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A Non-linear Dependency Test for Market Efficiency: Evidence from International Stock Markets

Samuel Tabot ENOW[*]
IIE Varsity College, Durban, South Africa

Abstract

One of the on-going difficulties for finance practitioners is to out rightly prove or disapprove the concept of market efficiency because the constituents of the concept do not always reflect real financial markets. Market efficiency is an idle state that varies with time and may have dire consequences for active market participants. The aim of this study was to empirically investigate market efficiency before, during and after a period of financial distress. A BDSL non-linear dependency test was used to observe the logic distance between the observed pairs of returns and the expected pair vectors in stock prices for the JSE, Nasdaq, CAC 40, DAX, Nikkei 225 and BIST100. The findings revealed that market efficiency is a dynamic concept. Most financial markets under consideration show strong signs of efficiencies before and after financial distress. However, significant inefficiencies were observed during a bearish period probably due to fear and greed. Considering the dynamic nature of market efficiency, market participants may enhance the value of their portfolios by alternating their investment style accordingly. More specifically, investors should consider investing in index fund EFTs during periods of financial distress and adopt an active management strategy during bullish periods. Also, scarce liquidity seems to be the major cause of market inefficiency during periods of financial distress therefore, quantitative easing is strongly recommended during these episodes.

Keywords: *Market Efficiency; Abnormal Returns; Stock Markets; Active Management; BDSL Test; Non-Linear Dependence.*

JEL Classification: *G11, G15, G17.*

[*] Corresponding author.
E-Mail: enowtabot@gmail.com

1. Introduction

One of the landmark theories in financial markets is the concept of market efficiency and therefore understanding this concept may be very useful to market participants and investment practitioners for good decision making. Market efficiency, according to Fama (1965) is the propensity of financial markets to promptly reflect all relevant information in the security price. Hence it might not be possible to achieve sustained anomalous returns above the market. Market participants cannot earn long-term abnormal returns because financial markets reflect the expected values of the asset as well as their relative volatilities. Consequently, the future value of the security is highly unpredictable. Stock prices will fluctuate arbitrarily when new information enters financial markets considering that information is similarly unpredictable (Shi, Broussard & Booth, 2022). Fama (1965) argues that because stock markets are highly competitive and market players are seeking to execute trades at the highest feasible price, security prices are generally in equilibrium and fairly priced. In these competitive markets, there are too many competing views between market participants which are reflected in the prices of the security. In essence, the price of the security becomes a mechanism to aggregate information and market expectations. Also, market participants with new information cannot interact with each other outside the market. As a result, it is exceedingly difficult for active market participants to regularly realize abnormal profits by trading on new information and detecting mispriced securities because their expectations are always relayed through asset prices (Daniel & Hirshleifer, 2015). In tandem with the propositions put forth by the market efficiency theory, there has been several robust empirical analyses of testing the concept. The most common test was on the ability for active market participants to outperform the market without taking additional risks (Shamshir & Mustafa, 2018). Considering that excess risk adjusted returns known as alpha are the ultimate goal of active market participants, the ability to generate consistent excess returns without taking additional risk will violate market efficiency. Most of the findings from these studies revealed that these market participants could not consistently outperform the market in the long run (De Renzis, Ferrari & Proietti, 2022). Also, active managed funds could not outperform their passive managed counterparts on average after deducting transaction cost advocating for the concept of market efficiency (MacGregor, Schulz & Zhao, 2021). However, due to documented market anomalies, the notion of market efficiency has been refuted by the development of behavioral finance and the psychology of investment. Behavioural finance contends that the concept of rationality proposed by market efficiency is flawed and market participants are subject to different types of behaviours (Kamoune & Ibenrissoul, 2022). The fair value and intrinsic price of an

asset are subject to an investor's perception mimicking the proverb *"beauty is in the eye of the beholder"*. Also, it is more likely for market participants to arrive at different conclusion even with the same information.

Enow (2022) also argues that it is inconceivable for investors to react rationally and in an unbiased manner given the volume of information that is dissipated to financial markets on a daily basis. The historical data of active fund performance for the years 2005 to 2011 likewise revealed these irrationalities, revealing that hedge fund managers generated a positive alpha of 0.17% every month (Bebchuk, Brav & Jiang, 2015). Irrespectively of the criticisms of market efficiency, the concept seems to have some bearings. This is especially true considering that over the past ten years, two-thirds of active and fund managers were unable to outperform the market on a risk-adjusted basis over an extended length of time (MacGregor, Schulz & Zhao, 2021). There is also a general consensus that the performance of stock prices in the past is no guarantee of future results. From the above mentioned arguments in favour and against market efficiency, it is possible that financial markets experience cycles of efficiency and inefficiency depending on other circumstances. Hence this study seeks to explore market efficiency for three different periods, before, during and after financial distress.

More specifically, this study investigates the following research questions; when should market participants expect efficiency in financial markets? Can market participants predictably achieve market efficiency? In modelling these research questions, this study makes a significant contribution to the body of knowledge in the frontier of market efficiency and inefficiency. Also, this study is the first as per our knowledge to empirically explore market efficiency for three different periods. The next section highlights the literature review.

2. Literature Review

The earliest application of computers in economics was in the 50s to analyse economic time series (Mahoney, 1988). During this period, many market participants believed that peaks and troughs in stock price charts were a natural occurrence which could be interpreted as discernible price patterns. However, Kendal (1953) investigated the behaviour of stock prices in which he later found otherwise. Kendal (1953) concluded that stock prices evolved randomly and the likelihood of increasing and decreasing was equal regardless of their past performance. This finding was however disappointing to most market participants at that time.

Later on, the concept of random price movement became apparent and was a building block of a well-functioning efficient market. The theory of market efficiency was first postulated in the early 60s by Fama (1965) in his ground breaking paper titled *"The Behavior of Stock Market Prices"*. Fama (1965) likened the behaviour of stock prices to a Brownian motion pattern due to what he coined, highly unpredictable. This stochastic nature was due to the fact that stock prices quickly incorporate new information (Enow, 2021).

Later on, Dimson and Mussavian (1998) concurred with the market efficiency theory and also proposed that stock prices displayed a random pattern because new information in itself is random. Competition for profits causes stock prices to change quickly to incorporate any new information. The basic principle of market efficiency is that financial markets are highly competitive inducing market participants to continuously adapt their expectations. In essence, investors and active market participants cannot consistently outperform the market. Also, the fact that active managers at times realise positive and negative alphas is a glaring proof of the existence of market efficiency. Several event studies that have been conducted on security indexes have indeed indicated that security prices incorporate new information quickly and active managers do trail the market on average. The table below highlights the most recent empirical evidence on market efficiency.

Table 1. Review of Prior Study on Market Efficiency

Study	Model	Period	Country	Findings
Lingaraja, Selvam & Vasanth (2014)	GARCH and Runs Test	January 2004 to December 2013	Asian Markets	Strong evidence of random price movements, hence evidence of market efficiency.
Phan & Zhou (2014)	VR, Runs Test & autocorrelation	July 2008 to July 2013	Vietnam	Evidence of market efficiency in Vietnamese markets.
Mandacı, Taşkın, & Ergün (2019)	Variance Ratio (VR) and Brock, Dechert and Schieinkman Test	January 2002 to April 2017	Turkey	Evidence of market efficiency due to unpredictable returns.
Kılıç (2020)	VR , Generalized Spectral Test, and Wild-bootstrapped Automatic	January 2013 to April 2019	Turkey	The Turkish stock market had high levels of market efficiency during the period under study.
Munir, Sukor & Shaharuddin (2022)	Cumulative average returns	1997 to 2018	Malaysia, Korea, China, Indonesia, Thailand, Philippines	The findings support the existence of market efficiency

One of the challenges with market efficiency is that it cannot be demonstrably supported or refuted despite the proposition put forth by the authors cited in table 1 above. The concept of market efficiency has been strongly criticised due to the existence of market anomalies (Tegtmeier, 2021; Aliyev, 2019; Enow, 2022; Patra & Hiremath, 2022). These anomalies are more often than not predictable and have been exploited to realise abnormal returns. Market anomalies are perceived to violate the core assumptions of market efficiency due to their predictable patterns. The emergence of known anomalies has led to the concept of adaptive markets. According to the adaptive market hypothesis, financial markets are occasionally efficient and inefficient (Akhter & Yong, 2020). Therefore, the aim of this study was to examine market efficiency before, during, and after a time of financial distress. The next section highlights the research methodology.

3. Methodology

The Brock, Dechert, Scheinkman and Le Baron (1996) (BDSL) non-linear dependency test was used to empirically explore the concept of market efficiency in the Johannesburg stock exchange (JSE), the Nasdaq Index, the French Stock Market index (CAC 40) and the German blue chip companies trading on the Frankfurt Stock Exchange (DAX), the Tokyo Stock Index (Nikkei 225) and the Borsa Istanbul 100 index (BIST100). Albeit complicated, the BDSL test provides an intuitive method for testing market efficiency by using the logic distance between the observed pairs of returns and the expected pair vectors (Genest, Ghoudi & Rémillard, 2007). The BDSL test is suitable for detecting non-linear patterns in time series by relying on correlational integrals between pairs of returns or triple pairs of returns (Maiti, Grubisic & Vukovic, 2020). The mathematical expression of the BDSL test is given by;

$$d = c_m - c_{1m}^m$$

$$v = 4(k^m + 2)\sum_{i=1}^{m-1} k^{m-1}c_1^{2i} + (m-1)^2 c_i^{2m} - km^2 c_1^{2m-2}$$

$$\delta = \sqrt{\frac{v}{n-m+1}}$$

$$z = \frac{d}{\sigma} \sim n(0,1)$$

Where c_{1m}^{m} is the correlation integral, k is the triple pairs of returns, m the number of intervals, n the sample size, v the variance, δ the standard deviation and z the z statistics. Where the time series returns are non-linearly independent or stochastic, the pairs of return and the triple pairs within the distance epsilon are insignificant at 5% (Brock, Dechert, Scheinkman and Le Baron, 1996). The sample period was split into three dispensations, before the Covid-19 pandemic (June 30, 2018 to June 30, 2019), during the Covid-19 pandemic (January 1, 2020 to January 1, 2021) and after the pandemic (March 1, 2022 to March 1, 2023). In so doing, the concept of market efficiency can be vividly understood. The daily price values were retrieved from yahoo finance. These daily prices were used to calculate the daily returns given by;

$$R_t = \frac{P_t}{P_{t-1}} \text{-} 1$$

The next section highlights the findings and discussions from the data analysis.

4. Results and Discussion

In exploring the concept of market efficiency, the BDSL test results before the covid-19 pandemic are given at table 2. From the figures, epsilon varies between 1.24% and 2.07% which is very low. These low values indicate less sensitive changes between the distances in returns. The epsilon results concur with the pairs within distance results denoted by c1 which is 70.3%. The 70.3% value implies that pairs of returns within distance are independent of each other. Although the values of the triple distance within returns (k) are lower, it is above 50% also confirming the presence of independent returns. Looking at the pairs between returns, the probability that returns within pairs are independent of each other is between 48.94% and 51.3% as seen in the DAX and Nasdaq. A much higher figure was observed for the pairs in trimmed return denoted by c12. As a result, only the Nasdaq was found to have a significant difference between the c2 and c12 confirming the presence of linear dependency. However, the JSE, CAC 40, DAX, Nikkei 225 and BIST100 all had insignificant difference between c2 and c12 indicating non-linear independence. A similar finding was observed for the triple pairs of returns where the Nasdaq and Nikkei-225 had significant triple of pairs (c3) and pairs in trimmed returns values. The Nasdaq once again show signs of market inefficiency together with the Nikkei-225 when considering triple pairs of return.

Table 2. BDSL Results before the Pandemic

	JSE	***Nasdaq***	***CAC 40***	***DAX***	***Nikkei -225***	***BIST100***
Epsilon (Distance)	2.07%	1.65%	1.24%	1.33%	1.51%	2.05%
n (Sample size)	247	247	247	247	247	247
c1 (pairs within distance)	70.30%	70.30%	70.30%	70.30%	70.30%	70.30%
k (triples within distance)	53.80%	54.30%	53.50%	53.40%	53.80%	53.30%
m=2(pairs of returns)						
c2 (pairs of pairs)	49.39%	51.30%	49.21%	48.94%	49.64%	49.62%
c12(pairs in trimmed returns)	70.23%	70.12%	70.12%	70.14%	70.04%	70.04%
difference	0.06%	2.14%	0.04%	-0.26%	0.59%	0.56%
Variance	0.79%	0.96%	0.69%	0.65%	0.78%	0.60%
standard deviation	0.57%	0.62%	0.53%	0.51%	0.56%	0.49%
z-stats	0.11	3.43	0.07	-0.51	1.05	1.13
p-value	45.56%	0.03%*	47.17%	30.41%	14.77%	12.83%
m=3(triple pairs of returns)						
c3 (triple of pairs)	35.50%	39.15%	35.61%	34.86%	37.95%	35.07%
c13(pairs in trimmed returns)	70.18%	70.07%	70.02%	70.03%	69.94%	69.95%
difference	0.93%	4.74%	1.28%	0.52%	3.73%	0.84%
Variance	1.98%	2.41%	1.72%	1.62%	1.96%	1.51%
standard deviation	0.90%	0.99%	0.84%	0.81%	0.90%	0.78%
z-stats	1.04	4.78	1.53	0.64	4.17	1.08
p-value	14.97%	0.00%*	6.31%	26.18%	0.00%*	14.09%

Note: The * indicates statistically significance at 5% level.

The table 3 shows results of market efficiency during the pandemic where the pairs of returns and the trimmed return had significant differences in all the sampled financial markets except the DAX confirming the presence of linear dependency. Also, a significant difference was observed between the triple pairs of returns and the pairs in trimmed returns. Once again, all the sampled financial markets displayed market inefficiency during the pandemic. This finding corroborates with studies like Tegtmeier (2021), Aliyev (2019), Enow (2022), Patra & Hiremath (2022), which also documented that financial markets are inefficient. By implication, the existence of market inefficiency suggests the presence of market anomalies during the pandemic. Hence, the competition for profit during periods of financial distress is purely driven by fear and greed.

Table 3. BDSL Results during the Pandemic

	JSE	***Nasdaq***	***CAC 40***	***DAX***	***Nikkei -225***	***BIST100***
Epsilon (Distance)	2.90%	2.62%	2.42%	2.49%	2.03%	2.12%
n (Sample size)	247	247	247	247	247	247
c1 (pairs within distance)	70.30%	70.30%	70.30%	70.30%	70.30%	70.30%
k (triples within distance)	53.90%	54.90%	54.80%	54.80%	54.30%	54.70%
m=2(pairs of returns)						
c2 (pairs of pairs)	50.30%	53.15%	51.42%	49.48%	52.20%	50.31%
c12(pairs in trimmed returns)	70.05%	70.08%	70.03%	70.13%	70.20%	70.37%
difference	1.23%	4.04%	2.37%	0.30%	2.92%	0.79%
Variance	0.81%	1.21%	1.15%	1.18%	0.97%	1.11%
standard deviation	0.57%	0.70%	0.68%	0.69%	0.63%	0.67%
z-stats	2.14	5.76	3.46	0.43	4.66	1.18
p-value	1.61%*	0.00%*	0.03%*	33.37%	0.00%*	11.87%
m=3(triple pairs of returns)						
c3 (triple of pairs)	37.06%	43.24%	38.92%	36.39%	40.23%	37.69%
c13(pairs in trimmed returns)	70.01%	69.96%	69.94%	70.06%	70.27%	70.60%
difference	2.74%	8.99%	4.70%	1.99%	5.54%	2.50%
Variance	2.04%	3.06%	2.91%	2.99%	2.43%	2.79%
standard deviation	0.91%	1.12%	1.09%	1.10%	1.00%	1.07%
z-stats	3	8.04	4.32	1.8	5.56	2.34
p-value	0.13%*	0.00%*	0.00%*	3.56%*	0.00%*	0.96%*

Note: The * indicates statistically significance at 5% level.

We also show results of market efficiency after the pandemic at table 4 where most of the financial markets also portray strong efficiencies. Only the JSE and BIST100 were found to be inefficient post the pandemic with significant p-values for the pairs of returns and triple pairs of returns. It is important to note that the JSE and the BIST100 are considered developing markets. Considering that these markets displayed strong signs of efficiency prior to the pandemic, it is possible the pandemic may have altered the market dynamics resulting to inefficiencies. These findings concur with the findings of Enow (2021) who also contends that the level of market efficiency in the JSE and Nikkei 225 has been altered significantly. Hence, market participants and investment practitioners are expected to alter their investment strategies during and after periods of financial distress. Investing strategies such as the five factor model which is perceived to have very little relevance (Kang & Jang, 2016) before the pandemic may actually be very useful during periods of financial distress.

Table 4. BDSL Results after the Pandemic

	JSE	***Nasdaq***	***CAC 40***	***DAX***	***Nikkei -225***	***BIST100***
Epsilon (Distance)	2.21%	2.90%	1.76%	1.87%	1.74%	2.53%
n (Sample size)	247	247	247	247	247	247
c1 (pairs within distance)	70.30%	70.30%	70.30%	70.30%	70.30%	70.30%
k (triples within distance)	53.80%	52.60%	53.30%	53.30%	53.30%	54.40%
m=2(pairs of returns)						
c2 (pairs of pairs)	51.45%	48.84%	49.85%	49.85%	49.79%	50.33%
c12(pairs in trimmed returns)	70.09%	70.14%	70.29%	70.09%	70.35%	70.04%
difference	2.32%	-0.36%	0.45%	0.72%	0.30%	1.27%
Variance	0.76%	0.40%	0.62%	0.62%	0.61%	1.02%
standard deviation	0.56%	0.40%	0.50%	0.50%	0.50%	0.64%
z-stats	4.18	-0.88	0.9	1.44	0.6	1.98
p-value	0.00%*	18.84%	18.52%	7.55%	27.46%	2.39%*
m=3(triple pairs of returns)						
c3 (triple of pairs)	38.16%	34.18%	35.85%	35.98%	35.14%	37.79%
c13(pairs in trimmed returns)	69.98%	70.12%	70.49%	70.36%	70.29%	70.00%
difference	3.89%	-0.30%	0.83%	1.15%	0.41%	3.49%
Variance	1.91%	1.00%	1.56%	1.56%	1.54%	2.56%
standard deviation	0.88%	0.64%	0.80%	0.80%	0.79%	1.02%
z-stats	4.4	-0.47	1.04	1.44	0.52	3.41
p-value	0.00%*	31.81%	15.03%	7.50%	30.15%	0.03%*

Note: The * indicates statistically significance at 5% level.

5. Conclusion

Market efficiency contents that only new information should elicit responses from market participants as security prices already incorporate all available information. Therefore, the only method of earning higher returns is to invest in riskier stocks. Evidence of market efficiency have been widely explored and validated (Lingaraja, Selvam & Vasanth, 2014; Mandacı, Taşkın, & Ergün, 2019; Kılıç, 2020; Munir, Sukor, & Shaharuddin, 2022). However, as with other theoretical propositions, market efficiency is not static. It will be very misleading to assume that markets are always or never efficient. Hence the purpose of this study was to investigate market efficiency prior, during and post the covid-19 pandemic era. From the findings presented in the results and discussion section, it can be suggested that market efficiency is a dynamic concept. During periods of

financial distress, most financial markets display strong signs of inefficiencies probably due to fear and greed. These inefficiencies may be due to scarcity of liquidity. However, before and after periods of financial distress, financial markets exhibit great signs of efficiency. Considering that most financial markets have recovered from the pandemic, investors in the Nasdaq, CAC 40, the DAX and Nikkei 225 will enhance the value of their portfolios by investing in index funds and EFTs as this funds are passively managed and match the market returns. Also, frequent quantitative easing by Federal governments is highly recommended during periods of financial distress.

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