock prices is not fully and immediately reflected in current prices leading to predictability and potential opportunities for investors.

Several theoretical explanations were also proposed to understand the long-term memory observed in stock markets. One prominent explanation is investor sentiment and herding behaviour which suggests that market participants may exhibit irrational behaviour and systematically overreact or underreact to new information leading to momentum or reversal patterns in stock prices (Choi & Yoon, 2020). This behaviour can contribute to the persistence observed in stock returns. Another explanation is the presence of fundamental factors that change gradually over time. Economic variables, such as interest rates, inflation, or corporate earnings, may have persistent effects on stock returns (Eldomiaty, Saeed & Hammam, 2018). Investors who incorporate these fundamental factors into their decision-making process can drive the long-term memory in stock markets.

While there are advocates that financial markets possess a degree of long-term memory, there are studies that challenge this notion (Chow, Denning, Ferris, Noronha, 1995; Caporale, Gil-Alana & Plastun, 2017). These studies argue against the existence of long-term memory in financial markets and propose alternative explanations for observed market patterns. More specifically, advocates against the long term memory suggests that financial markets are efficient, meaning that all available information is immediately and accurately reflected in asset prices. According to this hypothesis, past price patterns or trends are irrelevant for predicting future price movements (Lo & Foerster, 2021). Instead, prices are determined solely by new information.

According to Kılıç (2020), market participants constantly adapt their strategies based on changing information, which prevents the persistence of long-term memory. Descalzi and Rosso (2018) are of the opinion that financial markets exhibit nonlinear dynamics which can give rise to complex and unpredictable behavior. These nonlinearities, such as feedback loops and interactions between various market factors, can lead to short-term dependencies in prices but limit the presence of long-term memory. Critics of long-term memory argue that many apparent patterns or correlations in financial market data are the result of data mining and overfitting (Kaur & Dharni, 2022).

They argue that due to the vast amount of available historical data and the abundance of potential trading strategies, some patterns will inevitably emerge by chance alone. Such patterns, however, may not hold up in future periods, undermining the notion of long-term memory. It is important to note that these studies do not necessarily disprove or approve the existence of long-term memory in financial markets but rather present alternative perspectives and theories. The debate surrounding this topic is ongoing, and the field of financial economics continues to explore the complexities of market behaviour and the role of memory in shaping prices. Hence this study adds to the debate and frontier of the long-term memory of financial markets. The section below highlights the blueprint of the study.

Research & Methodology

A Hurst exponent model was used to quantify the long-term memory or persistence of stock market returns in five selected markets namely; The Nasdaq index, the French stock market index (CAC 40 index), Frankfurt stock exchange (DAX index), Japanese stock index (JPX-Nikkei 225) and Johannesburg stock exchange (JSE index) for a five-year period from June 1, 2018 to June 1, 2023. The Hurst exponent is often used to analyse the autocorrelation structure and predictability of stock price movements and is very useful to ascertain whether a time series exhibits a trend, mean-reversion, or random walk behaviour over different time horizons (Bui & Ślepaczuk, 2022). This model is very useful in estimating the extend in which a fitted a linear regression line correlates with a logarithm of the rescaled range as a function of the time series (Vogl, 2022). In its simplest form, the mathematical expression for the Hurst model is highlighted below;

$$\forall_n(x) = 1 - \beth_n = 1 - \frac{1}{n}\, log_2 s_n$$

The Hurst exponent, denoted by $\forall_n$ ranges between 0 and 1, the statistical analysis of these range is presented below. If;

$\forall_n$ < 0.5: A Hurst exponent greater than 0.5 indicates a persistent or trending behavior in the time series suggesting a positive autocorrelation. This implies that past values have an impact on future values hence the existence of long-term memory and the potential for predictable patterns.

$\forall_n$= 0.5: A Hurst exponent of 0.5 suggests a random walk behavior in the time series indicating no long-term memory or persistence and future values are independent of past values.

$\forall_n$> 0.5: A Hurst exponent less than 0.5 suggests an anti-persistent or mean-reverting behaviour implying a negative autocorrelation where past values have a tendency to be followed by opposite movements in future values. The findings and discussion are presented in the section below.

Analysis and Findings

The Hurst model findings and analysis are presented below.

Table 1: Hurst Model output

JSE Index								
Sum samples	2	4	8	16	32	64	128	256
Observations	625	312	156	78	39	20	10	5
Average (Rescale ranges)	23.0	16.2	12.1	8.7	6.0	4.2	2.7	1.7
Log(R/S)	3.1	2.8	2.5	2.2	1.8	1.4	1.0	0.5
Log(n)	6.4	5.7	5.1	4.4	3.7	3.0	2.3	1.6
Hurst exponent	0.530							
Standard error	0.017							
Expected Hurst	0.5							
t-stat	1.76							
Number of observations	8							
degree of freedom	6							
p-value	12.95%							
Nasdaq								
Sum samples	2	4	8	16	32	64	128	256
Observations	625	312	156	78	39	20	10	5
Average (Rescale ranges)	29.3	19.2	12.9	9.0	6.3	4.1	2.8	1.7
Log(R/S)	3.4	3.0	2.6	2.2	1.8	1.4	1.0	0.5
Log(n)	6.4	5.7	5.1	4.4	3.7	3.0	2.3	1.6
Hurst exponent	0.573							
Standard error	0.010							
Expected Hurst	0.5							
t-stat	7.17							
Number of observations	8							
degree of freedom	6							
p-value	0.04%*							
CAC 40								
Sum samples	2	4	8	16	32	64	128	256
Observations	625	312	156	78	39	20	10	5

Table cont'd

Average (Rescale ranges)	31.5	20.6	14.5	9.1	6.7	4.4	2.8	1.7
Log(R/S)	3.4	3.0	2.7	2.2	1.9	1.5	1.0	0.5
Log(n)	6.4	5.7	5.1	4.4	3.7	3.0	2.3	1.6
Hurst exponent	0.592							
Standard error	0.012							
Expected Hurst	0.5							
t-stat	7.53							
Number of observations	8							
degree of freedom	6							
p-value	0.03%*							
DAX								
Sum samples	2	4	8	16	32	64	128	256
Observations	625	312	156	78	39	20	10	5
Average (Rescale ranges)	31.4	20.6	13.4	9.0	6.5	4.3	2.8	1.7
Log(R/S)	3.4	3.0	2.6	2.2	1.9	1.5	1.0	0.5
Log(n)	6.4	5.7	5.1	4.4	3.7	3.0	2.3	1.6
Hurst exponent	0.587							
Standard error	0.010							
Expected Hurst	0.5							
t-stat	8.75							
Number of observations	8							
degree of freedom	6							
p-value	0.01%*							
Nikkei 225								
Sum samples	2	4	8	16	32	64	128	256
Observations	625	312	156	78	39	20	10	5
Average (Rescale ranges)	31.6	20.5	15.5	10.3	7.0	4.5	2.9	1.7
Log(R/S)	3.5	3.0	2.7	2.3	1.9	1.5	1.1	0.5
Log(n)	6.4	5.7	5.1	4.4	3.7	3.0	2.3	1.6
Hurst exponent	0.592							
Standard error	0.018							
Expected Hurst	0.5							
t-stat	5.15							
Number of observations	8							
degree of freedom	6							
p-value	0.21%*							

*Significant at 5%

Consistent with the studies of Lo (1991); Cutler, Poterba, and Summers (1991); Bouchaud, Matacz, and Potters (2001); Preis, Golke, and Paul (2006); Cont and Bouchaud (2008); Zunino et al. 2012 and Wang, Xie & Yang (2018), the findings revealed long term memory in the Nasdaq, CAC 40, DAX and Nikkei 225. However, there is no evidence to suggest long term memory in the JSE. This was evident in the p-values that are less than the 5% threshold in the Nasdaq, CAC 40, DAX and Nikkei 225. This finding suggests that past returns in the Nasdaq, CAC 40, DAX and Nikkei 225 can be reliably used to forecast future returns. The implications of long-term memory in financial markets are significant for market participants. Investors can incorporate long-term memory into their investment strategies by considering historical price patterns and trends. Strategies such as momentum or contrarian approaches can be employed to capitalize on the persistence in financial variables. Portfolio managers can utilize long-term memory to optimize asset allocation decisions, adjusting portfolio weights based on historical trends to enhance performance and manage risk effectively.

Conclusion

long-term memory observed in the Nasdaq, CAC 40, DAX and Nikkei 225 indicates that past price movements have a persistent influence on future returns. Empirical evidence supports the presence of long-term memory and suggest that investor behaviour and fundamental factors as possible drivers. Recognizing and incorporating long-term memory into investment strategies and risk management practices can provide market participants with insights to exploit predictable patterns and optimize portfolio performance for market participants willing to invest in the Nasdaq, CAC 40, DAX and Nikkei 225. Also, the existence of long-term memory in these stock markets questions the efficiency of markets by opening avenues for market participants to exploit predictable patterns and potentially generate abnormal returns. Portfolio managers can utilize long-term memory to optimize asset allocation decisions by considering the persistent effects of past returns and adjust portfolio weights to take advantage of potential return predictability and manage risk. Despite the profound findings of this study, it is important to note that the interpretation of the Hurst exponent should be considered in conjunction with other analyses and not used as a standalone indicator. The Hurst exponent provides a measure of long-term memory but does not capture short-term dynamics or the full complexity of stock market behaviour.

Despite the extensive research on long-term memory in financial markets, there are still areas that require further exploration. The impact of long-term memory on market stability, the role of different market participants in driving persistence, and the interaction between long-term memory and market microstructure are areas of further research.

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