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A comparative analysis of stock market efficiency of some selected economies across the globe

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Abstract
This study examines the random walk hypothesis and the weak-form efficiency of fifteen stock markets in lower-middle income, upper-middle income and high-income economies across the world. Statistical tests including the Jacque-Bera test, the Augmented Dickey-Fuller test, the runs test, the autocorrelation test and the variance ratio test are applied to weekly returns series of a major market index of each of the fifteen (15) stock markets collected over the period of January 2, 2011, to December 31, 2019. This study documents evidence that the stock markets of Australia, Chile, Germany, Norway, the United States of America, Argentina, Brazil, China, Russia, Egypt, India, Indonesia and the Republic of South Africa are weak-form efficient even though their return series do not follow a random walk. It is, however, found that the stock markets of Ghana and Mexico are not weak-form efficient. These findings imply that stock prices of the weak-form efficient markets fully reflect past price information and that investors cannot formulate investment strategies based on past price information in order to earn above-average returns. Conversely, the results on the Ghanaian and Mexican stock markets signify that stock prices of are predicable so there is a possibility for investors to exploit this market inefficiency.

Keywords: random walk, return series, stock indices, stock markets, weak-form efficiency

Introduction

1.1 Background of Study

The global financial crisis of 2008 has brought to light the many lapses in the global financial system, especially in the pricing of securities in financial markets. Two of the major questions are whether or not the prices of securities reflect available information about the securities and the extent to which they do reflect the available information. There is also the concern that persons with relevant insider information may use it for their own gain to the detriment of others. More recently, concerns and fears of a no-deal Brexit and growing trade tensions between the China and the United States have weighed heavily on financial markets worldwide. With the increase in the frequency and uncertainty of the impact of these interrelated global happenings, it is crucial to assess the nature of efficiency of stock markets.

Furthermore, there has been remarkable development the stock markets all over the world in recent years. The number and variety of listed securities, the number of market participants as well as the volume of transactions executed on a daily basis have risen considerably. In line with that, the scope and depth of empirical research into stock markets have been growing lately. However, the focus of these studies has been mostly on stock markets in European and North American economies, especially the developed ones. There is little research on stock markets in Africa, Asia and South America. Even for the few studies that do exist, substantial and extensive changes have occurred in the respective markets since those studies were performed. Thus, a considerable amount of existing literature comprises studies of shorter study periods or diminished recency.

The concept of the efficient market hypothesis describes three forms of efficiency of financial markets across the world. These forms include the strong form, the semi-strong form, and the weak-form efficient market hypotheses. Numerous studies have investigated the various forms of efficient market hypothesis. However, there are instances where the empirical findings “in the literature seem not consistent about market efficiency, even for the same market” (Senthilnathan, 2015). In light of the issues outlined above, this study examines the random walk process and the weak-form efficiency of fifteen stock markets across various income groups in accordance with World Bank’s classification of economies by income dated July, 2019, making it unique and original.

1.2 Sampled Stock Markets and Indices

1.2.1 Stock Markets of High-Income Countries

First, the Australian Securities Exchange (ASX) was formed in 1999 through the merger of the Australian Stock Exchange and Sydney Futures Exchange. The Sydney-based ASX is ranked among the top 10 global securities exchanges by market capitalization, which is currently about $2 trillion. The S&P/ASX 200 index, which is Australia’s main stock market index, is a float-adjusted market capitalization index of the ASX. The constituents of the S&P/ASX 200 Index are the 200 largest index-eligible stocks listed on the Australian Securities Exchange, representing about 85% Australia’s stock market. The S&P/ASX 200 Index is widely regarded as the benchmark of the performance of the Australian stock market.

Second, Latin America’s third largest stock exchange, the Santiago Exchange, was created in November, 1893. In 1973, it became a founding member of the Latin American Federation of Exchanges (FIAB) and later joined the World Federation of Exchanges (WFE) in 1991. Then in 1993, it inaugurated an electronic display system on the trading floor to replace its traditional chalk boards. Its demutualization was completed in June, 2017, allowing non-shareholders of the exchange to operate in the stock market and stimulating competition. The S&P/CLX IPSA is the main index of the Santiago Exchange. Created 1977, the Indice de Precios Selectivo de Acciones (IPSA) is composed of the stocks of the 40 largest and most liquid Chilean companies listed on the Santiago Stock Exchange.

Third, the Frankfurt Stock Exchange (FSE) is one of the largest stock exchanges in Germany. It was founded in 1585. It is owned and run by Deutsche Börse AG and Börse Frankfurt Zertifikate AG. Its main index, the DAX 30, is a free-floating blue-chip stock market index that covers the 30 largest listed German companies by market capitalization and book value, accounting for about 80% of the total market capitalization of the Frankfurt Stock Exchange. Created in 1988, it is the benchmark index of the FSE, thereby indicating the general direction of the German stock market.

Fourth, the Oslo Stock Exchange (OSE), established in 1819, serves as the sole provider of regulated markets for the trading of securities. The OBX, the headline index of the Norwegian stock market, is a free-float adjusted total return index made up of the 25 most traded securities listed on the OSE.

Last, the New York Stock Exchange (NYSE), also known as the Wall Street, was founded in May, 1792. The NYSE is owned by the American holding company Intercontinental, which is traded under the ticker "NYSE: ICE. The NYSE is the world's largest stock exchange by market capitalization. The S&P 500 is a capitalization-weighted stock market index which comprises 500 top companies in the United States, representing around 80% of available market capitalization. It is widely considered as the stock index with the best representation of the US stock market as a whole and is one of the most closely monitored indices worldwide.

1.2.2 Stock Markets of Upper Middle-Income Countries

One, the Buenos Aires Stock Exchange (BCBA) was founded in 1884. It succeeded the Banco Mercantil, which was founded in 1822 by Argentina's first president. In the present day, the BCBA is a self-regulated non-profit organization that grants thousands of member exchanges access to its exchange facilities at a fee. The Mercado de Valores (MERVAL) Index is the benchmark stock index of the BCBA. It is a price-weighted index.

Two, Brasil Bolsa Balcão (B3) is Portuguese for Brazil Stock Exchange and Over-the-Counter Market. Founded in 1890, the B3 is the largest stock exchange in Latin America and the second oldest stock exchange of Brazil. It successfully introduced an electronic trading system, the Mega Bolsa, in 1997. The B3 is a public company, trading under the ticker "B3SA3". Its main index, the Bovespa Index, was created in 1968. It is composed of stocks listed on B3 that account for about 80% of the number of trades and the financial volume.

Three, Shanghai is known to be the first city of Mainland China to witness the emergence of stocks, stock exchanges and stock trading, with stock trading starting in Shanghai in the 1860s. After years of several developments and unsuccessful attempts to open and maintain securities exchanges, the Shanghai Stock Exchange (SSE) was established in November, 1990. In 2018, the World Federation of Exchanges ranked the Shanghai Stock Exchange 4th in the world in terms of total market capitalization. This places the SSE among the world's topmost exchanges. The Shanghai Stock Exchange Composite Index (SSECI) is a capitalization-weighted index made up of all the A-shares and B-shares that trade on the SSE. It is regarded as a measure of the performance of the Chinese stock market.

Four, the Mexican Stock Exchange (BMV) was formed as a partnership by a group of brokers under the name Bolsa de Mexico (Mexico's Stock Exchange), registering the public deed on June 14, 1895. Then in 1999, its trading system became fully electronic for the first time. It later went public in 2008 in Mexico's first IPO, listing itself at 16.50 pesos a share and trading under the ticker code BOLSAA.MX. Today, the BMV is the second largest stock exchange in Latin America (after Brazil's B3) and the fifth largest in the Americas by market capitalization of listed companies. Today, the total market capitalization of BMV is more than US$ 530 billion. The main index of the BMV is the S&P/BMV Índice de Precios y Cotizaciones (IPC). The S&P/BMV IPC is an index of 35 largest and most liquid listed stocks that trade on the BMV.

Five, the Moscow Exchange (MOEX) was established on 19 December, 2011, through a merger of two large exchanges: the Moscow Interbank Currency Exchange (MICEX) and the Russian Trading System (RTS). The MOEX went public in 2013, listing on its own trading platform. It has since been trading on the platform under the ticker "MOEX". Today, the MOEX ranks among the top 20 exchanges in the world by total market capitalization of traded shares and is Russia's largest stock exchange. The MOEX Russia Index (MOEXRI) is a market capitalization-weighted composite index that is computed based on prices of the most liquid Russian stocks of the largest and dynamically developing Russian companies listed on the MOEX. Previously known as the MICEX Index, the MOEXRI is a major benchmark for the stock market of Russia and is closely tracked by key stakeholders worldwide.

1.2.3 Stock Markets of Lower Middle-Income Countries

Egypt's oldest stock exchange was established in Alexandria in 1861 for cotton trade. Two attempts by brokers to set up a stock exchange in Egypt in 1890 and in 1898 failed. Hence, the brokers resorted to trading without written rules until 1903 when the Cairo Stock Exchange was established. Though the Alexandria Stock Exchange was established in 1883, it was not considered part of the stock exchange until 1902. The Egyptian Exchange (EGX), thus, consists of the Cairo Stock Exchange and the Alexandria Stock Exchange under the control and leadership of one Board of Directors. The two exchanges also share trading, clearing, and settlement systems. The EGX is regarded as one of the oldest stock exchanges in the Middle East. The EGX 30 is a major index of the Egyptian Exchange. It is a free-float capitalization weighted index comprising the top 30 EGX-listed stocks by market capitalization and liquidity. It was previously known as the CASE 30 Index.

Next, the Stock Exchange Act of Ghana was enacted in 1971. Then in July, 1989, Ghana Stock Exchange (GSE) was incorporated as a private company limited by guarantee under the Companies Code 1963. After years of preparatory work, the GSE was officially launched on January 11, 1991. In April 1994, its status changed to a public company limited by guarantee under the Company Code 1963 (Act 179). The Ghana Stock Exchange Composite Index (GSECI) is the main stock market index of the GSE. The GSECI is a market capitalization weighted index computed based on volume-weighted average closing prices of all stocks listed on the GSE.

The BSE, formerly known as the Bombay Stock Exchange, was established as ‘The Native Share & Stock Brokers' Association’ in Bombay (now Mumbai) in India in 1875, making it the first in Asia. Its main index the Standard & Poor Bombay Stock Exchange Sensitive Index (the S&P BSE SENSEX) was launched on January 01, 1986. The S&P BSE SENSEX is a free-float market capitalization index comprising 31 stocks of companies listed on the BSE, including 2 stocks of Tata Motors. The component companies include players in the financial, automobile, energy, tele communications, information technology and pharmaceutical sectors of the Indian economy. It is the most closely monitored bellwether index in India, the second most populous country on earth.

From 1988 to 1990, the Indonesian government implemented a deregulation programme in the areas of banking and capital markets, which attracted foreign investors and improved market activity. During these reforms, the Jakarta Stock Exchange (JSX) was formed in 1912. The stock market became inactive during the period of World War I, World War II and the independence struggle of Indonesia. It was later re-opened by the Indonesian government in 1977 amidst improved regulation and other supporting conditions. The then Jakarta Stock Exchange (JSX) introduced its electronic trading system, the Jakarta Automated Trading System (JATS), in 1995 after it went into private ownership in 1992. Then in 2007, the Jakarta Stock Exchange (JSX) merged with the Surabaya Stock Exchange (SSX) and changed its name to the Indonesia Stock Exchange (IDX). The IDX Composite Index (IDXCI) is a capitalization-weighted index of all stocks listed on the Main Board of the IDX. It was previously known as the JSX Composite. Today, the IDXCI is widely tracked by investors and industry watchers as a signal of the general direction of the Indonesian stock market.

More, the Johannesburg Stock Exchange (JSE) was established in 1887; at a time that was characterized by the first gold rush in South Africa. In 1963, the JSE became a member of the World Federation of Exchanges. The JSE migrated onto an electronic trading system in the 1990s. In 2005, the JSE demutualized and listed on its own exchange. In the present day, the JSE is ranked as the largest stock exchange on the continent of Africa and the 19th largest stock exchange in the world by market capitalization. The FTSE/JSE All Shares Index (ALSI) is a market capitalization-weighted index made up of some 150 companies listed on the Main Board of the JSE, accounting for 95% of the full market capitalization of all eligible stocks listed on the Main Board of the JSE, making it the largest index by size and overall value.

1.3 Significance and Limitations of Study

The findings of this study will be of immense benefit to investors, regulatory authorities, researchers, policy makers, the academia and other stakeholders of the financial markets. This study has the potential to provide guidance to investors concerning the nature of investment strategy to adopt in the respective markets. Based on the research findings, this study will give a general view on the feasibility and scope for above-average earnings from the use of active or passive investment strategies in the respective markets. Also, the findings of this study will guide policy makers in making better policies and regulations for the respective markets. Such policies may include tailor-made policies and measures to enhance investor protection, improve disclosure requirements, ensure market stability, boost market performance, enforce stringent trading practices and stimulate economic development.

Also, the findings will help researchers to identify new research gaps. These gaps may come from differences in time intervals of data, sample sizes, geographical spread of the sampled stock markets and statistical techniques employed in this study. The identification and bridging of these research gaps could open new frontiers in the research and application of efficient market hypothesis. Moreover, this study will provide instructors and students with current information on stock market efficiency from a global perspective. This is due to the fact that the sampled market indices are drawn from markets in Africa, the Asia-Pacific region, Europe, Latin America, and North America. Hence, this study will enable instructors and students to obtain a worldview of stock market efficiency and to make comparisons of the study results of stock markets across income classifications and geographical viewpoints.

Even though this study fills a number of research gaps, it has some limitations. Firstly, this research uses data comprising values of stock indices, but does not use actual share prices. Since stock market indices usually serve as a measure of overall market performance, the findings may not necessarily reflect the behavior of specific stocks listed on the individual stock markets. More, this study employs only weekly values of the indices. Daily or monthly or other index values were not included. An examination of daily, weekly, and monthly values the indices, or any combinations thereof, may yield dissimilar results. Lastly, this study excludes stock markets of low-income economies due to the paucity of data.

2. Literature

2.1 Theoretical Review

The concept of efficient market hypothesis came into fashion at the beginning of the 20th century when French mathematician Louis Bachelier did his dissertation on the topic “The Theory of Speculation” for a PhD in mathematics in 1900. In the middle of the century, Louis Bachelier’s dissertation caught the attention of leading academics and researchers. It later served as the basis for the development of the random walk hypothesis and the efficient market hypothesis. Developed by Kendall (1953), the concept of the random walk hypothesis posits that stock prices follow a random walk and are, therefore, not predictable. Kendall (1953) conducted an analysis of the return series of twenty-two stock market indices and reached the conclusion no one can consistently predict the performance of a stock market. The random walk hypothesis is usually regarded as a component of the efficient market hypothesis, which was developed by Eugene Fama in 1970 [6]. Fama (1970, p. 383) [6] contends that security prices in an efficient market “fully reflect all available information” at all times. In other words, there are no over-valued or under-valued securities because prices of securities on efficient markets reflect all available relevant information. The efficient market hypothesis suggests that no investor can outperform the market consistently. It therefore renders fundamental analysis and technical analysis a futile exercise since security prices already reflect their fundamental values and technical analysts cannot profit from past trend and volume data of securities. Market efficiency refers to the extent to which the prices of securities reflect all available pertinent information, both public and private. According to Fama (1970) [6], there are three conditions (which are considered as sufficient but not necessary) on which efficient market hypothesis depends. These sufficient conditions are the absence of transaction costs, the existence of free and public information and the incorporation of all available relevant information in current stock prices. Even though these conditions constitute a vital foundation for efficient market hypothesis, Malkiel and Fama (1970) [6] argue that their contravention does not necessarily render a market inefficient. Fama (1970) [6] categorized efficient market hypothesis into three forms. They are the strong-form, the semi-strong form and the weak-form efficient market hypotheses. The strong- form efficient market hypothesis states that stock prices reflect all relevant public and private information so investors cannot beat the market by trading with any new piece of information. It is highest form of market efficiency. The next form is semi-strong form efficiency, which posits that public information is incorporated in prevailing stock prices. Lastly, weak-form efficient market hypothesis states that stock prices reflect only past volume and price information of stocks. Future prices and returns on securities cannot be predicted based on historical price information. The weak form efficiency of capital markets can be tested using the runs test, serial correlation test, simulation tests, and filter tests among others.

2.2 Empirical Review

There has been a number of studies in the area of stock market efficiency in Europe, Asia, Africa and other parts of the world. Earlier studies, which were predominately based on developed economies of Europe and America, appeared to support the notion of efficient markets. However, recent studies on various markets have shown mixed results. Focusing on the emerging equity markets of Latin America, Urrutia (2004) employ the variance ratio tests to investigate the random walk hypothesis in the stock markets of Argentina, Brazil, Chile, and Mexico. The research data consists of monthly index values from December 1975 to March 1991. The study finds evidence that the stock prices of all the equity markets did not follow a random walk. The results of the runs test, however, indicate that the equity markets of Argentina, Brazil, Chile, and Mexico are weak-form efficient. In addition, Worthington and Higgs (2004) [14] test the random walk hypothesis and weak-form efficiency in sixteen developed European equity markets (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom) and four emerging European equity markets (Czech Republic, Hungary, Poland and Russia). According to the findings of the unit root, serial correlation, and multiple variance ratio tests, Hungary is the only emerging market that exhibited a random walk. Among the developed markets, only Germany, Ireland, Portugal, Sweden and the United Kingdom meet the most stringent criteria of a random walk. France, Finland, the Netherlands, Norway and Spain fulfill just part of the requirements for a random walk. Asteriou and Kavetsos (2006) [7] examine the efficient market hypothesis in eight (8) transition economies (the Czech Republic, Hungary, Lithuania, Poland, Romania, Russia, Slovakia, and Slovenia) by testing for the presence or absence of the January effect using monthly time series of the stock markets over the 1991-2003 period. The findings evidence the existence of the January effect in the stock markets of most of the sampled transition economies. Especially, the empirical findings provided stronger evidence of the existence of the January effect in the stock markets of Hungary, Poland and Romania. More, the results for Hungary and Romania also provide evidence in support of the tax-loss selling hypothesis. Moreover, Simões, van Aduard de Macedo-Soares, Klotzle, and Pinto (2012) [11] assess the semi-strong form efficiency of the Latin American stock markets of Argentina, Brazil, and Chile using the event study method and stock price data from October, 1995, to August, 2008. The study documents evidence of an efficient reaction to stock prices to the announcement of mergers and acquisitions, in line with the semi-strong efficient market hypothesis, in Brazil but not in Chile and Argentina. Ayentimi, Mensah, and Naa-Idar (2013) [4] investigate the weak-form efficiency of the Ghana Stock Exchange (GSE). Following the analysis of weekly return series of listed financial stocks from January, 2007 to June, 2012, the study finds evidence of volatility clustering. More, the returns are not normally distributed. They therefore conclude that the GSE is weak-form inefficient. As well, Sheefeni (2015) [10] examines the strong-form efficiency of the Namibian capital market. In the research, autoregressive conditional heteroscedasticity (ARCH) and general autoregressive conditional heteroscedasticity (GARCH) modelling techniques are applied on the monthly data for the period stretching from 1997 to 2012. The study finds no evidence of strong form efficiency of Namibia's stock market. It, however, finds evidence of weak-form efficiency. Chavannavar and Patel (2016) [5] test the weak-form and semi-strong form of market efficiency of the Indian stock market. In the study, daily closing prices of the NIFTY 50 index and 50 individual stocks collected for the 3-year period from April 1, 2013, to March 31, 2016, are analyzed using event study and statistical tests including autocorrelation and runs tests. The results of the runs test show that successive price changes are independent and random. Moreover, the autocorrelation is insignificant, with values close to zero. For the event study, it is found that the announcement of the event has no bearing on returns. Thus, they conclude that the Indian stock market is efficient, in both the weak form and the semi-strong form. Also, Rossi and Gunardi (2018) study important market anomalies (January and weekday effects) in France, Germany, Italy and Spain stock exchange indices over the period of 2001 to 2010. They employ the GARCH model and the OLS regression to verify the distribution of the returns of the indices and their autocorrelation. The findings of the analysis do not show any strong proof of comprehensive calendar anomalies, which refute the efficient market hypothesis, in the four countries examined. Furthermore, Angelovska (2018) [2] examine the weak form efficiency of the emerging Macedonian Stock Exchange (MBI10) using daily stock returns from January 4, 2005, to April 2, 2018. The Random Walk Model and GARCH (1, 1) model are applied to the time series. The findings reject the hypothesis of non-stationarity. The results of the unit root tests suggest a high persistence of volatility clusters over the study period. Thus, the Macedonian stock market is not weak-form efficient. Ali, Shahzad, Raza and Al-Yahyaee (2018) [1] use multifractal de-trended fluctuation analysis (MF-DFA) to examine the relative efficiency of 12 Islamic and conventional stock markets counterparts in Jordan, Malaysia, Pakistan, Turkey, Brazil, Russian, India, China, South Africa, USA, UK and Japan using daily returns data of stock indices of the respective markets. Their findings indicate that developed markets were comparatively more efficient, followed by the stock markets of Brazil, Russia, India, China and South Africa (BRICS). They also show that nearly all Islamic stock markets (with the exception of Russia, Jordan, and Pakistan) are more efficient than their conventional counterparts, thanks to their compliance with Shariah law, good governance and disclosure practices. More, the Turkish stock market is found to be the most efficient Islamic market while Pakistan's is the least efficient. Based on the foregoing review, we conclude that there is still no consensus in the literature with regard to the efficiency of stock markets. The findings remain mixed and inconclusive, especially over time. This is in spite of the recent growth in the number of studies on the subject.

3. Methodology

This study examines the random walk process and the weak-form efficiency of fifteen (15) stock markets of Africa, Europe, Latin America, North America, and the Asia-Pacific region. The study period spanned January 2, 2011, to December 31, 2019. Log returns on the stock indices are used as a proxy for returns on listed stocks.

3.1 Basis of Classification of the Economies

The economies of the world have been categorized into four income groups by the World Bank based on Gross National Income (GNI) per capita and updated in July every year. The updated classification thresholds are set by the World Bank at the beginning of its fiscal year in July for the coming 12-month period. These thresholds stay the same even if the estimates are revised afterwards. The new thresholds for classification of economies by income as of July 1, 2019, are given below:

Table 1: Thresholds of World Bank's Classification of Countries by Income

Threshold	July 2019/$ (new)	July 2018/$ (old)
Low income		
Lower-middle income	1,026 - 3,995	996 - 3,895
Upper-middle income	3,996 - 12,375	3,896 - 12,055
High income	> 12,375	> 12,055

3.2 Research Data and Approach

This study uses secondary data, comprising the weekly values of a major stock index of each of the fifteen sampled stock markets. The data has been collected from Investing.com and the official websites of the respective stock exchanges. Additionally, this study follows the quantitative approach to research. The choice of sample was based on the World Bank's income classification of economies dated July, 2019, as well as the need for a fair regional spread of the sampled stock markets. Five countries are chosen from each income category, except the low-income category.

The exclusion of countries in the low-income category from this study is largely due to the paucity of data. In the sample, the United States of America,

Chile, Norway, Germany and Australia are chosen from the high-income category; Egypt, Ghana, India, Indonesia, and South Africa are selected from the lower-middle income category; and Argentina, Brazil, China, Mexico, and Russia are picked from the upper-middle income category. Then a fairly representative stock market index is then chosen for each stock market and economy.

3.3 Test Hypotheses

This study investigates the random walk process and the weak-form of the efficient market hypothesis in the stock markets of fifteen (15) economies using the weekly return of their stock indices.

The analysis of the return series is done using the EViews and SPSS statistical packages. Based on the literature review conducted, we propose and investigate the following null and alternate hypotheses.

H_0: Each stock market index follows a random walk.

H_1: Each stock market index does not follow a random walk.

The continuously compounding return series of each of the sampled indices is generated by applying the natural logarithm to its weekly values. The returns of each index are calculated using the formula below.

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

Where: r_t is the return at time t, P_t is the price at time t, and P_{t-1} is the price at time t – 1.

3.4 Data Analysis

The statistical tests employed in the analysis of the data include the Jacque-Bera test, the Augmented Dickey-Fuller test, the runs test, the variance ratio test and the autocorrelation test. All the statistical tests, excluding the runs test, are performed using EViews.

4. Discussion of Findings

4.1 Test of Normality

The Jarque-Bera test is used to determine whether returns series of the sampled indices follow a normal distribution. It is complemented by the descriptive statistics of skewness and kurtosis.

Table 2: Jacque-Bera (JB) Test Results for Indices of the Sampled Economies

Country	Index	Obs.	Max	Min	Median	Mean	Std. dev.	Skew.	Kurt.	JB Stat.	Prob.
Australia	ASX200	470	0.073	-0.075	0.00217	0.00075	0.018	-0.435	4.62	66.026	0.00
Chile	IPSA	470	0.069	-0.085	-0.00002	-0.00004	0.02	-0.271	4.65	58.919	0.00
Germany	DAX30	470	0.102	-0.138	0.00415	0.00138	0.0259	-0.571	5.30	129.35	0.00
Norway	OBX	470	0.073	-0.133	0.00356	0.00161	0.0221	-0.714	6.81	324.63	0.00
USA	S&P500	470	0.071	-0.075	0.00308	0.00201	0.0188	-0.578	5.26	125.74	0.00
Argentina	MERVAL	470	0.155	-0.378	0.00683	0.00520	0.0499	-1.113	10.19	1109.5	0.00
Brazil	Bovespa	470	0.166	-0.105	0.00226	0.00113	0.0293	0.154	4.99	79.246	0.00
China	SSECI	461	0.091	-0.143	0.00220	0.00020	0.0288	-0.805	6.52	287.8	0.00
Mexico	IPC	470	0.067	-0.077	0.00085	0.00031	0.0199	-0.026	4.01	19.92	0.00

Russia	MOEXRI	468	0.082	-0.130	0.00165	0.00128	0.0254	-0.440	5.30	118.5	0.00
Egypt	EGX 30	463	0.193	-0.171	0.00230	0.00144	0.0374	-0.134	7.53	397.59	0.00
Ghana	GSECI	416	5.057	-5.049	0.00093	0.00197	0.4416	-0.060	110.93	201903.2	0.00
India	SENSEX	470	0.071	-0.069	0.00253	0.00155	0.0205	0.015	3.44	3.8394	0.15
Indonesia	IDXCI	465	0.087	-0.113	0.00232	0.00115	0.0208	-0.516	6.76	294.13	0.00
South Africa	JSE ALSI	470	0.065	-0.065	0.00160	0.00125	0.0188	0.014	3.33	2.0915	0.35

The results in Table 4.1 show that, among the indices of high-income countries, the S&P 500 records the largest mean over the study period, followed by the OBX, the DAX 30, the ASX 200, and the IPSA in that order. However, the DAX 30 and the ASX 200 records the highest and lowest standard deviations respectively. Also, all the five indices have a skewness of less than zero, which indicates that they are negatively skewed. Further, all the five indices record a kurtosis that is greater than three, implying that their distributions are leptokurtic. Last, the results show that all the indices have a Jacque-Bera test statistic with a p-value of zero so the null hypothesis of normality is rejected for all the indices of the high-income countries.

For the upper middle-income countries, the results indicate that the Merval has the largest mean of 0.005195 while the Sseci has the lowest mean of 0.000203. More, the Merval has the highest standard deviation of 4.987% whereas the IPC has the least standard deviation of 1.99%. Further, the results indicate that all the return series, except that of the MOEXRI, are negatively skewed. Moreover, the values of kurtosis indicate that the distributions of the five indices are all leptokurtic. Finally, all p-values of the Jacque-Bera test statistic of all the indices is less than 0.05 so the hypothesis of normality is rejected for all the indices of upper middle-income countries. Next, the results in Table 4.1 show that, the GSECI records the largest mean of 0.00196 while the IDXCI records the smallest mean of 0.00115 among the lower middle-income countries. The GSECI also records the highest standard deviation of 44.159%. It is followed by the EGX 30, the IDXCI, the Sensex and, lastly, the JSE ALSI with the lowest standard deviation of 1.88%. Further, the EGX 30, the GSECI, and the IDXCI have a skewness of less than zero, indicating that they are negatively skewed. Conversely, Sensex and the JSE ALSI have a skewness of greater than zero, which is evidence of positive skewness. The results also show that the distributions of all the return series are leptokurtic. Further, the p-values of the Jacque-Bera test statistic of the EGX 30, the Gseci, the Sensex, the Idxci, and the JSE ALSI are 0.000, 0.000, 0.147, 0.000, and 0.351 respectively. Comparing these p-values to the level of significance of 0.05, the hypothesis of normality of the return series is rejected for the EGX 30, the Gseci, and the IDXCI. The hypothesis is, however, accepted for the Sensex and the Jse Alsi.

4.2 Augmented Dickey-Fuller Test

This study uses the Augmented Dickey-Fuller (1979) unit root test to determine whether the returns series of the sampled indices are stationary.

A time series is said to be stationary if its characteristics, such as mean and variance, are time-invariant.

A stationary time series does not have a unit root but a nonstationary time series does. The random walk is a common example of a nonstationary time series.

Table 3: Results of the Augmented Dickey-Fuller Test (at level) for Indices of the Sampled Economies

Country	Index	Test statistic	Probability
Australia	S&P ASX200	-24.08607	0.0000
Chile	S&P/CLX IPSA	-21.98322	0.0000
Germany	DAX 30	-22.68499	0.0000
Norway	OBX	-22.96117	0.0000
USA	S&P 500	-23.94338	0.0000
Argentina	S&P MERVAL	-21.20078	0.0000
Brazil	Bovespa	-22.14433	0.0000
China	SSECI	-19.60154	0.0000
Mexico	S&P/BMV IPC	-24.37753	0.0000
Russia	MOEXRI	-21.28724	0.0000
Egypt	EGX 30	-18.77352	0.0000
Ghana	GSECI	-15.42612	0.0000
India	S&P BSE SENSEX	-21.16737	0.0000
Indonesia	IDXCI	-24.44835	0.0000
South Africa	FTSE/JSE ALSI	-22.13794	0.0000

From Table 4.2, the results indicate that the return series of each index records a p-value of 0.000 for the Augmented Dickey-Fuller test statistic. Since this value is less than 0.05, the hypothesis of non-stationarity is rejected for all the indices. Therefore, the return series of all the indices of the sampled high-income, upper middle-income, and lower middle-income economies are stationary at level and do not follow a random walk.

4.3 Runs Test

The runs test is used to measure the randomness of each return series it is non-parametric. Below are its results.

Table 4: Results of the Runs Test for Indices of the Sampled Economies

Index	Country	Null Hypothesis	Sig.	Decision
ASX 200	Australia	The sequence of values defined by ASX200 Returns is random.	0.166	Retain the null hypothesis
IPSA	Chile	The sequence of values defined by IPSA Returns is random.	0.782	Retain the null hypothesis
DAX30	Germany	The sequence of values defined by DAX30 Returns is random.	0.268	Retain the null hypothesis
OBX	Norway	The sequence of values defined by OBX Returns is random.	0.853	Retain the null hypothesis
S&P 500	USA	The sequence of values defined by S&P500 Returns is random.	0.460	Retain the null hypothesis
MERVAL	Argentina	The sequence of values defined by MERVAL Returns is random.	0.782	Retain the null hypothesis
BOVESPA	Brazil	The sequence of values defined by BOVESPA Returns is random.	0.644	Retain the null hypothesis
SSECI	China	The sequence of values defined by SSEC Returns is random.	0.816	Retain the null hypothesis
BMV IPC	Mexico	The sequence of values defined by BMV IPC Returns is random.	0.034	Reject the null hypothesis

MOEXRI	Russia	The sequence of values defined by MOEXRI Returns is random.	0.355	Retain the null hypothesis
EGX 30	Egypt	The sequence of values defined by EGX30 Returns is random.	0.056	Retain the null hypothesis
GSECI	Ghana	The sequence of values defined by GSECI Returns is random.	0.000	Reject the null hypothesis
SENSEX	India	The sequence of values defined by S&P BSE SENSEX Returns is random.	1.000	Retain the null hypothesis
IDXCI	Indonesia	The sequence of values defined by IDXCI Returns is random.	0.104	Retain the null hypothesis
JSE ALSI	South Africa	The sequence of values defined by JSE ALSI Returns is random.	0.140	Retain the null hypothesis

From Table 4.3, returns of all indices of the high-income countries record p-values that are greater than the level of significance of 0.05 set for the test. Hence, the null hypotheses are retained for all the indices of the high-income countries, implying that the sequence of their returns series is random.

Next, the returns series of the MERVAL, the Bovespa, the SSECI, the IPC, and the MOEXRI record p-values of 0.782, 0.644, 0.816, 0.034, and 0.355 respectively. All the p-values, except that of the IPC, are greater than the level of significance of 0.05. Hence, the hypothesis of randomness is retained for all the index return series, except the IPC. This means that the sequence each of the return series of the upper middle-income countries, with the exception of that of Mexico, is random.

For the lower middle-income countries, the returns series of the EGX 30, the GSECI, the SENSEX, the IDXCI, and the JSE ALSI have p-values of 0.056, 0.000, 1.000, 0.104, and 0.140 in that order. All the p-values, except that of the GSECI, are greater than the level of significance of 0.05. Thus, the null hypothesis of is rejected for the GSECI, but retained for the remaining return series. This indicates that the sequence of each of the return series of the lower middle-income countries, except that of the GSECI of Ghana, is random.

4.4 Variance Ratio Test

After using the variance ratio test to ascertain whether each return series follows a random walk, the following are the results.

Table 5: Results of the Variance Ratio Test for Indices of the Sampled Economies

Index		Joint test	Lags			
			2	4	8	16
ASX 200	VR		0.437488	0.246464	0.114455	0.057156
	Z-Statistic	8.201808	-8.20181	-6.36043	-5.08876	-3.78296
	P-values	0	0	0	0	0.0002
IPSA	VR		0.501256	0.255442	0.130976	0.056937
	Z-Statistic	7.552896	-7.5529	-6.31285	-4.98251	-3.84486
	P-values	0	0	0	0	0.0001
DAX 30	VR		0.46376	0.235359	0.128096	0.060458
	Z-Statistic	7.533272	-7.53327	-6.07138	-4.58011	-3.41425
	P-values	0	0	0	0	0.0006
OBX	VR		0.484343	0.241268	0.12279	0.058024
	Z-Statistic	7.230466	-7.23047	-6.07726	-4.69259	-3.51258
	P-values	0	0	0	0	0.0004
S&P 500	VR		0.45402	0.241177	0.105659	0.059099
	Z-Statistic	7.706714	-7.70671	-5.98606	-4.58083	-3.40681
	P-values	0	0	0	0	0.0007
Merval	VR		0.501049	0.257508	0.127264	0.060113
	Z-Statistic	6.802485	-6.80249	-5.86904	-4.72036	-3.71098
	P-values	0	0	0	0	0.0002
Bovespa	VR		0.465124	0.252569	0.134267	0.066321
	Z-Statistic	8.412646	-8.41265	-6.78914	-5.29432	-4.00772
	P-values	0	0	0	0	0.0001
Sseci	VR		0.519582	0.269955	0.140038	0.069649
	Z-Statistic	7.382055	-7.38206	-5.76927	-4.19254	-3.12043
	P-values	0	0	0	0	0.0018
Bmv ipc	VR		0.440534	0.215921	0.123601	0.056326
	Z-Statistic	8.144413	-8.14441	-6.47221	-4.90677	-3.75783
	P-values	0	0	0	0	0.0002
Moexri	VR		0.498729	0.274836	0.136446	0.071256
	Z-Statistic	7.237335	-7.23734	-6.2222	-5.18741	-3.89272
	P-values	0	0	0	0	0
EGX 30	VR		0.599911	0.283203	0.138905	0.0738
	Z-Statistic	6.168013	-5.80455	-6.16801	-5.18147	-4.04953
	P-values	0	0	0	0	0.0001
GSECI	VR		0.334308	0.169292	0.086176	0.03067
	Z-Statistic	1.932023	-1.93202	-1.56433	-1.45023	-1.42464
	P-values	0.2398	0.0534	0.1177	0.147	0.1543
SENSEX	VR		0.517823	0.261944	0.147162	0.062035
	Z-Statistic	7.25976	-7.25976	-6.29862	-4.85078	-3.74669

	P-values	0	0	0	0	0.0002
IDXCI	VR		0.429534	0.233201	0.113466	0.052417
	Z-Statistic	7.248244	-7.24824	-5.39048	-4.27129	-3.36462
	P-values	0	0	0	0	0.0008
JSE ALSI	VR		0.530123	0.266778	0.127667	0.062442
	Z-Statistic	8.1065	-8.1065	-7.18799	-5.70567	-4.29895
	P-values	0	0	0	0	0

From Table 4.4, the variance ratios of all the indices of high-income countries are less than 1 at all the 4 lags, indicating the presence of negative serial correlation. Further, the p-value of each index is 0.000 at each of the 4 lags. Since the p-value of 0.00 is less than 0.05, the null hypothesis is strongly rejected for all the above indices, implying that the return series of the high-income countries do not follow a random walk.

Similarly, the results provide evidence of the existence of negative serial correlation for the upper middle-income countries, as shown variance ratios that are less than 1 for all the indices at all the lags. Also, the p-values of all the indices are equal to 0.00 at all the 4 lags. Hence, the null hypothesis of a martingale is strongly rejected for all the indices. Thus, like the return series of the high-income countries, none of the return series of the upper middle-income countries follows a random walk.

Furthermore, Table 4.4 documents the presence of negative serial correlation in the return series of the lower middle-income countries. The results also indicate that the GSECI has insignificant p-values at all the 4 lags. However, the remaining indices have significant p-values at all the 4 lags. Hence, the null hypothesis is retained for the GSECI, but strongly rejected for the remaining indices. Therefore, with the exception of the GSECI, the returns series of the lower middle-income countries are not martingales.

4.5 Autocorrelation Tests

Autocorrelation tests are used to measure the correlation or dependence between returns at time t and returns at time t-k. If the serial correlation coefficients are significantly different from zero, there is autocorrelation. Below are the test results.

Table 6: Results of Autocorrelation Test for Indices of the Sampled Economies

Index	Lags	1	2	3	4	5	6	7	8	9	10
ASX 200	AC	-0.11	0.03	-0.08	-0.08	0.01	-0.05	0.05	0.01	0.06	0.01
	Q-Stat	5.54	6.06	9.38	12.48	12.55	13.72	15.08	15.10	16.60	16.65
	Prob.	0.02	0.05	0.03	0.01	0.03	0.03	0.04	0.06	0.06	0.08
IPSA	AC	-0.02	-0.02	0.04	-0.04	-0.06	-0.04	0.02	-0.07	0.02	0.00
	Q-Stat	0.20	0.37	1.10	1.88	3.80	4.65	4.81	6.93	7.15	7.15
	Prob.	0.66	0.83	0.78	0.76	0.58	0.59	0.68	0.54	0.62	0.71
DAX 30	AC	-0.05	0.03	0.00	0.03	-0.02	-0.03	-0.08	-0.05	0.02	-0.08
	Q-Stat	1.12	1.58	1.58	1.87	2.07	2.56	5.46	6.49	6.72	0.67
	Prob.	0.29	0.46	0.66	0.76	0.84	0.86	0.60	0.59	9.42	0.49
OBX	AC	-0.06	-0.02	-0.08	-0.01	-0.03	-0.03	0.07	-0.02	0.09	-0.08
	Q-Stat	1.74	1.99	4.99	5.07	5.40	5.87	8.18	8.30	12.19	15.27
	Prob.	0.19	0.37	0.17	0.28	0.37	0.44	0.32	0.40	0.20	0.12
S&P 500	AC	-0.10	0.00	-0.04	-0.05	-0.07	-0.01	-0.03	0.09	-0.01	-0.08
	Q-Stat	4.92	4.92	5.74	6.99	9.17	9.19	9.69	13.63	13.71	17.06
	Prob.	0.03	0.09	0.13	0.14	0.10	0.16	0.21	0.09	0.13	0.07
MERVAL	AC	0.02	0.02	-0.10	0.00	0.05	0.00	-0.08	0.02	-0.09	-0.08
	Q-Stat	0.16	0.33	4.68	4.68	5.97	5.98	8.79	8.99	13.10	16.23
	Prob	0.69	0.85	0.20	0.32	0.31	0.43	0.27	0.34	0.16	0.09
Bovespa	AC	-0.02	0.05	0.00	-0.03	0.03	0.07	-0.03	-0.08	-0.05	-0.04
	Q-Stat	0.28	1.50	1.50	1.81	2.13	4.57	5.06	7.78	9.08	10.95
	Prob	0.60	0.47	0.68	0.77	0.83	0.60	0.65	0.46	0.43	0.45
SSEC	AC	0.09	0.06	0.01	0.02	-0.01	-0.01	-0.02	0.00	0.06	-0.04
	Q-Stat	3.49	4.88	4.90	5.18	5.19	5.22	5.43	5.43	6.92	7.85
	Prob	0.06	0.09	0.18	0.27	0.39	0.52	0.61	0.71	0.65	0.64
BMV IPC	AC	-0.12	0.02	-0.07	0.04	-0.05	-0.06	0.02	-0.09	0.05	-0.05
	Q-Stat	6.82	6.95	9.49	10.06	11.19	12.74	12.85	16.67	17.74	18.78
	Prob	0.01	0.03	0.02	0.04	0.05	0.05	0.08	0.03	0.04	0.04
MOEXRI	AC	0.02	0.02	-0.11	-0.07	-0.06	-0.02	-0.01	-0.05	0.02	-0.03
	Q-Stat	0.10	0.31	6.03	8.41	10.34	10.50	10.57	11.73	11.93	12.35
	Prob	0.75	0.86	0.11	0.08	0.07	0.11	0.16	0.16	0.22	0.26
EGX30	AC	0.13	-0.04	-0.03	0.00	0.02	-0.04	-0.02	0.01	-0.03	-0.03
	Q-Stat	8.17	8.79	9.14	9.14	9.41	10.04	10.17	10.27	10.62	10.97
	Prob	0.00	0.01	0.03	0.06	0.09	0.12	0.18	0.25	0.30	0.36
GSECI	AC	-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q-Stat	104.90	104.90	104.90	104.90	104.90	104.90	104.90	104.90	104.90	104.90
	Prob	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SENSEX	AC	0.02	-0.01	-0.03	-0.02	-0.09	0.02	-0.01	-0.01	-0.03	0.03
	Q-Stat	0.22	0.31	0.72	0.97	5.13	5.26	5.27	14.00	14.37	14.74
	Prob	0.64	0.86	0.87	0.92	0.40	0.51	0.63	0.08	0.11	0.14
IDXC	AC	-0.13	0.04	-0.06	-0.05	0.06	0.05	-0.04	-0.01	-0.06	0.08
	Q-Stat	7.55	8.12	9.55	10.68	12.21	13.52	14.31	14.39	15.90	19.29
	Prob	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.07	0.07	0.04
JSE ALSI	AC	-0.02	-0.08	-0.08	-0.08	-0.07	0.05	0.02	-0.03	0.03	-0.04
	Q-Stat	0.27	3.50	6.35	9.75	11.91	12.97	13.08	13.52	13.96	14.81
	Prob	0.60	0.17	0.10	0.05	0.04	0.04	0.07	0.10	0.12	0.14

The results in Table 4.5 show that the Q-Statistic of the ASX 200 is significant from lag 1 to lag 7, recording p-values less than 0.05 at each lag. The Q-Statistic is, however, insignificant from lag 8 to lag 10, where the Q-Statistic records p-values greater than 0.05. For the IPSA, the DAX30, and the OBX, the Q-Statistic is insignificant at all the lags since it records a p-value of greater than 0.05 at each of the 10 lags. This implies that there is no serial correlation in the return series of the S&P/CLX IPSA, the DAX 30, and the OBX. For the S&P 500, however, the Q-Statistic is significant only at lag 1 but insignificant from lag 2 to lag 10. Thus, there is no serial correlation at most of the lags of the S&P 500.

Also, the Q-Statistic of the MERVAL, the Bovespa, the SSECI, and the MOEXRI has a p-value that exceeds 0.05 at all the 10 lags, indicating the absence of serial correlation. For the IPC, however, the Q-Statistic of is significant from lag 1 to lag 6 and then from lag 8 to lag 10, with p-values less than 0.05 at those lags. It is significant at only lag 7. Thus, the results provide evidence of the absence of autocorrelation at the 10 lags of return series of the MERVAL, the Bovespa, the SSECI, and the MOEXRI; but there is autocorrelation in the return series of the IPC at almost all the lags.

The results of Table 4.5 also show that the Q-Statistic of the EGX 30 is significant at only lags 1 to 3, but insignificant from lag 4 to lag 10. Thus, there is no autocorrelation at most of the lags. For the SENSEX, the Q-Statistic is insignificant at all the lags, indicating the absence of autocorrelation. Further, the p-values of the Q-Statistic of the IDXCI are greater than 0.05 at only lags 8 and 9, but are less than 0.05 at the rest of 8 the lags. Thus, there is evidence of autocorrelation at most of the lags. Lastly, the Q-Statistic of the JSE ALSI is significant at only lags 4, 5, and 6, but is insignificant for the remaining 7 lags. Hence, there is no autocorrelation at most of the lags of the JSE ALSI.

5. Conclusion

To begin with, the results of the Augmented Dickey-Fuller test strongly reject the hypothesis of non-stationarity the return series of all the stock markets. Since non-stationarity is an important characteristic of a random walk process, the random walk hypothesis is rejected for all fifteen stock markets over the study period. Furthermore, results of the single variance ratio test provide evidence that return series of all the sampled stock markets of high-income and upper middle-income countries are not random processes. Similarly, the return series of all the lower middle-income countries, except Ghana, are also not random. Hence, we conclude that the stock markets of Australia, Chile, Germany, Norway, the United States, Argentina, Brazil, China, Mexico, Russia, Egypt, India, Indonesia and the Republic of South Africa do not follow a random walk. However, there results are inconclusive for the Ghanaian stock market.

Moreover, the runs and autocorrelation tests provide evidence that the return series of the IPSA, the DAX 30, the OBX, the S&P 500, the MERVAL, the Bovespa, the SSECI, the MOEXRI, the EGX 30, the SENSEX, and the JSE ALSI do not exhibit dependence or significant serial correlation over the study period. Thus, the stock markets of Chile, Germany, Norway, the United States of America, Argentina, Brazil, China, Russia, Egypt, India, and the Republic of South Africa are found to be weak-form efficient. Yet, the stock markets of Ghana and Mexico are found to be weak-form inefficient. The return series of the GSECI of Ghana and the IPC of Mexico show significant serial correlation and dependence. Furthermore, based on the results of the runs test, the stocks markets of Australia and Indonesia are weak-form efficient even though their returns series possess some amount of serial correlation.

Therefore, the stock markets of all the high-income countries (Australia, Chile, Germany, Norway, and the United States), almost all the upper middle-income countries (Argentina, Brazil, China, and Russia), and almost all the lower middle-income countries (Egypt, India, Indonesia and the Republic of South Africa) are weak-form efficient even though their prices do not follow a random walk. Conversely, the stock markets of Ghana and Mexico are not weak-form efficient. The results also suggest that stock market of high-income countries tend to be more efficient than their counterparts in other countries. This is in line with the findings of Urrutia (2004), Ayentimi, *et al*. (2013), and Chavannavar and Patel (2016) [5].

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