A technical analysis of market efficiency of emerging economies: the case of BRICS countries

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Abstract

The concept, also known as the efficient market hypothesis (EMH), is a subject of debate in the field of finance. Proponents of the EMH theory claim that it offers a foundation for understanding financial markets, but opponents claim that the theory is irrational in its assumptions about the actual functioning of these markets. While the EMH may be flawed, it offers an acceptable foundation for analysing financial markets. In recent years, researchers have broadly analysed the efficiency of markets, mainly in developed and well-established financial markets. However, there has been a scarcity of studies conducted on emerging economies. Hence, this study investigates the weak-form EMH of the BRICS to determine whether the financial markets of Brazil, Russia, India, China, and South Africa may be considered weak-form efficient. This study analysed the BRICS and four benchmark economies using daily observations from 16th January 1995 to 16th June 2023, divided into six periods to identify if specific economic events impacted the market efficiency. Analysis was carried out using various statistical tests, i.e., ARMA, GARCH, Variance ratio, Runs test, Cox-Stuart test, Bartels test, Difference Sign test and Mann-Kendall test. Ultimately, the findings were that BRICS countries' markets are efficient markets and follow a weak-form efficiency, and specific patterns or trends could be identified in some cases that could be profitable for investors. This study recommends valuable insight for investors and policymakers of how they can use a hedge strategy to hold more assets in emerging economies that are weak-from EMH.

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Acronyms

AC	Autocorrelation
ACF	Autocorrelation Function
ARCH	Autoregressive Conditional Heteroskedasticity
ARMA	Autoregressive Moving Average
BRICS	Brazil, Russia, India, China, and South Africa
BVSP	Ibovespa Index
DJIA/DJ	Dow Jones Industrial Average
EMH	Efficient Market Hypothesis
FTSE	Financial Times Stock Exchange
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
IMOEX	MOEX Russia Index
JSE	Johannesburg Stock Exchange
LS	Left Side
NASDAQ	Nasdaq Index
NIKKEI	Nikkei Index
NRW	Non-Random Walk
NSEI	Nifty 50 Index
RS	Right Side
RW	Random Walk
S&P	Standard and Poor's
SA	South Africa
SSE	SSE Composite Index
UK	United Kingdom
US	United States

Chapter 1
Introduction

1.1 Background to the Study

Over the past decades, the Efficient Market Hypothesis (EMH) has been extensively debated in financial literature. The EMH states that asset prices reflect all publicly accessible information. An efficient market is one in which prices promptly adjust to incorporate all accessible information (Fama, 1970). Kolb and Rodriguez (1992) also characterise this phenomenon as one in which prices promptly adapt upon the introduction of novel information. Hence, alterations in price are indicative of the economic worth of this novel information. The efficiency of financial markets is upheld by the substantial presence of traders who consistently seek to capitalise on mispriced securities. For instance, hedge funds, in contrast to mutual funds, aim to generate absolute returns by taking advantage of securities that are mispriced (Brown, Goetzman, & Ibbotson, 1999). Because the hedge fund sector is not subject to as strict restrictions as the mutual fund industry is, hedge funds have greater flexibility when it comes to making investing decisions (Liang, 1999). A hedge fund has the ability to use leverage and derivatives products, invest in concentrated portfolios, trade fast between markets, and take both long and short positions in the market at the same time (Agarwal & Naik, 2004; Amin & Harry, 2003).

The significance of securities from emerging economies in the portfolios of international investors has been highlighted by recent financial developments. Froot, O'Connell and Seasholes (2001) studied the international portfolio flows and found that for emerging markets, the inflows predict positive future returns on average, and countries are more strongly correlated within regions. In addition, emerging markets are vital for international investors, whether they invest in public or private firms. Investors prefer privately owned firms and institutions that possess comparatively greater quantities of tangible assets and tend to exhibit disfavour towards government-owned firms that possess a high degree of liquidity (Badawi, Qudah and Rashideh, 2019). Investors in wealthy countries have shown growing interest in emerging nations due to their greater economic development and potential for higher profits. Additionally, it has been suggested that these assets offer diversification advantages for investors in the US due to their low correlations with domestic assets (Hali, Francis

& Warnock, 2004; Conover, 2011). Consequently, there have been some studies conducted on the weak-form efficiency of these markets or have too small of a sample of data. For instance, Mishra (2015) studied specific emerging economies from 2007 to 2012 on capital market efficiency, which is crucial for investors and regulatory authorities, as it ensures capital is allocated to projects with high expected returns, reducing opportunities for continuous trading. Inefficient markets allow regulatory bodies to ensure correct stock pricing, leading to stock market efficiency. A study by Raquid and Alom (2015) solely tested the market efficiency of the Dhaka Stock Exchange from 2001 to 2013 but argued there are still some issues in emerging economies and agreed with some positive correlation. In addition, the Dhaka Stock Exchange was also considered weak-form efficient (Raquid & Alom, 2015). A study by Awiagah and Choi (2018) utilises historical daily, weekly, monthly, and quarterly returns over a 28-year period to investigate the predictability of index returns on the Ghana stock market within the framework of the weak-form efficient market hypothesis (1990-2017). Another study by Hameed, Ashraf and Siddiqui (2006) attempted to use daily closing prices for the Pakistani stock market from December 1998 to March 2006 to model the volatility of stock returns and test for weak form efficiency, and their findings highlight the permanence and volatility clustering of returns. Studies on emerging countries are present but only focus on one market whilst this study investigated BRICS market efficiency.

The BRICS abbreviation stands for the five significant emerging economies of Brazil, Russia, India, China, and South Africa. The term "BRIC" was first used in 2001 by economist Jim O'Neill to refer to the four countries of Brazil, Russia, India, and China, which he predicted would become important economic players by the year 2050. The group's name was changed to BRICS in 2010 when South Africa joined. According to Li, He, Huang, Li, Liu, and Dai, (2022) the BRICS countries represent a significant proportion of the world's population, with over forty per cent of the global population residing in these five countries and also account for a large share of global economic output, with a combined GDP of over $18 trillion. These countries are considered major players in the global economy and are expected to continue to grow in importance over the coming decades. In order for these countries to grow the financial markets are important for global business because they provide a platform for raising capital, managing risk, and facilitating trade. Furthermore, financial markets play a key role in

determining the cost of capital and the availability of funding for businesses around the world, influencing investment decisions and economic growth (Levine, 2021).

In fact, investors and policymakers find it vital to test if the financial markets are efficient, both managing the portfolio of financial assets and operating at the macroeconomic level are necessary for a capital market to be effective (Dorina & Simina, 2007). The efficient market hypothesis (EMH) states financial markets are efficient, and that current asset prices reflect all relevant information. If a market is informationally inefficient, then it might be possible to earn abnormal profits by exploiting the information that has not been incorporated into prices. Profits (returns) are said to be abnormal if they are larger than those from a passive investment strategy, such as a buy-and-hold strategy. The abnormal return associated with a particular active investment strategy might be assessed by comparing the sample mean return generated from the strategy with the sample mean return from a buy-and-hold strategy. Although the efficient market hypothesis contends that financial markets are effective and that current asset prices accurately reflect all relevant information, it is nonetheless feasible for investors to make anomalous gains in an informationally inefficient market. Fama (1965) introduced the efficient market hypothesis and argues that all investors are instantly informed of new information that enters a market, making it impossible to estimate asset prices using prior prices. All available information is reflected in the stock prices at the moment, which is helpful for predicting and making forecasts. This publicly available information will spread, causing buying and selling that will impact the price until it reflects the new value and a new stock price. According to Dorinda and Simina (2007: 827) “the share price may at any moment be an accurate forecast of future share prices, a behaviour known as a random walk, and this random walk has significant financial ramifications for investors”. The efficient market theory comes in three different forms: weak, semi-strong, and strong. In conclusion, the weak form suggests that current asset prices reflect all historical data, the semi-strong form that current asset prices reflect all information that is publicly available, and the strong form that current asset prices reflect all aspects of the weak, semi-strong, and private information (Fama, 1970).

Another reason why it is important to assess efficiency in BRICS, is to see the impact of portfolios from developed economies and emerging economies when it comes to

any crisis. Considering this study looks at weak-form EMH of BRICS and four benchmark (developed) markets. In developed economies, the correlation is strong, and if something happened to that portfolio, like the 2008 crisis, those markets are considered riskier and lose funding compared to the emerging economies. Investors make use of a hedge strategy is a way to protect investments from losing value by taking an opposite position in a related asset. This helps balance risks and keep the investor's money safer from market ups and downs. According to Marey and Simpson (2001) studied the effectiveness of the hedging techniques investigated by Eaker and Grant using different data, and come up with three approaches a) not hedging foreign exchange exposures; b) using forward contracts to hedge exchange risk at all times; and c) hedging such risk selectively, purchasing forward contracts only when the forward rate is higher.

1.2 Problem Statement

The Efficient Market Hypothesis (EMH) states that market efficiency ensures the prompt incorporation of all relevant information into share prices (Fama, 1966). However, the varied outcomes witnessed in BRICS developing stock markets raise questions regarding the applicability of this theory. This study seeks to examine the extent to which data from BRICS stock markets support the EMH theory and aims to rank their respective market efficiencies. By doing so, it aims to provide insights into the discrepancies observed and contribute to a deeper understanding of market dynamics within the BRICS economies.

The study aims to cover a period from 16th January 1995 to 16th June 2023, encompassing significant events such as the Asian crisis (starting in 1997), Dot Com buddle and fall of Enron, the 2008 subprime crisis, the global COVID-19 pandemic, and the Ukraine war. While efficient market theory suggests that stock returns are unpredictable, this study aims to explore the reasons behind investor interest and continued investment in the rapidly growing emerging economies of the BRICS countries. By assessing the efficiency of their financial markets, the research aims to shed light on the efficacy of investment strategies in these markets and provide insights into the factors influencing investor decision-making.

1.3 Motivation and objectives

The motivation behind this study was to evaluate the type of EMH and the profitability of the BRICS stock markets, should they be deemed weak-form efficient. The investigation of this aspect serves a dual objective: firstly, to ascertain the congruence between BRICS markets and the EMH, and secondly, to offer valuable perspectives for investors aiming to exploit profitable prospects within these economies and similar settings.

i) Investigate and compare the type of EMH.
ii) Evaluate if the EMH for those economies could impact informed decision-making and maximising investment returns.
iii) Comment if global crises have an impact on these economies.

A study by Kiran and Rao (2019) also examined the efficiency of BRICS markets using daily data from 25 September 1997 to 31 March 2018, and a similar approach was applied to this study by dividing period into sub-periods by they used both linear and non-linear tests whilst this study used linear dependencies. Their findings for linear dependencies demonstrated that market efficiency changes during the chosen time periods (Kiran & Rao, 2019).

This study is based on the BRICS (emerging) economies and four benchmark (emerged) and consists of daily observations from 16th January 1995 to 16th June 2023; the large sample was divided into six sub-periods. The reason for the multiple periods is to answer the objectives of the study.

1.4 Hypothesis of the Study

The aim of this research was to test the EMH in BRICS markets. This study used eight different methods that are ARMA, AR-GARCH, Variance ratio, Runs test, Cox-Stuart test, Bartels test, Difference Sign test and Mann-Kendall test. These methods were used to analyse daily price stock prices of ten different indices. The various null and alternative hypotheses were tested using these methods. The study was guided by the following null and alternative hypotheses.

In order to achieve the research objectives stated above, the study tested the following

hypotheses

Null Hypothesis

H_0: The BRICS economies demonstrate weak-form efficiency.

Alternative Hypothesis

H_1: The BRICS economies does not demonstrate weak-form efficiency.

1.5 Contributions of the Study

Numerous scholars have conducted investigations into the weak-form efficiency of various security markets, building upon the influential research conducted by Fama (1965). Gupta and Basu (2007) examined the weak form efficiency for the two main Indian equity markets from 1991 to 2006 within the framework of the random walk hypothesis. In addition, a study by Asiri (2008) measured the weak-form efficiency of Bahrain Stick Exchange using a random walk. Another study by Fawson, Glover, Fang and Chang (2010) examined the Taiwan monthly stock market price for evidence of weak-form efficiency. Most of these studies have only measured efficiency of one market using two-three empirical methodologies. This study uses eight linear dependence tests to confirm if the results vary and also parametric and non-parametric tests if they differ. This contributes to the body of knowledge and goes beyond what other scholars have done, not only in methodologies but also in markets analysed.

Furthermore, the existing body of work has predominantly concentrated on developed nations, specifically the US, and has presented conflicting findings. In this context, and with the objective of mitigating the intensity of these conflicts, the present study seeks to contribute to the existing body of literature of the EMH by employing a range of statistical tests and time-varying methodologies that have been applied to diverse financial markets but have received limited attention in research conducted within the context of BRICS.

In addition, here are few to no contempered studies on market efficiency on BRICS. This study will capture various current and past global issues like the COVID-19 and the impact of war in Ukraine. The South African market is a new addition to BRICS. Past literature excludes multiple global impacts such as financial crises, the COVID-19 pandemic and the current Ukraine war.

This study is of great significance as it seeks to explore the weak-form efficiency of the BRICS nations in the wake of multiple global economic crises. The findings of this research will be further compared with previous studies conducted on the BRICS nations, along with several developing.

1.6 Organisation of the Study

The research is structured in the following manner. The first section started with an introduction of the study's contextual framework, the research problem, motivation and objectives, hypothesis and significance.

The second chapter provides a comprehensive review of literature concerning the EMH, BRICS economies, and financial crises. Initially, it delves into the literature comprising of the concept of the EMH, forms of the EMH, the debate between fundamental efficiency and technical efficiency. Additionally, the chapter critically assess criticisms and alternative theories challenging the EMH paradigm. Following this the importance of emerging economies and how certain crises have more of an impact on developed economies.

Chapter three of the study focuses on clarifying the methodology utilised for data analysis, as well as offering a justification for the choice of variables. In addition, the chapter presents and discusses eight different economic tests employed in the study.

Chapter four comprises the data analysis section, where findings are presented through a series of tables accompanied by detailed explanations. This section also revisits the eight tests outlined in the previous chapter, providing further clarification on their application and implications within the context of the study.

The fifth and concluding chapter functions as the final stage of the study, providing a thorough examination of the results in accordance with the problem statement, motivation and objectives, and research hypotheses. Moreover, it positions the results within the framework of prior research on BRICS and developed economies, thus enhancing comprehension of their significance. In addition, the chapter acknowledges the inherent limits of the study and offers useful suggestions for various stakeholders

of the BRICS, including researchers, investors, regulatory bodies, and managers. Finally, it underscores avenues for future research, thereby contributing to the ongoing discourse and advancement of knowledge in this field.

1.7 Summary

This chapter began with an introduction, providing background information on the study and clarifying the research problem statement. Following this the motivation behind the research, objectives, and research hypotheses was explained. Concluding this chapter is an overview of the mini thesis. The following chapter delves into the literature on key themes including the EMH, BRICS economies, and financial crises, as themes for investigation.

Chapter 2

Literature Review

2.1 Introduction

This chapter introduces the theoretical and empirical analysis to provide a comprehensive understanding of existing research on the topic, identifying gaps or contradictions in the literature, and establishing the theoretical framework upon which the research hypotheses and methodology are built. The three main themes are investigated. Firstly, the EMH is researched, and various past studies either support EMH or are inconsistent, and gaps for specific economies, such as emerging ones, are identified. Following this, various studies done on financial markets for BRICS countries are examined, and various methodologies are noted. Finally, financial crises and economic events are studied, and gaps and patterns are recognised.

2.2 Theoretical and Empirical Analysis

2.2.1 Efficient Market Hypothesis

A key theme and reason for investigation is the EMH theory in financial economics that argues that asset prices fully reflect all available information in the market (Fama, 1970). According to Fama (1970), the EMH implies that it is impossible for investors to consistently achieve abnormal returns by using any information that the market does not already reflect. In addition, Fama (1970) classified market efficiency into three forms: weak-form efficiency, semi-strong-form efficiency, and strong-form efficiency.

Weak-form efficiency suggests that past prices and trading volumes are already reflected in current prices (Fama, 1970). This implies that technical analysis, which relies on historical price data, cannot generate excess returns over the long term. Semi-strong-form efficiency extends this concept to suggest that all publicly available information, including fundamental data and public announcements, is rapidly incorporated into prices (Fama, 1970). Therefore, neither fundamental analysis nor the use of public information can consistently beat the market. Finally, strong-form efficiency posits that all information, both public and private, is reflected in prices (Fama, 1970). This implies that even insider information cannot provide investors with an edge in the market. These forms of efficiency reflect varying degrees of information

incorporation into asset prices, with strong-form efficiency representing the most stringent form where any market participant can gain no information advantage.

The concept of market efficiency was introduced by Fama and Blume (1966) through the utilisation of Samuelson's (1965) study, which subsequently led to the formalisation of the testing technique. According to Fama and Blume (1966), the efficiency of a market can be measured by the speed and fairness with which information is disseminated. In practical terms, this implies that the dissemination of fresh stock information to all market participants occurred simultaneously, so ensuring that the potential for profit generation through the utilisation of this knowledge was distributed, thereby preventing any profits from surpassing the established benchmarks. Nevertheless, in the event that the data was frequently employed to generate profits that surpassed market benchmarks, it indicated the presence of inefficiencies inside the market. This served as the foundation for evaluating efficiency using the profitability approach. The integration of Fama and Blume's (1966) notion of efficient markets with Samuelson's (1965) theory of random walks resulted in the establishment of a validated approach for evaluating EMH through the application of technical trade strategies.

Studies such as Lo and MacKinlay (1988) and Jegadeesh and Titman (2001) have identified anomalies and patterns in asset prices that seem to contradict the predictions of the EMH. These anomalies include momentum effects, where assets that have performed well in the past tend to continue outperforming, and value effects, where undervalued assets tend to yield higher returns over time. Additionally, a study by Shiller (1981) had documented instances of stock market bubbles and overreactions, suggesting inefficiencies in price formation. Moreover, research on the EMH has expanded to consider its implications in different market contexts. For instance, studies by Chen, Firth and Kim (2002) and Kim and Shamsuddin (2008) have examined market efficiency in emerging markets, highlighting the role of institutional factors, information asymmetries, and regulatory environments in shaping market dynamics. Furthermore, studies by Malkiel and Fama (1970) and Jensen (1978) have investigated the performance of professional fund managers relative to market benchmarks, with mixed evidence on their ability to consistently outperform the market.

There are studies that support the EMH such as Park and Irwin (2007) conducted an analysis of international trade literature to evaluate the validity of the EMH in the US financial markets. The researchers conducted the analysis to assess the profitability of the buy and sell signals produced by different trade methods in relation to the chosen market benchmarks. The study focused on the time frame spanning from 1974 to 2002. The trade techniques implemented throughout the subperiod from 1974 to 1984 resulted in trade signals that surpassed the profitability of the benchmarks. As a result, Park and Irwin (2007) reached the conclusion that the markets under evaluation did not exhibit weak-form efficiency throughout the specified period. However, upon examining the subsequent timeframe spanning from 1985 to 2002, it was observed that these stated markets exhibited weak-form efficiency. The researchers reached the conclusion that the effectiveness of the trades was hindered by a decline in market volatility, which they observed to occur over time and as the market evolved. Although the reasons for the limited profitability were acknowledged, it was recommended that further investigation be carried out to establish definitive proof of the profitability of related techniques. Because of the advancements of the technology, some recent studies on EMH have suggested markets to be more efficient, especially cryptocurrencies. Kristoufek and Vosvrda (2019) tested the EMH of cryptocurrencies (and tokens) and ranked the efficiency of each, finding that the historical coins are all inefficient (weak-form efficient). This has also led to a similar concept of EMH, which is called the adaptive market hypothesis. The adaptive market hypothesis, unlike the efficient market hypothesis, does not have a formal test procedure and evidence of variations in market efficiency and price predictability over time confirms this hypothesis, indicating that market efficiency varies over time (Chu, Zhang & Chan, 2019).

The examination of weak-form market efficiency was undertaken by Phiri (2015) utilising JSE market data from January 2000 to December 2014. In a study conducted by Phiri (2015), an analysis was performed on five separate subsections of the JSE stock indexes. The author utilised a range of unit root testing methodologies in order to assess the sequence of integration. The approaches employed in this study encompassed the Augmented Dickey-Fuller test, the two regime threshold autoregressive unit roots test, and the three regime unit roots test. Phiri (2015)

conducted a study that revealed a higher level of efficiency in the primary sector indices, particularly in the gold and mining sectors, when compared to the secondary sector indices. This observation implies that countries characterised by stock markets that have a greater propensity towards the primary sector may exhibit elevated levels of efficiency. In addition, a study by Sandubete, Belena and Garcia-Villalobs (2023) studied the EMH on foreign exchange market for time intervals of 15, 30, 60 minutes with various macroeconomic factors to determine the efficiency or impact on the exchange market. In other words, if the news reported by those countries impacted any of the macroeconomic sales, they could see how efficient the market was within an hour. Sandubete, Belena and Garcia-Villalobs (2023) used a model-data paradox of chaos which is not applicable to my study. Serrano-Monge (2022) did a similar study with three emerging countries and studied the impact of macroeconomic and foreign exchange variables influencing the country risk and the currency market's efficiency by using the Emerging Market Bond Index. The timeframe of Serrano-Monge (2022) was only nine years and only used three countries developing countries, and the results looked more at-risk categories. The Serrano-Monge (2022) Emerging Market Bond Index adds variables and market relationships that would make this study too complicated, but interesting to see how investors act to risk. Ozdemir (2022) tested the weak-form efficiency using various statistical tests such as runs test, variance ratios test, unit root tests and nonlinear tests, with daily, weekly and monthly returns for the BIST100 index over the past ten years. The Ozdemir (2022) study used similar methodologies and found that the Istanbul market is weak-form efficient; however, this study will look at ten different indices.

Smith and Dyakova (2014) conducted a study to examine the suitability of the EMH in different African stock markets. The study utilised the random walk method to examine weak-form market efficiency in eight African countries. The research conducted the time frame spanning from February 1998 to December 2011. In addition, many African indices were used in the selection of the study. The authors employed variance ratio tests to assess whether these indices had certain characteristics and, as a result, adhered to a random walk process. The researchers conducted an evaluation and classification of the market efficiency of the chosen countries. Their findings revealed that certain African countries such as Zambia, Kenya, Egypt and South Africa were identified as weak-form efficient. The evidenced rise in weak-form market efficiency

within highly developed African nations provides substantiation for the fundamental tenets of the efficient market theory.

Several studies have presented findings that challenge the EMH suggesting deviations from its assumptions. For instance, Malkiel (2003) argues that market anomalies and inefficiencies persist, contradicting the notion of market efficiency. Additionally, Lo and MacKinlay (1999) highlight the presence of predictable patterns in stock prices, indicating that markets may not fully reflect all available information as suggested by the EMH. Furthermore, Sappideen (2009) propose that investor sentiment and behavioural biases can lead to market inefficiencies, undermining the EMH's assumption of rationality. Kwon and Kish (2002) conducted an analysis of data from the value-weighted NYSE index covering the period from 1962 to 1996. The researchers employed the simple moving average trading approach to evaluate the possibility of achieving returns that surpass the market benchmark. They applied the two-sample t-test for the purpose of assessment. In summary, their findings indicated a deficiency in weak-form efficiency within the NYSE. In order to examine potential changes in market efficiency across different subperiods, Kwon and Kish (2002) divided the observation period into three unique ranges: 1962-1972, 1973-1984, and 1985-1996. Significantly, they saw a pause in earnings exceeding the benchmark between 1985 and 1996, suggesting a change in market dynamics. This result is consistent with the findings of Park and Irwin (2007), indicating that technology progress plays a role in expediting the spread of information and enhancing the efficiency of market pricing as time progresses. Maloumian (2022) suggested the EMH is incapable to cope with the consequences of information in financial markets and the relationship it has on the price and value. These studies demonstrate that while the EMH provides a useful framework for understanding financial markets, its assumptions may not always hold true in practice, emphasising the importance of considering alternative perspectives in market analysis.

The reviewed literature yielded divergent conclusions regarding the weak-form efficiency of the studied markets, with several studies suggesting that these markets were not weak-form efficient. Researchers often cited factors such as low market

maturity and liquidity constraints as reasons for the inefficiency observed in these markets. Mobarek and Fiorante (2014) determined the BRIC equity markets may be considered weak-form efficient based on daily price data from 1995 to 2010 and concluded that the markets in BRIC countries may have been approaching a level of weak-form efficiency, indicating the future possibilities of these countries.

2.2.2 BRICS

The BRICS nations Brazil, Russia, India, China, and South Africa have emerged as significant players in the global economy, collectively representing a substantial portion of the world's population, landmass, and economic output. The concept of BRICS as an economic bloc gained traction in the early 2000s, propelled by the influential Goldman Sachs report by O'Neill (2001), which projected these nations to become dominant global economic powers by the year 2050. As these countries continue to evolve and assert their influence on the world stage, scholars have increasingly turned their attention to understanding the dynamics of their economies, financial markets, and policy frameworks. These countries' economies are among the biggest and fastest growing in the world, and over the past 20 years, their financial markets have grown dramatically. However, some researchers have disagreed on the effectiveness of these markets. Additionally, the EMH is a theory that holds that financial markets are efficient and that asset prices effectively reflect all available information. The weak-form means that all past prices are reflected in current prices, which precludes the use of past prices to forecast future prices. By examining previous price fluctuations, this hypothesis contends that it is impossible to continually outperform the market. Thus, the investigation of the suitability of the EMH in relation to the financial markets of BRICS countries offers valuable insights into the effectiveness, mechanisms of information processing, and pricing dynamics within these developing economies.

Studies have investigated the drivers of economic growth and development within the BRICS nations. Huang and Wang (2011) highlighted the role of investment and technology transfer in promoting economic growth in China and India, while Ribeiro and Guilhoto (2017) emphasised the importance of innovation and productivity growth in sustaining long-term economic expansion across the BRICS countries. Economic

growth has an impact on financial markets. There are numerous studies on financial markets within BRICS, these specific markets for the mini thesis are discussed in Chapter 3.

Using varied techniques, several studies have looked into the effectiveness of BRIC financial markets. Groenewold, Tang and Wu (2003) used a sample of 50 A-share companies listed on the Shanghai Stock Exchange to analyse the effectiveness of the Chinese stock market. According to the study, the Chinese stock market exhibits weak-form efficiency, which means that present prices accurately reflect all previous prices. Similar to this, Maneli, Pace and Leone (2024) used a sample of 56 companies listed on the Moscow Exchange to analyse the effectiveness of the Russian stock market. The study discovered that, notwithstanding differences in efficiency between sectors, the Russian stock market was weak-form efficient. The entire stock market is represented by very small samples of enterprises in the studies of Zhan *et al.* (2013) and Maneli, Pace and Leone (2024). It's possible that the results don't apply to the entire market, even though the sample sizes employed in the studies may be suitable for the analysis carried out. Additionally, neither study looks at the reasons behind any potential market inefficiencies. Some things, including information asymmetry, market frictions, and behavioural biases, can lead to inefficiencies. Market players and regulators can create policies that enhance market efficiency by better understanding the reasons behind inefficiencies. To put it briefly, future study can overcome these constraints by looking at market efficiency using various approaches, bigger samples, and over longer time periods, as well as by looking into the reasons behind any potential inefficiencies.

Numerous studies have examined the efficiency of the financial markets by sector, albeit distinct sectors may operate at varying levels of efficiency. Maneli, Pace and Leone (2024) used a sample of 120 companies listed on the Moscow Exchange to analyse the effectiveness of the Russian stock market by sector. The utilities sector was determined to be the most efficient, while the energy sector was found to be the least efficient, according to the survey. Additionally, Ahmad (2015) used a sample of 11 industries to analyse the efficiency of the Indian stock market by sector. The information technology sector was determined to be the most efficient, while the healthcare sector was found to be the least efficient. There are several potential

weaknesses and limitations in the analyses by Maneli, Pace and Leone (2024) and Ahmad (2015), despite the fact that they offer insightful information about the effectiveness of the Russian and Indian stock markets by sector. While analysing the efficiency of individual sectors can be helpful for investors and policymakers, neither study looks at the efficiency of the respective stock markets as a whole. As a result, it is possible that the efficiency of the market as a whole is different from the efficiency of individual sectors. The results of both studies do not generalize to the entire sector because they employ relatively small samples of enterprises to represent each sector. The research by Maneli, Pace and Leone (2024) and Ahmad (2015), while offering some information about the effectiveness of the Russian and Indian stock markets by sector, may have certain flaws and gaps. Future study can overcome these constraints by looking at market efficiency using various approaches, larger samples, and over longer time periods, as well as by looking into the reasons behind any potential inefficiencies.

2.2.3 Financial crises, COVID-19 and Ukraine war

Financial crises are pivotal events in economic history characterised by abrupt disruptions to financial markets and the broader economy. Kindleberger and Bernstein (2000) famously described them as episodes of "Manias, Panics, and Crashes," emphasising the role of speculative bubbles, herd behaviour, and market euphoria. Reinhart and Rogoff (2009) comprehensively analyse financial crises throughout history, documenting their diverse manifestations and identifying common patterns and triggers. These crises, which can take various forms such as banking, currency, sovereign debt, and systemic financial crises, have far-reaching implications, affecting financial markets, real economic activity, and income distribution. Financial crises can significantly impact market efficiency by disrupting the normal functioning of financial markets, leading to increased volatility, reduced liquidity, and impaired price discovery mechanisms (Brunnermeier, 2009). During crises, informational asymmetries may widen, investor confidence may wane, and asset prices may deviate significantly from fundamental values, challenging the assumptions of the EMH (Lo and Mackinlay, 1999). These deviations highlight the limitations of market efficiency in times of extreme stress, as markets may fail to fully incorporate available information and efficiently allocate resources (Fama, 1970).

Financial markets' effectiveness can be significantly impacted by economic crises. Two of the most severe economic crises in recent memory the 1997 Asian crisis and the 2008 subprime crisis had a substantial effect on the economies of the BRICS countries. Chiang, Liu and Wan (2021) looked at how well the Chinese stock market performed throughout the Asian financial crisis. The study found that the Chinese stock market was weak-form efficient during the crisis, meaning that current prices reflected all past prices. The study only examines the efficiency of the market during a specific crisis. While the Asian crisis was a significant event in the history of the Chinese stock market, it is possible that the efficiency of the market may vary during other crises or periods of economic and political turmoil. Similarly, Mishra (2009) examined the efficiency of the Indian stock market during the 2008 subprime crisis. The study found that the Indian stock market was weak-form efficient during the crisis, meaning that current prices reflected all past prices. The market is represented by a somewhat small sample of companies in the study. Although the study's sample size may have been appropriate for the analysis done, it is still possible that the findings might not apply to the full market. Furthermore, it would have been ideal to see pre- and post-crisis for these studies.

The COVID-19 global pandemic that began in 2020 has had a significant impact on financial markets worldwide, including those of the BRICS economies. The pandemic caused significant volatility in global financial markets, leading to significant declines in asset prices. Several studies have examined the impact of the pandemic on the efficiency of financial markets in BRICS economies. For instance, Chiang, Liu and Wan (2021) examined the efficiency of the Chinese stock market during the pandemic. The study found that the Chinese stock market was weak-form efficient during the pandemic, meaning that current prices reflected all past prices. However, the efficiency of the market was lower during the pandemic compared to normal times. A study by Ozkan (2021) on the impact of COVID-19 on developed countries found that those markets deviated from market efficiency during COVID-19. The study found that the Indian stock market was weak-form efficient during the pandemic. A study by Alajiani, Khan, Yesufu and Khan (2024) only analysed the impact of the pandemic on the stock markets of BRICS for eight months and found that the pandemic had a significant negative impact on the BRICS stock markets, with Brazil and India

experiencing the largest declines. The study by Alajiani *et al.* (2024), has such a short time period and highlights the need for research on the efficiency of the BRICS financial markets during the COVID-19 pandemic.

The Russian economy and financial markets have been significantly impacted by the Ukraine conflict, which started in 2014. Economic sanctions on Russia as a result of the conflict significantly impacted its financial markets. Several studies have examined the impact of the Ukraine war on the efficiency of the Russian financial market. Maneli, Pace and Leone (2024) examined the efficiency of the Russian stock market during the war. The study found that the Russian stock market was weak-form efficient during the war. In brief, while the study by Maneli, Pace and Leone (2024) provides valuable insights into the efficiency of the Russian stock market during the war, it is important to consider potential shortcomings and gaps in the study such as comparing market efficiency to other markets or examining the efficiency of individual sectors, and considering other potential factors that may have influenced market efficiency during the war can provide a more comprehensive understanding of market efficiency during that period.

Previous literature and studies have been done on BRIC countries but there have been studies on market efficiency on South Africa. Grater and Struweg (2015) examined the weak-form efficiency of the South African equity market and found that it is weak-form efficient with a positive risk premium. Dassios, Kostakis, and Skiadopoulos (2020) examined the efficiency of the South African equity market using long-term memory tests and found that the market exhibits long-term memory, indicating that the market is not fully efficient. Finally, Sarpong, Sibanda and Holden (2016) also tested the weak-form efficiency of the Johannesburg Stock Exchange and found that it is weak-form efficient, but the efficiency varies across sectors. The studies suggest mixed results on the efficiency of the South African equity market and the importance of considering different testing approaches and periods. The past literature by Grater and Struweg (2015) and Dassios *et al.* (2020) does not include information on the impact of COVID-19 on the South African equity market and which sectors were most affected.

Overall, the evidence suggests that the financial markets of BRICS economies are generally weak-form efficient, although the efficiency varies across sectors and can

be impacted by economic crises and other external factors. Further research is needed to examine the efficiency of these markets over longer time periods and to assess the practical implications of these findings for investors and policymakers. Equally important is to include South Africa as it has been left out of the other studies and see how COVID-19 has impacted the BRICS financial markets.

2.3 Summary

This chapter introduced the theoretical and empirical analysis to provide a comprehensive understanding of existing research on the topic, identify gaps or contradictions in the literature, and establish the theoretical framework upon which the research hypotheses and methodology are built. Extensive research suggested the debate about EMH and most studies done on developed economies and the various efficiencies of those countries over certain periods and the various tests involved and the limitations. In addition, the research on BRICS and the economic growth and trade of those countries have increased over the past few year and how it draw attention of investors. The impact of global and economic events on certain economies and how that impacts their own country and others was researched. This allowed for the various methodology tests to emerge and in the next chapter this will be explained. Furthermore, there is a gap in the literature because most past literature studied only one market and used two-three methods to test weak-form efficiency. In addition, the past literature did not expand into large time frames such as this study with eight methods to examine the BRICS market efficiency.

Chapter 3

Research Methodology and Data

3.1 Introduction

This chapter discusses the research approach, research design and data and sample used to achieve the purpose of this study which aims to examine the weak-form efficiency of the BRICS. This chapter outlines the methodology that has been applied for the eight econometric tests some are more common and this is discussed in the empirical framework.

3.2 Research approach

This study employs a quantitative methodology, which is valuable for analysing statistical data to identify trends and uncover empirical evidence in research (DeFranzo, 2011). In addition, this study involves the collection and analysis of numerical data to identify patterns, relationships, and statistical significance. Researchers often employ statistical methods such as regression analysis or experimental designs to draw objective and measurable conclusions from their data (Creswell & Creswell, 2017). Bryman (2016) underlines that a quantitative research strategy places significant importance on numerical data and statistical analysis. Utilising statistical data in research analysis and descriptions significantly decreases the time and effort the researcher requires to explain the findings. Computational efficiency is enhanced as computerised statistical programs, such as SPSS, Stata, E-views, R, and Excel, enable data calculation and analysis. This study utilised a quantitative research methodology to examine the weak-form efficiency of BRICS markets, as outlined in the previous reasoning.

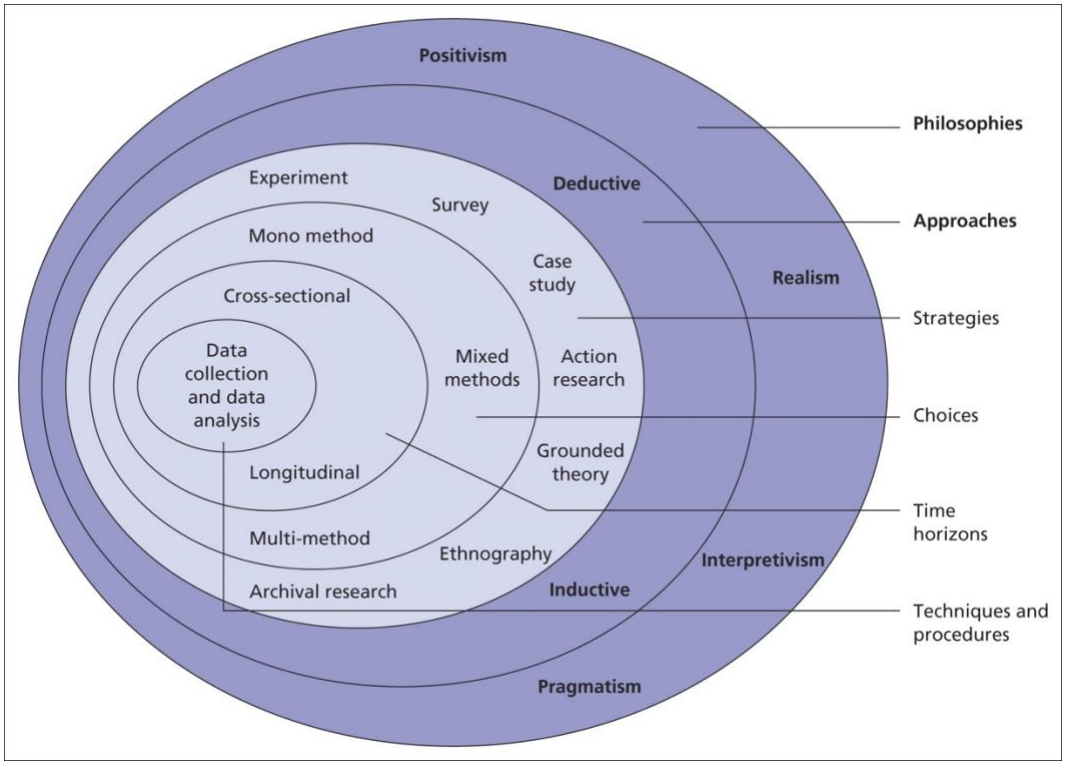


Figure 1: The Research Onion Model (Saunders, Lewis & Thornhill, 2019).

As per Figure 1, the famous “research onion” that has been “peeled” for this study will be discussed in this Chapter. This study has a positivism philosophy, deduction approach, experimental research strategy, mono method (quantitative), longitudinal time horizon, and secondary data collection and econometric model testing.

3.3 Research philosophy

Research philosophy refers to the underlying set of beliefs, assumptions, and principles that guide the design and conduct of a research study. It serves as the foundation for the researcher's worldview and influences the choice of research methods and methodologies. There are three main research philosophies: positivism, interpretivism, and pragmatism, as seen in Figure 1. Positivism emphasises objectivity and the use of quantitative data to discover general laws, interpretivism focuses on understanding subjective meanings and social context through qualitative methods, and pragmatism adopts a flexible approach, combining elements of both paradigms to address specific research questions (Saunders *et al*., 2019). This study employed a positivism research philosophy. In brief, a positivism research philosophy relies on quantifiable observations that lead to statistical analyses, and the researcher's job is

primarily to collect and interpret data. Furthermore, a researcher using a positivism method remains detached from their research and maintains strict objectivity. Essentially, research employing this technique perceives the world as external and objective and relies solely on factual information.

This study employed a positivism research philosophy because it was limited to data collection and interpretation of the daily historical stock prices of the ten different markets. This study's final aspect of positivism is that the research process was carried out without subjective values, as Saunders *et al*. (2019) stated.

3.4 Research design

A research design is a systematic plan or blueprint outlining the procedures and methods for conducting a study to address a specific research problem. It encompasses decisions about data collection, sampling, measurement, and analysis, providing a structured framework to ensure the study's validity and reliability. There are various types of research designs, including experimental, quasi-experimental, correlational, and descriptive designs, each tailored to different research questions and objectives (Creswell & Creswell, 2017). The selection of an appropriate research design is crucial as it directly influences the study's ability to draw valid conclusions and contributes to the overall rigour and credibility of the research process (Trochim & Donnelly, 2008). This study uses a conclusive research design which is aimed at providing clear, definitive answers to specific research questions, often through structured data collection and analysis. It is characterised by its emphasis on reaching conclusive results, making it particularly useful for decision-making purposes in business and applied settings (Cooper & Schindler, 2019). This study analysed daily historical stock prices of the ten different markets over a 27-year period. In addition, various statistical tests such as random walk, variance ratio test, and runs test were applied to examine the weak-form efficiency of the BRICS markets. Many studies focus on only two or three methods to analyse market efficiency, limiting the scope of their findings. In contrast, this study employs eight different methods, considering both linear and non-linear aspects, providing a more comprehensive and robust analysis.

3.5 Theoretical argument

This study employs both traditional and dynamic frameworks to evaluate the effectiveness of a weak-form market. The random walk hypothesis is the most popular method to test for weak-form market efficiency. According to Deguitis and Novicktye (2014), “the random walk testing process is typically tested by using either serial correlation tests, variance ratio tests or unit root tests, to measure how much of the previous data is incorporated in the price by measuring the unpredictability of returns. This study tests the random walk properties of historical stock prices by implementing a series of tests, such as the serial correlation test, the runs test” (Wallis & Roberts, 1956), variance ratio test (Lo & MacKinlay, 1988), Cox-Stuart test (Cox & Stuart, 1955), Bartels test (Bartels, 1982), Rank test (Mann, 1945), and Difference sign test (Wilcoxon, 1945).

3.6 Data and sample

This study utilised historical data retrieved from online databases such as Yahoo Finance and Investing.com (Boritz and No, 2020). Specifically, closing prices, rather than adjusted closing prices, were employed to compute index returns. This decision was made because adjusted closing prices incorporate additional factors such as stock splits or new stock offerings that may influence the index price after the market closes, whereas closing prices represent the raw price of an index at the market's closing time. The study relied on secondary data, which sometimes is previously gathered and utilised by researchers for purposes other than those originally intended. Although secondary data offers advantages in terms of cost and time efficiency, its reliability and relevance to the specific research context must be carefully considered (Bryman, 2016; Sekaran & Bougie, 2016). Nonetheless, it is essential to note that collecting, verifying, organising, and sorting the data according to the econometric model still demands the researcher's time and attention.

Country		Market	Index
BRICS			
Brazil		Brazil Stock Exchange	Ibovespa (BVSP)
Russia		Moscow Exchange	MOEX Russia (IMOEX)
India		National Stock Exchange of India	Nifty 50 (NSEI)
China		Shanghai Stock Exchange	SSE Composite (SSE)
South Africa		Johannesburg Stock Exchange	FTSE/JSE SA All Share (JSE)
Japan		Tokyo Stock Exchange	Nikkei 225
United Kingdom (UK)		Financial Times Stock Exchange	FTSE 100
Unites States (US)		New York Stock Exchange	NASDAQ
Unites States (US)		New York Stock Exchange	S&P 500
Unites States (US)		New York Stock Exchange	Dow Jones

Figure 2: The Countries, Markets, and Indices for this study[1]

The data is based on the BRICS (emerging) economies and four benchmark (emerged) markets as per Figure 2, and consists of daily observations from 16th January 1995 to 16th June 2023[2]; the large sample was divided into six sub-periods as per Figure 3. The reason for the multiple periods is to answer the objectives of the study. The chosen indexes have been picked based on characteristics such as their size, significance, trading frequency, and the frequency with which both domestic and

[1] Source: Self/Author
[2] This was the time frame, however some markets have more or less observations because either the data was not available from the beginning but still fell into the period or because of weekend or country specific holidays within those markets.

foreign investors use them to measure performance. Furthermore, the benchmark is used that includes the equity markets of Japan, UK and the US for comparing results and efficiency. All this data was obtained from public databases, and none of the data has been manipulated. Hence, there was no need for ethical clearance. The multiple statistical tests are applied independently to the selected countries' most significant stock indices.

Figure 3: The six sub-period timelines[3]

3.7 Empirical framework

The data studied consisted of the past share prices of the BRICS markets and four benchmark markets. This study takes the daily close share prices, and the researcher calculates the logarithmic returns due to the non-normal distribution of asset returns and simple returns do not consider compounding effects. Furthermore, it is worth noting that investors prioritise the attainment of profits in the form of returns, rather than exclusively concentrating on pricing (Wang & Vergne, 2017).

Therefore, the researcher had to calculate the compounded returns for all the markets and each sub-period using this formula:

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

Where:

R_t= is the return of the price at time t.

P_t= is the closing price at time t.

P_{t-1}= is the closing price of the previous observation at time t-1.

ln= is the natural log

The study employed the natural logarithm of price returns, drawing upon the methodologies employed in prior research conducted by Mobarek and Fiorante (2014) to examine the weak-form efficiency of BRIC countries, as well as the study conducted by Njuguna (2016) to assess the weak-form efficiency of the Nairobi Securities

[3] Source: Self/Author

Exchange. Furthermore, Abakah *et al.* (2018) conducted prior research on the weak-form efficiency of five specific African stock markets. Additionally, Ggayi (2021) examined the weak-form efficiency of the JSE following a worldwide financial crisis.

This study subsequently divided the data into six sub-periods to facilitate the analysis, as the market efficiency may have undergone changes over these specific periods due to potential societal shifts and evolving market conditions. The data utilised in the first sub-period are affected by the aftershocks of the Asian crisis that commenced in 1997, which had a direct influence on Japan and Southeast Asia. In addition, in 1994, South Africa saw the end of the apartheid era and entered into a democratic government system, which would have an impact from 1995 onwards. Yet, the interconnected market economies may have had an indirect impact on the markets of China, India, the US, and the UK. A few years later, in 1998, Russia experienced a crisis because of the Asian crisis, while Brazil faced a currency crisis between 1998 and 1999.

In the second sub-period is an event known as the “Dot-Com Bubble” because of a rapid rise in the valuation of internet-based companies that was fuelled by speculative investments and a belief in the transformative power of the internet. However, this bubble burst, leading to a significant market correction and the collapse of numerous dot-com companies, highlighting the risks associated with speculative investing and the importance of fundamental business principles in the evaluation of market trends (Corporate Finance Institute, n.d.). Furthermore, in the second sub-period, 2001, was the Enron scandal in the US. The scandal highlighted significant shortcomings in corporate governance and ethical practices, prompting extensive academic research and analysis on the causes and consequences of the Enron debacle (Healy & Palepu, 2003).

In sub-period three, the 2007-2008 financial crisis, triggered by the collapse of the subprime mortgage market, had profound implications for market efficiency. The crisis exposed vulnerabilities in financial markets, leading to a re-evaluation of the EMH as it became evident that markets were not fully incorporating available information. Academic research, such as that by Fama (1997), has since explored the challenges to market efficiency posed by the crisis and the evolving understanding of how financial markets process and respond to information.

In sub-period four, the "Flash Crash" of May 6, 2010, marked by a rapid and severe decline in U.S. stock market indices, raised concerns about the stability of financial markets and prompted scholarly investigations into the role of high-frequency trading and market structure (Kirilenko, Kyle, Samadi, & Tuzun, 2017).

In sub-period five, 2014 till presently is the Ukraine-Russia war and fluctuates on the severity based on the political factors. In addition, in 2016 the Brexit referendum, which resulted in the UK's decision to leave the European Union, has been studied extensively in academic literature to understand its political, economic, and social implications (Hobolt & Leeper, 2020). Lastly, in sub-period five, the end of 2019 was the COVID-19 pandemic, with its unprecedented global health and economic implications, significantly impacted market efficiency, challenging traditional notions of information processing and pricing in financial markets. Furthermore, sup-period six is to test the aftermath of the pandemic and whether the EMH is weak-form.

The following sub-sections explain the various multiple tests that were used to investigate the weak-form efficiency of the BRICS markets.

3.7.1 Autoregressive model: Random walk

Autoregressive modelling is a statistical method used to analyse time series data, where the values of a variable are regressed on its own past values. In autoregressive models, each observation is expressed as a linear combination of its lagged values, with the order of the model indicating the number of past observations considered. This approach is particularly useful for capturing temporal dependencies and trends in data, making it a valuable tool in various fields such as economics, finance, and signal processing (Box, Jenkins, & Reinsel, 2015). The general autoregressive model of order p [AR(p)] is written as:

$$Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots + \alpha_p Y_{t-p} + \varepsilon_t [2]$$

Where:

Y_t= prediction at that current point in time (dependent variable).

α_p= coefficients.

Y_{t-p}= observations from the past (lagged values of Y_t).

ε_t= white noise or error term.

A random walk is a specific type of time series model where future values are predicted based on the current value plus a random shock or innovation. In a random walk, each future value is the sum of the previous value and a random error term. This modelling concept is widely applied in financial markets to describe the unpredictable nature of stock prices and is a fundamental concept in the efficient market hypothesis (Malkiel, 2003). Random walks are characterised by the absence of systematic patterns or trends, and they provide a benchmark for evaluating the predictability of time series data. The random walk model is written as:

$$Y_t = Y_{t-1} + \varepsilon_t [3]$$

Where:

Y_t= dependent variable.

Y_{t-1}= dependent variable of previous period.

ε_t= white noise or error term.

To understand the wandering behaviour of random walk model by doing some recursive substitution.

$$Y_1 = Y_0 + \varepsilon_1 [4]$$

$$Y_2 = Y_1 + \varepsilon_2 = (Y_0 + \varepsilon_1) + \varepsilon_2 = Y_0 + \varepsilon_1 + \varepsilon_2 = Y_0 + \sum_{i=1}^{2} \varepsilon_i$$

...

$$Y_t = \varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2} + \cdots \varepsilon_1 + Y_0 = Y_0 + \sum_{i=1}^{t} \varepsilon_i [5]$$

Where:

$\sum_{i=1}^{t} \varepsilon_i$ is known as the stochastic term.

This then also proves that the random walk model is not stationary, because it has a mean equal to its initial value and a variance that increases over time. In addition, the increasing variance implies that the series may not return to its mean concluding the model is not stationary and works well to test efficiency and using variance ratio tests have been proven successful, because they yield more powerful and accurate results compared to other tests. In this study the single variance ratio test is used.

3.7.2 Volatility model: GARCH (1,1)

The Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model is a time series econometric model designed to capture the volatility clustering observed in financial data. Introduced by Robert Engle in 1982, the GARCH model extends the ARCH (Autoregressive Conditional Heteroskedasticity) model by allowing for a more flexible and dynamic representation of conditional variances. GARCH models assume that the conditional variance of a time series is a function of past squared observations and past conditional variances (Engle, 1982). This study econometrically analysed the volatility model or GARCH (1,1) model due to its advantage over a basic linear regression model, this approach examines the relationship between historical and present returns while also accounting for the fluctuating variability of the model's error structure.

Furthermore, the model has proven to be highly effective in explaining the patterns observed in financial return data, as it is able to accurately represent both the clustering of volatility and the distributions of unconditional returns (Ggayi, 2021). Furthermore, the model is advantageous as it clarifies the inherent trade-off between stock returns and risk, a common attribute frequently seen in developing stock markets. Moreover, the model accommodates a conditional variance that changes over time and unpredictability in the producing mechanism. Ggayi (2021) highlights that the basic GARCH model adequately captures the presence of volatility clustering and the distribution of unconditional returns, which exhibit heavy tails in the data. The primary reason for using this model in the study was due to the fact that the effectiveness of emerging economies tends to change over time as these markets consistently enhance their regulatory framework. The Ljung-Box test is a statistical method commonly applied in the context of GARCH models to assess the adequacy of the model's fit by examining the autocorrelation of the residuals. Specifically, it tests the null hypothesis that the autocorrelations of the residuals up to a certain lag are zero, indicating no remaining patterns or information in the residuals (Ljung & Box, 1978). The GARCH model is written as:

$$Mean\ Equation: r_t = \beta_0 + \beta_1 r_{t-1} + \gamma\sigma^2 + e_t [6]$$

$$Variance\ Equation: \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 [7]$$

$$e_t \sim N(0, \sigma_t^2)$$

Where:

r_t= stock market return.

σ_t^2= the time- varying conditional variance.

β_0, β_1, γ= intercept AR(1) is the coefficient and risk premium parameter respectively in the mean equation.

$\alpha_0, \alpha_1, \alpha_2$= intercept, is the coefficient of the lag residual and coefficient of the last period's forecast variance, respectively.

ε_t= a gaussian innovation with zero mean and time-varying covariance σ_t^2.

The coefficients above are for the long-run estimates of the mean and variance equations. According to Bahadur (2010) "if the summation of α_1 and β_1 is greater than or very close to one, the market is inefficient, and it shows high persistence in volatility clustering and it if it is not close to one, this shows low persistence in volatility clustering and the market is deemed efficient".

In this study, the GARCH model has one assumption: no serial correlation in residual. The GARCH model is considered good if there is an absence of serial correlation. Ggayi (2021), explains that "the existence of serial correlation can be determined by applying several different statistical tests". Based on the AR model, the Ljung-Box test is used to check if autocorrelation exists in a time series and uses a test statistic which is written as:

$$Q = n(n+2)\sum_{k=1}^{h}\frac{p_k^2}{n-k}\,[8]$$

Where:

Q= the test statistic.

n= the sample size.

h= the number of lags being tested.

p_k= the sample autocorrelation of lag k.

In this study, the Ljung-Box test is applied using the following null and alternate hypotheses:

H_0: There is no serial correlation in residuals (independently distributed).

H_1: There is serial correlation in residuals (not independently distributed).

If the p-value is less than the 5% significance level the null hypothesis is rejected, meaning the residuals over the time series are independent. The Ljung-Box test can be applied to assess whether the residuals from a random walk model exhibit significant autocorrelation at various lags (Ljung & Box, 1978). If the market exhibits serial correlation, this indicates weak-form inefficiency. However, if it exhibits autocorrelation, this indicates weak-form efficiency.

Random walk has been used as benchmark model. We improve the model by using other models. By using other models, we aim to improve accuracy and predictability beyond this basic, random approach.

3.7.3 Variance ratio test

The variance ratio test is a statistical method used to assess the randomness or predictability of a time series by examining the ratio of variances of different lags. It is commonly applied in financial research to evaluate whether asset prices follow a random walk or exhibit some form of serial correlation. The test assesses the efficiency of a market by comparing the observed variance of price changes over different intervals with the expected variance under a random walk hypothesis. Deviations from the expected random walk behaviour may suggest the presence of predictability or inefficiency in the market (Lo & MacKinlay, 1988). According to Mobarek and Fiorante (2014), “variance ratio tests are designed to test for type-1 random walk (RW1), which assumes homoskedastic increments as well as type-3 random walk (RW3) if the increments are assumed to be subject to heteroskedasticity”. The variance ratio test, as developed by Lo and Mackinlay (1988), was employed in this study to evaluate the level of randomness in stock returns. "The superiority of this test over others, such as the unit root test, is often debated due to its higher level of statistical power and greater accuracy in generating results" (Mobarek & Fiorante, 2014). The issue of whether this test is susceptible to errors arising from misleading autocorrelation due to “non-synchronous trading” has been a topic of controversy among researchers (Fuss, 2005). The variance ratio test used in this study, which was used by Mobarek and Fiorante (2014)

$$R_t = R_{t-1} + \mu + \varepsilon_t [9]$$

Where:

R_t= the log of the equity return series at time t.

μ= a drift parameter.

ε_t= error term.

The usual stochastic assumption on μ_t is the Gaussian error structure, $E(\varepsilon_t) = 0$ and $E(\varepsilon_t^2) = \sigma_\varepsilon^2$

The variance ratio test applied in this study examined the following null and alternative hypotheses where:

$H_0 = VR(q) = 1$ which states that the market under study follows the random walk and is weak-form efficient.

$H_1 \neq VR(q) \neq 1$ which states that the market under study does not follow the random walk and is weak-form inefficient.

The provided null and alternative hypotheses serve as the basis for analysing the outcomes of the variance ratio test, aiming to determine whether the return series adhere to a random walk pattern. Essentially, this examination seeks to ascertain whether stock prices exhibit unpredictability, indicating independence between today's price and tomorrow's price. The conclusive findings from this analysis will contribute to determining the weak-form efficiency status of the BRICS markets.

The calculation of the variance test involves the use of logarithmic returns and mean data, which accounts for the presence of drift. The study employed asymptotic normal probability and utilised the standard test periods of 2, 4, 8, and 16 days. If the p-value exceeds the 5% or 0.05 level of significance, it can be inferred that the market at the given period adheres to a random walk and exhibits weak-form efficiency, hence accepting the null hypothesis. If the p-value is less than the 5% or 0.05 level of significance, the null hypothesis is rejected, indicating that the market at that time does not exhibit a random walk and is weak-form inefficient.

3.7.4 Runs test

The Runs test is a non-parametric statistical method used to analyse the presence of patterns or trends in a sequence of binary or categorical data. It examines whether the data values tend to cluster together in runs of consecutive highs or lows, suggesting a departure from randomness. The test calculates the number of runs (sequences of

consecutive identical values) and compares it to the expected number of runs in a random sequence. Significant deviations from the expected number of runs may indicate non-randomness or the presence of a systematic pattern in the data. In addition, the runs test can be used to investigate the randomness of a series of stock returns (Urquhart & Hudson, 2013). The runs test does not assume any distribution. Furthermore, a stock can either increase or decrease the next day, or over a week it can increase three times and decrease four times, the runs test is a way to count how many times the price increased or decreased of the sequence of same information. According to Borges (2010), "the runs test is based on the notion that if price changes follow the random walk, the actual number of runs should not be far from the expected number of runs." Over a period, multiple runs can exist, the minimum requirement for a run to start is to have the same outcome twice, in other words price decreased on day two and day three. However, if the price where to then increase on day four, the previous run is disrupted until a new run is established. The formula for the runs test is written as:

$$m = \frac{N(N+1) - \sum_{i=1}^{3} n_i^2}{N} [10]$$

Where:

m= the total number of expected runs.

N= total number of runs.

n_i^2= sample size of each category of price change.

For large number of observations (N>30), the sampling distribution of m is approximately normal and the standard error of σ_m is given by:

$$\sigma_m = \left\{ \frac{\sum_{i=1}^{3} n_i^2 [\sum_{i=1}^{3} n_i^2 + N(N+1) - 2N \sum_{i=1}^{3} n_i^3 - N^3}{N^2(N-1)} \right\}^{\frac{1}{2}} [11]$$

The standard normal Z-statistic to test the hypothesis is:

$$Z = \frac{R \pm 0.5 - 3}{\sigma_m} [12]$$

Where:

R= actual number of runs.

m= expected number of runs.

0.5= continuity adjustment.

The following null and alternative hypotheses are tested:

H_0: The price fluctuations of the time series exhibit a random pattern.
H_1: The price fluctuations of the time series do not exhibit a random pattern.

Utilising the hypotheses, this analysis aims to examine the outcomes of the runs test in order to determine whether the return series adhere to a random walk pattern. Specifically, it seeks to ascertain whether stock prices exhibit unpredictability and whether the price of today is unrelated to the price of tomorrow. The conclusion can prove the weak-form efficiency of the market.

If the number of runs is below the expected runs, $R \geq m$, the Z-value will be positive, which is an indication of the presence of negative serial correlation. If the number of runs is below the expected runs, $R \leq m$, the Z-value will be negative, which is an indication of the presence of positive serial correlation. The presence of negative correlation in the return series shows the negative dependence of stock returns which implies the observation of random walk and thus fail to reject the null hypothesis. The presence of positive correlation in the return series shows the positive dependence of stock returns which implies violation of random walk and thus reject the null hypothesis.

3.7.5 Cox-Stuart test

The Cox-Stuart test is another non-parametric test for detecting trends in ordered data. The test statistic is based on the count of runs, where a run is a sequence of consecutive data points with the same sign (increasing or decreasing) (Logos, 2009). The difference between this test and the runs test is it is designed for ordinal or ranked data, focusing on the detection of monotonic trends (Cox & Stuart, 1955). The formula for the Cox-Stuart test is written as:

$$W = \frac{R - E(R)}{\sqrt{V(R)}} [13]$$

Where:
W= test-statistic.
R= number of runs.
$E(R)$= expected number of runs under the null hypothesis of randomness.
$V(R)$= is the variance of the number of runs.

When the test statistic is compared to the critical values to determine whether the observed number of runs deviates significantly from what would be expected by chance.

The Cox-Stuart test can be used to show a one-tail test (increasing or decreasing) or a two-tail test (test for randomness). In this study, it analysed if there was a monotonic trend and if the trend was skewed to the left or right tail (direction), as it does not follow a normal distribution. In this study, the Cox-Stuart test (one-tail) is applied using the following null and alternative hypotheses:
H_0: There is a positive monotonic trend (increasing).
H_1: There is a negative monotonic trend (decreasing)
Furthermore, the Cox-Stuart test (two-tail) is applied using the following null and alternative hypotheses:
H_0: There is randomness.
H_1: There is non-randomness.

The same application of the Runs test can be used here, if p-value is less than 5% level of significance the null hypothesis is rejected and the market is weak-form inefficient, if p-value is greater than 5% level of significance the null hypothesis is accepted and the market is weak-form efficient.

3.7.6 Bartels test

The Bartels test, introduced by Bartels (1982), is a non-parametric statistical test designed for detecting monotonic trends in time series data. Unlike parametric methods, the Bartels test does not assume a specific form for the underlying distribution of the data. It calculates the correlation between the data values and their respective time indices, measuring the strength and direction of any linear trend present in the series (Bartels, 1982).

The Bartels test calculates the rank correlation between the data values and their corresponding time indices, and it is designed to detect monotonic trends in time series data. The formula for the Bartels test is written as:

$$B = \frac{\sum_i (X_i - \bar{X})(T_i - \bar{T})}{\sqrt{\sum_i (X_i - \bar{X})^2 \sum_i (T_i - \bar{T})^2}} [14]$$

Where:

B= test statistic.

X_i=is the i-th observation.

T_i= is the i-th time index.

$\bar{X}, \bar{T}$= is the means of the data values and time indices.

The Bartels ratio test is applied using the following null and alternative hypotheses:

H_0: There is randomness.

H_1: There is non-randomness.

The same application of the Runs test can be used here, if p-value is less than 5% level of significance the null hypothesis is rejected and the market is weak-form inefficient, if p-value is greater than 5% level of significance the null hypothesis is accepted and the market is weak-form efficient.

3.7.7 Difference sign test

The Wilcoxon signed-rank test, often referred to as the difference sign test, is a non-parametric statistical method used to assess whether the median of a paired sample is significantly different from a hypothesised median. Developed by Wilcoxon in 1945, this test is particularly useful when dealing with small sample sizes or when data does not meet the assumptions of normality. The test involves ranking the absolute differences between pairs of observations, considering their signs, and then summing the ranks of the positive or negative differences (Wilcoxon, 1945). The formula for the difference sign test is written as:

$$W = \sum_{i=1}^{N} R_i [15]$$

Where:

W= test-statistic.

N= number of pairs.

R_i= is the absolute difference between the paired observations with non-zero differences that contribute to the sum.

The difference sign test (two-tail) is applied using the following null and alternative hypotheses:

H_0: There is randomness.

H_1: There is non-randomness.

The same application of the Runs test can be used here, if p-value is less than 5% level of significance the null hypothesis is rejected and the market is weak-form inefficient, if p-value is greater than 5% level of significance the null hypothesis is accepted and the market is weak-form efficient.

3.7.8 Mann-Kendall rank test

The Mann-Kendall rank test is a non-parametric statistical method used to detect trends in time series data. Developed by Mann in 1945 and later refined by Kendall in 1955, the test evaluates whether there is a monotonic trend (increasing or decreasing) in a set of observations over time. The test is based on the ranks of the data, comparing the number of concordant and discordant pairs of observations. If the number of concordant pairs is significantly different from the number of discordant pairs, it suggests the presence of a trend in the data (Mann, 1945; Kendall, 1955). The formula for the rank test is written as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \, [16]$$

Where:

n= is the number of observations.

x_i, x_j= is the data values at the time i and j.

$sign(.)$=is the sign function returning -1 if the argument is negative, 0 if it is zero, and 1 if it is positive.

The variance of the rank test is written as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{p=1}^{m} t_p(t_p-1)(2t_p+5)}{18} \, [17]$$

Where:

t_p= is the number of tied groups of the size of p in the data.

The calculated rank test is then compared to critical values from standard normal distribution tables to determine whether the observed trend is statistically significant using the following null and alternative hypotheses:
H_0: There is no trend in the series.
H_1: There is a trend in the series.

If the p-value is less than the 5% level of significance, the conclusion is there is a trend in the series, meaning the market is inefficient. If the p-value is greater than the 5% level of significance, the conclusion is there is no trend in the series, meaning the market is efficient.

3.8 Summary

For any researcher, it is important to use the Research Onion Model, and the different layers of the study were discussed and motivated how well it fits the study. The data and various samples and periods were explained, and so were the various emerging economies market indices and the developed economies indices introduced. In addition, how the multiple hypothesis tests are calculated to then show the eight different econometric tests were explained, and credit was given to past literature and sources recognised and modified to suit this study. The multiple tests were used to compare the efficiency of each economy and the type of efficiency that could be determined. In the next chapter will the empirical results and findings will be investigated and compared.

Chapter 4

Empirical Results and Analysis of Findings

4.1 Introduction

This chapter is the application of the previous one. Firstly, the source data of the selected markets are analysed, the graphical illustrations of stock market returns for the full period are shown and the descriptive statistics are highlighted. Following this is the more common tests to test EMH are investigated followed by other tests. Important to note that each test was applied for the full period of each market then applied to the six sub-periods, and various patterns and trends linked to EMH, developed and emerging economies and economic events were identified which link back to the purpose of this study.

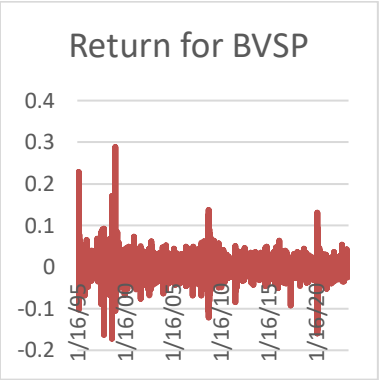
4.2 Analysis of source data of selected markets

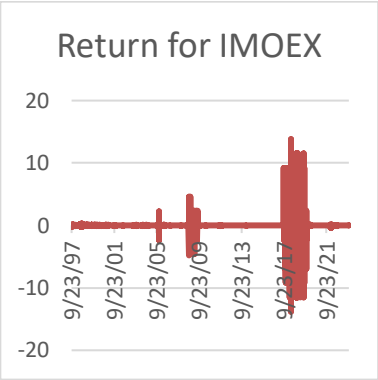
This study used the daily closing price of the stock markets and the returns of the markets for the full period can be seen in the various figures below. The primary objective of this analysis is to evaluate the entire performance of these indices throughout the duration of the study and verify if the time series exhibits stationarity or non-stationarity. According to Ggayi (2021) “stationarity simply means that the time series (stock prices) do not change over time and mean reversion means that stock prices tend to move back to their average price over time”. The existence of mean reversion suggests that market players can anticipate the future price of an asset, enabling them to generate an exceptional return. This validates the weak-form inefficiency of BRICS.

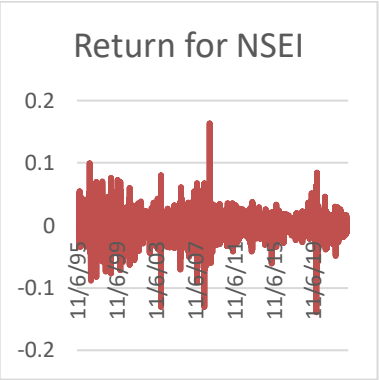
Figures 4-5 illustrate the full period and individual market performance over the study period. Note the spikes and drops for each market and whether the crisis was impacted one market or more. Furthermore, the plots in Figures 4-5 depict the log returns that have been computed utilising the technique outlined in Chapter 3, in order to incorporate the impact of compounding. All ten indices demonstrate stationarity around the mean and mostly reflect mean reversion in their continuously compounded returns. The presence of mean reversion implies the potential for predicting future prices of a security inside this market, enabling market participants to attain an

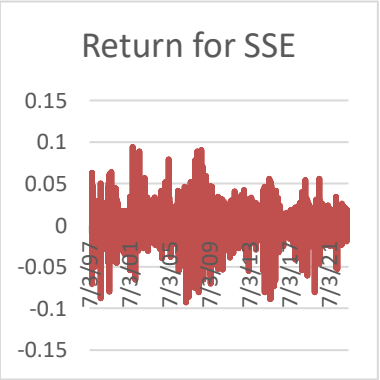
extraordinary return that challenges the assumptions of random walk and efficient market. The volatility of Russia and its return in Figure 4 has a different pattern to the rest of the emerging economies, a study by Umar, Polat, Choi and Teplova (2022) analysed the financial depth of the Russian economy can be considered insufficient when compared to other emerging economies and its nearest rivals, Brazil, India, and China. In addition, growth potential in the Russian financial market is matched with extraordinarily high risk. Its vulnerability to shocks in the global market is increased and its long-term competitiveness is compromised by an inadequate depth of the financial system (Umar, Polat, Choi & Teplova, 2022).

Based on the Figures 4-5, it can be concluded that the BRICS and benchmark markets do not follow a random walk, indicating its weak-form inefficiency. Thus, investors are able to predict the future price of an asset which enables them to earn an abnormal return potentially. While the graphs display various upward and downward trends in all ten indices, it is challenging to determine whether these movements are random or predictable. Consequently, the subsequent tests in the following sections aim to yield a definitive outcome regarding the BRICS weak-form efficiency.









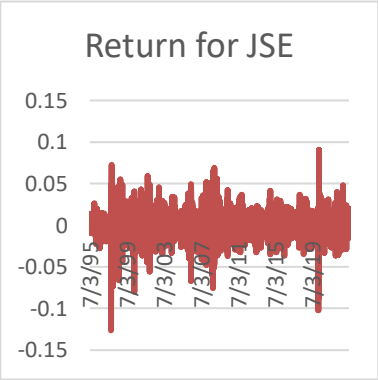


Figure 4: Emerging Economies: BRICS market returns[4]

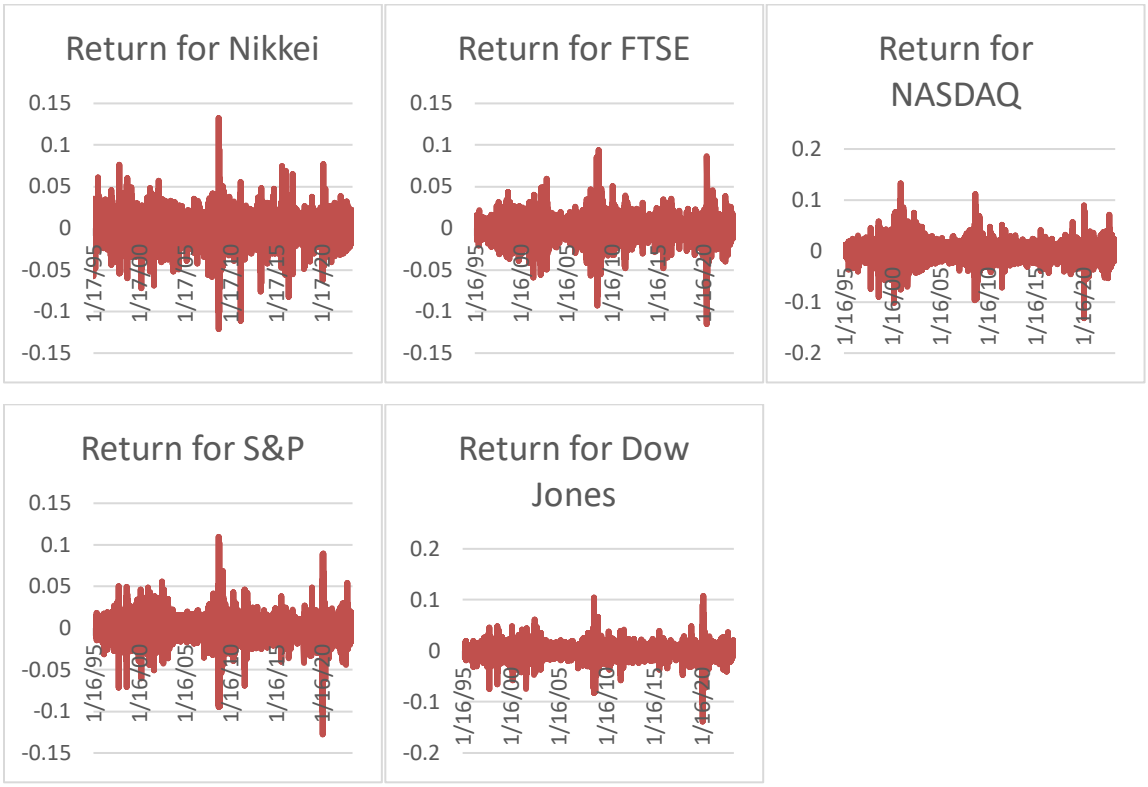


Figure 5: Developed Economies: Japan, UK and US market return[5]

Table 1 displays a concise overview of the descriptive statistics of the daily return data over the entire period of the ten markets, as well as for all sub-periods. The mean in statistics is often represented as the expected value, serves as a central measure indicating the average or central tendency of a distribution and is a fundamental concept in statistical modelling (Woolridge, 2019). The BRICS equities markets, on average, exhibit higher mean returns and standard deviation compared to the benchmark markets. This emphasises the increased level of risk associated with investing in emerging economies. These findings support the idea that investing in mature markets is linked to reduced risk and lower average returns compared to riskier markets, which provide higher returns to compensate for the increased risk that investors must take on.

[4] Source: Self/Author based on secondary data collection
[5] Source: Self/Author based on secondary data collection

In sub-period one, the negative mean for Japan is reflecting the impact of the Asian crisis. In sub-period two, the “Dot-Com bubble burst” is seen in the benchmark markets and the impact it had on China, all of them showing negative mean returns, out of the BRICS emerging economies, China is the closest to being an emerged or developed country such as the US. In sub-period three, the supreme financial crisis that started in the US certainly impacted the benchmark markets with negative mean returns whilst the BRICS markets managed to remain positive because they recovered because the time period includes two years of “recovery”. In sub-periods four and five, most of the markets had a positive mean return even though there was a pandemic in 2020. In sub-period six, the benchmark markets indicate a negative mean return whilst the Brazil, India, South Africa indicate a positive mean return. Based on all the return series have periods that show less or more volatility, and the distribution properties appear to be non-normal (random), and this has been tested using Jarque-Bera test of normality, which all return series have rejected the null hypothesis. The Jarque-Bera assesses the normality of a sample by examining the skewness and kurtosis, providing a statistical measure to evaluate departures from a normal distribution (Woolridge, 2019). The kurtosis measures the degree of peakedness or flatness of a probability distribution, providing insights into the tails and potential outliers in a dataset. The use of many methods, like the Runs Test, to counter skewness because skewness can distort our analysis of market data. By applying different techniques, we can get a more accurate and balanced understanding of market behaviour.

Table 1: Descriptive statistics of the daily returns of the BRICS and the benchmark markets.

Market	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque–Bera[1]
Full period: 1995-01-16 - 2023-06-16								
BRICS								
Brazil	0.0004	0.0009	0.2883	-0.1720	0.0200	0.2898	15.1877	69222.535*
Russia	0.0005	0.0009	13.8153	-13.8212	0.9671	-0.3962	93.1798	2362576.974*
India	0.0004	0.0007	0.1633	-0.1390	0.0146	-0.3154	8.8668	22623.591*
China	0.0001	0.0004	0.0940	-0.0925	0.0148	-0.3937	5.3683	7931.560*
South Africa	0.0003	0.0006	0.0904	-0.1262	0.0121	-0.4608	6.8758	14070.466*
Benchmark								
Japan	0.0000	0.0004	0.1323	-0.1211	0.0142	-0.3219	5.8218	10248.129*
UK	0.0001	0.0003	0.0938	-0.1151	0.0113	-0.3237	7.5946	17411.184*
US (NASQ)	0.0004	0.0011	0.1325	-0.1315	0.0155	-0.1916	5.9760	10696.473*

US (S&P)	0.0003	0.0006	0.1095	-0.1276	0.0120	-0.4001	10.0360	30236.306*
US (DJ)	0.0003	0.0005	0.1076	-0.1384	0.0115	-0.4023	12.1132	43967.821*
Sub period 1: 1995-01-16 - 1999-12-31								
BRICS								
Brazil	0.0011	0.0016	0.2883	-0.1720	0.0287	0.8561	14.4884	11518.772*
Russia	0.0007	0.0015	0.2750	-0.2333	0.0504	0.2368	4.8375	565.528*
India	0.0003	0.0000	0.0993	-0.0884	0.0172	0.1374	3.3696	496.989*
China	0.0002	0.0001	0.0637	-0.0872	0.0155	-0.2202	5.0316	698.793*
South Africa	0.0004	0.0007	0.0726	-0.1262	0.0121	-1.5028	15.9080	12522.990*
Benchmark								
Japan	-0.0000	0.0001	0.0766	-0.0595	0.0139	0.0779	2.3808	308.835*
UK	0.0005	0.0008	0.0434	-0.0388	0.0099	-0.1125	1.5979	141.636*
US (NASQ)	0.0013	0.0022	0.0584	-0.0895	0.0132	-0.5739	3.7645	813.113*
US (S&P)	0.0009	0.0009	0.0498	-0.0711	0.0100	-0.4940	5.5116	1644.961*
US (DJ)	0.0008	0.0009	0.0486	-0.0745	0.0098	-0.5922	5.6571	1752.416*
Sub period 2: 2000-01-03 - 2005-12-31								
BRICS								
Brazil	0.0004	0.0007	0.0733	-0.0753	0.0181	-0.1680	0.5951	30.602*
Russia	0.0011	0.0023	2.3007	-2.3068	0.0868	-0.1422	659.0593	27129807.082*
India	0.0003	0.0015	0.0796	-0.1305	0.0149	-0.8140	6.3041	2672.0157*
China	-0.0001	0.0000	0.0940	-0.0654	0.0127	0.7085	6.1826	2631.574*
South Africa	0.0004	0.0005	0.0589	-0.0794	0.0113	-0.1701	3.1449	631.168*
Benchmark								
Japan	-0.0001	0.0000	0.0573	-0.0723	0.0135	-0.2936	1.7707	228.413*
UK	-0.0000	0.0004	0.0590	-0.0588	0.0115	-0.2129	3.4317	777.521*
US (NASQ)	-0.0004	0.0003	0.1325	-0.1016	0.0205	0.2099	3.2309	669.955*
US (S&P)	-0.0001	0.0002	0.0557	-0.0600	0.0119	0.1156	2.2237	315.821*
US (DJ)	-0.0000	0.0002	0.0615	-0.0739	0.0115	-0.0321	3.4288	742.204*
Sub period 3: 2006-01-02 - 2010-03-31								
BRICS								
Brazil	0.0007	0.0017	0.1367	-0.1209	0.0218	-0.0239	5.3826	1286.072*
Russia	0.0002	0.0014	4.6068	-4.8117	0.4858	-0.7665	49.7366	108767.173*
India	0.0005	0.0013	0.1633	-0.1301	0.0206	-0.0093	6.0481	1604.958*
China	0.0009	0.0028	0.0903	-0.0925	0.0213	-0.4335	2.0843	221.010*
South Africa	0.0004	0.0012	0.0683	-0.0758	0.0162	-0.1684	2.4006	261.737*
Benchmark								
Japan	-0.0003	0.0003	0.1323	-0.1211	0.0186	-0.3837	7.6051	572.176*
UK	-0.0001	0.0001	0.0938	-0.0926	0.0155	-0.0666	6.4224	1830.985*
US (NASQ)	0.0000	0.0009	0.1115	-0.0958	0.0169	-0.1448	6.2408	1744.942*

US (S&P)	-0.0000	0.0009	0.1095	-0.0946	0.0163	-0.2318	8.5414	3269.606*
US (DJ)	0.0000	0.0005	0.1050	-0.0820	0.0149	0.0370	8.7718	3438.353*
Sub period 4: 2010-04-01 - 2019-10-31								
BRICS								
Brazil	0.0001	0.0002	0.0638	-0.0921	0.0141	-0.1462	1.8924	365.363*
Russia	0.0031	0.0001	13.8153	-13.8212	1.5507	-0.2184	36.0081	130506.63*
India	0.0003	0.0004	0.0518	-0.0609	0.0096	-0.0871	1.9707	395.177*
China	-0.0000	0.0004	0.0560	-0.0887	0.0137	-0.9210	6.0561	3896.442*
South Africa	0.0002	0.0004	0.0423	-0.0369	0.0095	-0.1606	1.3265	186.799*
Benchmark								
Japan	0.0003	0.0006	0.0742	-0.1115	0.0130	-0.5735	5.6273	3261.241*
UK	0.0001	0.0000	0.0394	-0.0477	0.0090	-0.2099	2.5428	661.331*
US (NASQ)	0.0005	0.0008	0.0567	-0.0714	0.0108	-0.4381	3.3818	1230.832*
US (S&P)	0.0003	0.0005	0.0484	-0.0689	0.0093	-0.4783	4.5635	2191.784*
US (DJ)	0.0003	0.0005	0.0486	-0.0570	0.0089	-0.4628	4.0051	1703.735*
Sub period 5: 2019-11-01 - 2021-12-30								
BRICS								
Brazil	-0.0000	0.0007	0.1302	-0.1599	0.0216	-1.5643	15.8693	5850.781*
Russia	0.0004	0.0015	0.0743	-0.0864	0.0133	-0.8703	9.5829	2170.806*
India	0.0007	0.0016	0.0840	-0.1390	0.0157	-1.8282	17.3736	6601.653*
China	0.0003	0.0006	0.0555	-0.0803	0.0109	-0.8670	7.4442	1298.725*
South Africa	0.0004	0.0010	0.0904	-0.1022	0.0149	-0.7896	10.9539	2786.882*
Benchmark								
Japan	0.0004	0.0002	0.0773	-0.0627	0.0137	0.1041	4.2809	408.603*
UK	-0.0000	0.0006	0.0866	-0.1151	0.0140	-1.2132	13.2710	4071.432*
US (NASQ)	0.0011	0.0020	0.0893	-0.1314	0.0172	-1.0478	11.2807	3017.034*
US (S&P)	0.0008	0.0015	0.0896	-0.1276	0.0159	-1.0860	15.9255	5917.587*
US (DJ)	0.0005	0.0011	0.1076	-0.1384	0.0167	-1.0786	17.8869	7434.184*
Sub period 6: 2022-01-03 - 2023-06-16								
BRICS								
Brazil	0.0003	0.0002	0.0539	-0.0340	0.0129	0.0004	0.4652	3.549*
Russia	-0.0003	0.0007	0.1826	-0.4046	0.0271	-6.9576	112.0905	242460.783*
India	0.0001	0.0002	0.0298	-0.0489	0.0097	-0.4058	2.0707	76.058*
China	-0.0002	-0.0002	0.0342	-0.0526	0.0102	-0.7199	3.3930	202.604*
South Africa	0.0001	0.0003	0.0481	-0.0363	0.0122	0.1496	0.9087	14.456*
Benchmark								
Japan	0.0003	0.0014	0.0386	-0.0316	0.0118	-0.0893	0.3300	2.276*
UK	0.0002	0.0006	0.0383	-0.0395	0.0094	-0.4665	2.8502	138.955*
US (NASQ)	-0.0004	-0.0009	0.0709	-0.0529	0.0181	-0.0412	0.3539	2.202*

US (S&P)	-0.0002	-0.0007	0.0539	-0.0441	0.0137	-0.0787	0.6835	7.872*
US (DJ)	-0.0001	-0.0002	0.0362	-0.0402	0.0113	-0.1144	0.7178	9.094*

[1]For the JB test of normality, the null hypothesis is rejected at 5%, indicating that the return series are not normally.

* Significant at 5%

4.3 Results of autocorrelation

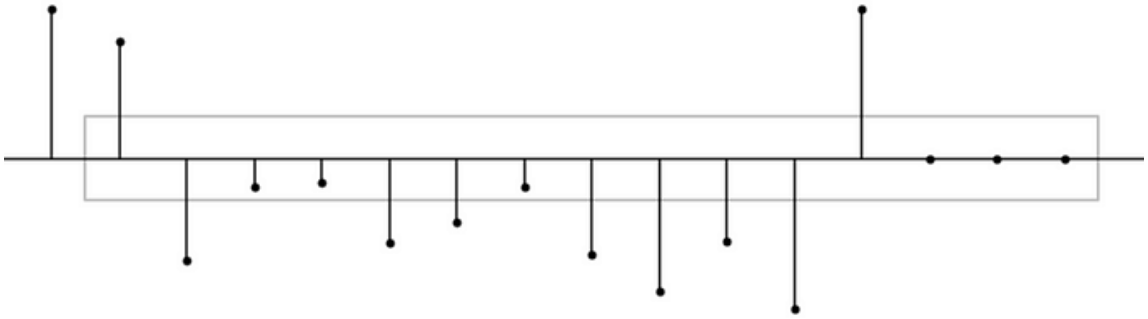


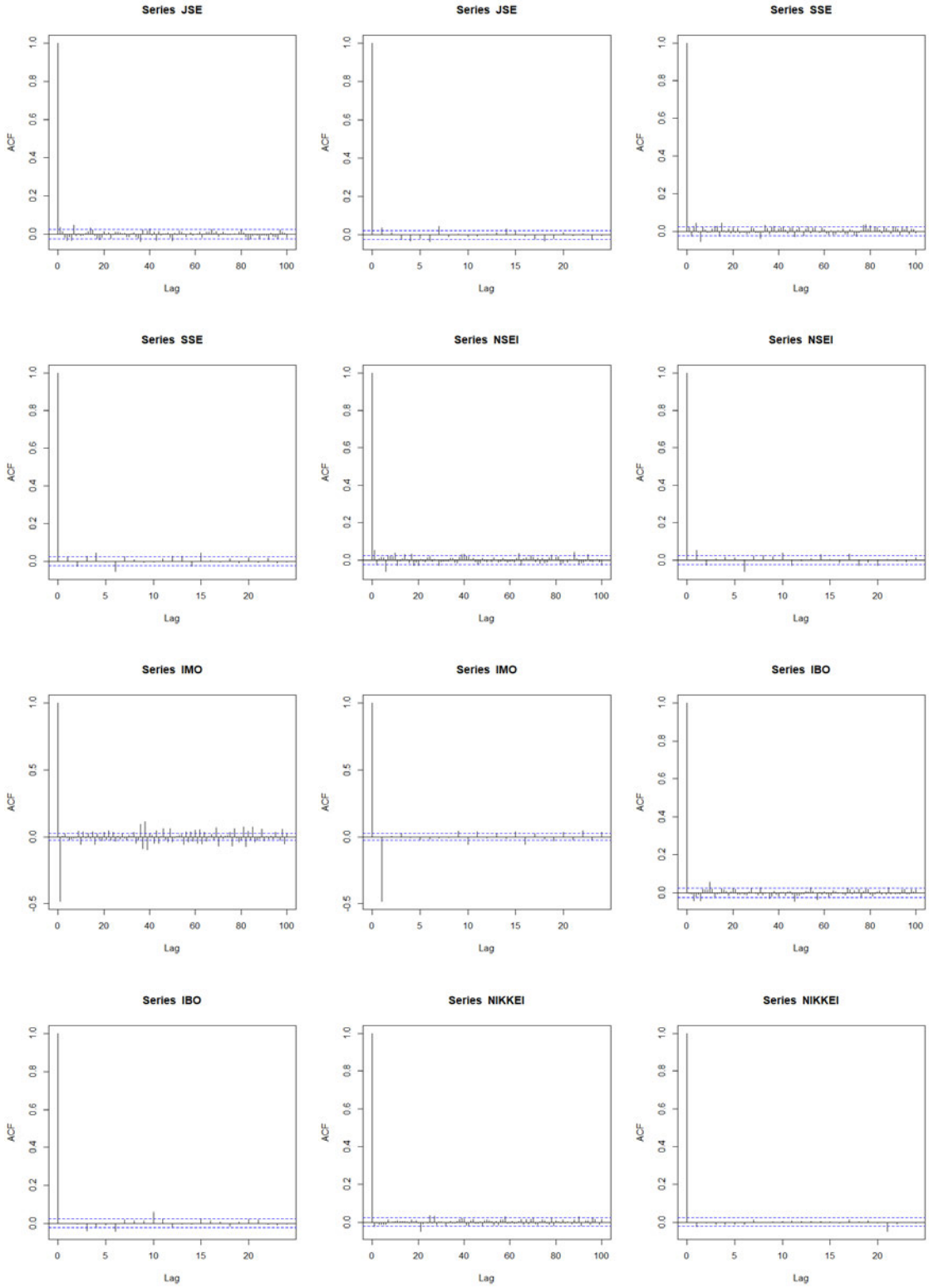
Figure 6: Autocorrelation illustration[6]

The autocorrelation (AC) is an analysis that measures the correlation between a time series and its lagged values, providing insights into the persistence of patterns over time. Autocorrelation analysis is a crucial component of the exploratory data analysis process for time series forecasting and is a useful tool for identifying patterns and assessing the presence of randomness (Monigatti, 2022). It is particularly crucial when planning to utilise an autoregressive–moving-average (ARMA) model for prediction, since it aids in determining the model's parameters. Based on the equation of the Autoregressive model in Chapter 3, the researcher can then conclude if past observation will have a lagged effect on predicting future observations. Figure 6, is an example of what a typical AC analysis looks like and can indicate the strength of the correlation and how they change over time. On the y-axis is the autocorrelation function (ACF) which start from zero and either have a positive correlation (upwards) or negative correlation (downwards) and the x-axis is the lag at that particular time period.

Below you can see the AC series graph for the full period for all the markets. As you can see in all AC that the correlation is not that significant and can be upwards or

[6] Source: (Monigatti, 2022)

downwards.



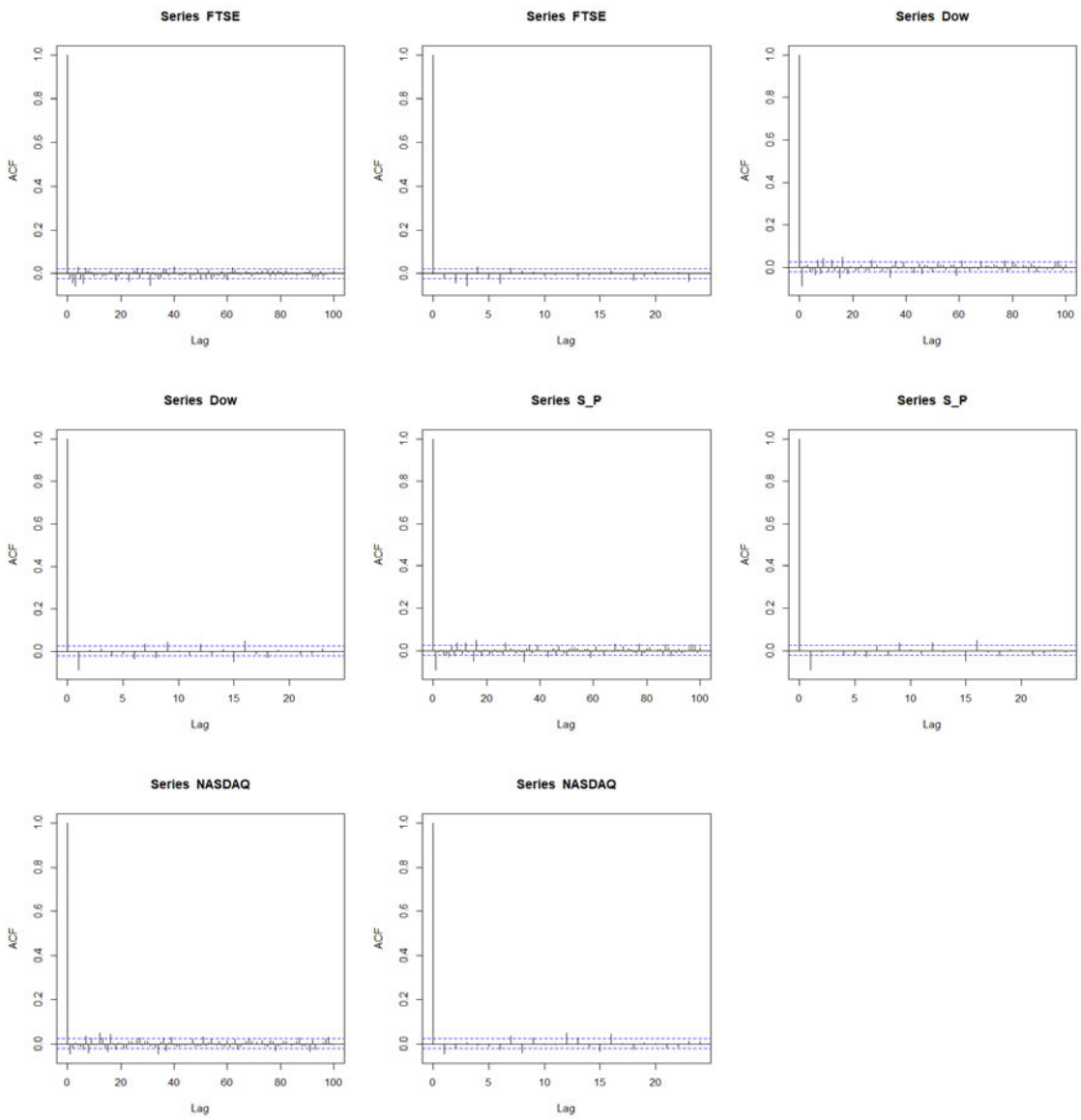


Figure 7: AC Graphs

Table 2 summarises Table 3 and indicates the trend of autocorrelation and the Ljung-Box test. Most of the markets exhibit autocorrelation and the residuals are independent thus proving weak-form efficiency. Based on this test, only Brazil and China markets in period one exhibit autocorrelation whilst the other periods there is serial correlation.

Table 2: Autocorrelation summary

	Autocorrelation					
	Period 1	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Period 6**
BRICS						
Brazil	Positive**	Positive	Negative*	Positive	Negative**	Negative
Russia	Negative***	Negative***	Negative***	Negative***	Negative**	Negative**
India	Positive	Negative**	Negative**	Positive***	Positive**	Positive
China	Positive**	Positive	Positive	Positive**	Positive	Positive
South Africa	Positive***	Positive**	Negative**	Negative**	Negative**	Negative
Benchmark						
Japan	Negative	Positive	Negative**	Positive**	Positive**	Positive
UK	Negative***	Negative***	Negative***	Negative**	Negative**	Positive
US	Negative**	Negative**	Negative***	Negative**	Positive***	Positive

* significant at 10%, ** significant at 5%, *** significant at 1%

Table 3 shows the results of the AC and the lags at 1, 5, and 30 days the Ljung-Box test is used to assess the presence of autocorrelation in a time series. The test statistic is based on the Ljung-Box Q statistic, and under the null hypothesis of no autocorrelation, this statistic follows a chi-square distribution (Ljung & Box, 1978). Figure 8 illustrates the GARCH Graphs for BRICS and link with the returns and AC.

Table 3: Results of autocorrelation

Sub period 1: 1995-01-16 - 1999-12-31

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.044	2.4727	0.1158	0.087	9.794	0.00***	-0.004	0.020832	0.8852*
5	-0.038	8.3923	0.1359	-0.038	27.857	0.00***	-0.071	11.273	0.04623**
30	0.002	38.648	0.1338	-0.013	60.309	0.00***	-0.021	62.157	0.00***
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.039	1.9258	0.1652	0.148	12.437	0.00***	0.028	0.81585	0.3664
5	-0.033	10.939	0.05261*	-0.114	23.167	0.00***	0.031	4.4037	0.4929
30	0.009	60.386	0.00***	-0.045	53.167	0.00***	-0.002	35.516	0.2244
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.008	0.041705	0.8382	0.134	20.501	0.00***			
5	0.045	13.727	0.01744**	0	29.886	0.00***			
30	-0.022	64.708	0.00***	0.002	60.15	0.00***			

Sub period 2: 2000-01-03 - 2005-12-31

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.015	0.33361	0.5635	-0.056	4.8231	0.02**	-0.026	0.99881	0.3176
5	0.007	2.4963	0.7771	-0.035	24.955	0.00***	-0.028	5.6597	0.3408
30	0.006	24.511	0.7484	0.056	109.61	0.00***	-0.008	45.252	0.0365**
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.043	2.9442	0.08619*	-0.467	326.65	0.00***	0.106	16.887	0.00***
5	-0.021	5.904	0.3157	0.007	326.74	0.00***	-0.006	37.686	0.00***
30	0.012	36.615	0.1886	-0.007	327.55	0.00***	-0.048	89.882	0.00***
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.035	1.9571	0.1618	0.096	14	0.00***			
5	-0.052	6.6996	0.244	-0.036	22.909	0.00***			
30	0.014	27.903	0.5756	0.019	58.772	0.00***			

Sub period 3: 2006-01-02 - 2010-03-31

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.052	2.8935	0.08894*	-0.081	6.9845	0.00***	-0.132	18.531	0.00***
5	-0.036	6.4104	0.2683	-0.074	38.913	0.00***	-0.027	41.725	0.00***
30	-0.014	56.724	0.0022**	-0.005	82.581	0.00***	0.022	115.39	0.00***
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.021	0.45362	0.5006	-0.456	219.28	0.00***	0.054	3.1064	0.07799*
5	-0.017	9.6572	0.08555*	-0.078	231.16	0.00***	-0.026	5.3743	0.3719
30	-0.008	40.731	0.09147*	-0.021	274.34	0.00***	-0.004	47.257	0.02348**
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.003	0.00678	0.9344	0.03	0.96954	0.3248			
5	0.006	8.8381	0.1157	-0.038	11.214	0.04731**			
30	0.001	41.111	0.08508*	-0.009	51.439	0.008748**			

Sub period 4: 2010-04-01 - 2019-10-31

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.037	3.1898	0.0741	0.026	1.6636	0.1971	-0.048	5.6723	0.01723**
5	0.010	11.327	0.04527*	-0.026	13.78	0.01707*	-0.081	24.906	0.00*
30	0.015	36.601	0.1891	-0.014	38.086	0.1476	0.010	72.252	0.00*
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.007	0.13142	0.717	-0.488	574.34	0.00***	0.065	10.255	0.00***
5	0.016	3.2545	0.6608	-0.023	577.51	0.00***	-0.018	15.358	0.00***
30	0.005	27.775	0.5824	-0.024	639.94	0.00***	0.017	34.211	0.2725
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.039	3.4812	0.06207*	-0.016	0.63962	0.4238			
5	0.002	12.841	0.02491**	-0.032	12.348	0.03031**			
30	-0.033	101.06	0.00***	-0.034	36.588	0.1894			

Sub period 5: 2019-11-01 - 2021-12-30

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.033	0.58842	0.443	-0.033	0.58608	0.4439	-0.312	53.183	0.00***
5	-0.058	13.06	0.02282**	0.095	8.2044	0.1453	0.130	101.48	0.00***
30	0.026	56.347	0.00249**	-0.032	83.859	0.00***	0.026	361.23	0.00***
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	-0.250	33.346	0.00***	-0.014	0.11159	0.7383	-0.094	4.4551	0.0348**
5	0.106	53.882	0.00***	-0.026	11.402	0.04397**	0.221	30.398	0.00***
30	-0.074	122.75	0.00***	-0.019	40.474	0.096*	0.034	119.84	0.00***
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.028	0.41653	0.5187	-0.104	5.8797	0.01532**			
5	-0.046	5.1412	0.3989	0.071	21.774	0.00***			
30	0.075	35.887	0.2118	-0.053	105.96	0.00***			

Sub period 6: 2022-01-03 - 2023-06-16

Lags	Japan			UK			US (S&P)		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.010	0.034219	0.8532	-0.054	1.0498	0.3055	0.007	0.017619	0.8944
5	0.017	1.6977	0.8892	0.002	6.3322	0.2752	0.013	1.6982	0.8891
30	-0.031	18.327	0.953	0.043	34.173	0.274	-0.091	29.709	0.4806
Lags	Brazil			Russia			India		
	AC	Q-Stat	P-value	AC	Q-Stat	P-value	AC	Q-Stat	P-value
1	0.092	3.0841	0.07906*	-0.149	10.072	0.001506**	0.012	0.048017	0.8266
5	-0.071	7.2099	0.2055	0.022	11.641	0.04006**	0.02	0.34103	0.9968
30	-0.091	32.755	0.3333	-0.08	44	0.04769**	-0.106	18.348	0.9526
Lags	China			South Africa					
	AC	Q-Stat	P-value	AC	Q-Stat	P-value			
1	0.001	0.000301	0.9862	0.06	1.3347	0.248			
5	-0.015	2.2214	0.8177	-0.016	9.8413	0.07986*			
30	0.083	38.945	0.127	-0.053	30.651	0.4327			

* significant at 10%, ** signifcant at 5%, *** significant at 1%

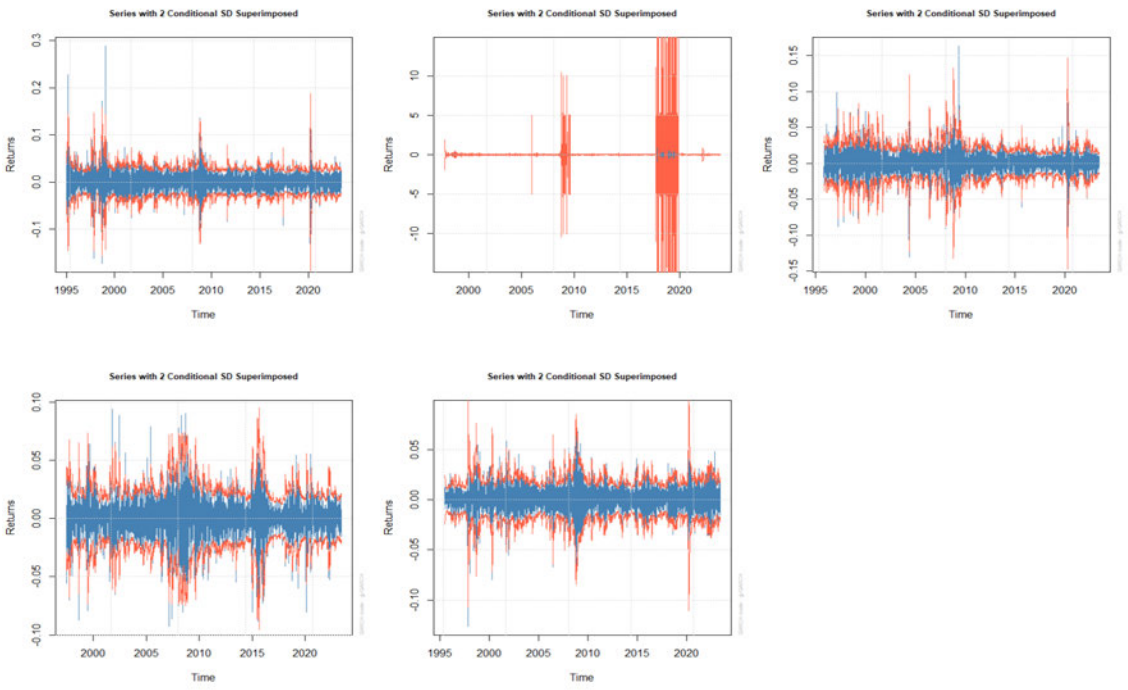


Figure 8: BRICS GARCH (1,1)

4.4 Results of variance ratio test

The variance ratio test is used to assess the randomness or predictability of a time series by examining the ratio of variances of different lags. This study used the Lo and Mackinlay (1988) variance ratio test to assess the randomness of stock returns.

As mentioned in Chapter 3 the variance ratio test was done for 2-day, 4-day, 8-day and 16-day returns. Table 4 is a summary of Table 5, it is clear to see how to benchmark markets (developed) are very similar in nature throughout all the periods, the same can be said for the BRICS markets (emerging). RW stands for random walk because the p-value was above the 5% level of significance, which indicates the market is weak-form efficient. NRW stands for non-random walk, which, because the p-value was below the 5% level of significance, indicates the market is weak-form inefficient. In Table 4, Con stands for conclusion which is based on observations from full period and sub-periods 1-6.

The conclusion is that the benchmark markets are market-inefficient, meaning they follow a strong EMH, and the BRICS markets (except Russia) are market-efficient, meaning they follow a weak EMH. The variance test for BRICS markets

proves that these emerging economies mainly follow a random walk whilst the developed markets follow a non-random walk.

Table 4: Variance ratio test summary

	Full Period	Period 1	Period 2	Variance Period 3	Period 4	Period 5	Period 6	Con
BRICS								
Brazil	B	RW	RW	NRW	B	B	RW	RW
Russia	NRW	RW	NRW	NRW	NRW	RW	RW	NRW
India	B	RW	B	RW	B	RW	RW	RW
China	B	RW	RW	RW	RW	RW	RW	RW
South Africa	B	NRW	B	RW	NRW	RW	RW	RW
Benchmark								
Japan	NRW	NRW	NRW	NRW	RW	RW	RW	NRW
UK	NRW	B	NRW	NRW	B	RW	B	NRW
US	NRW	RW	NRW	NRW	NRW	NRW	RW	NRW

Table 5: Results of variance ratio test

Full period: 1995-01-16 - 2023-06-16					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000242	0,00046	0,000877	0,001675	0,003127179
VR		-0,047225	-0,092841	-0,133222	-0,19096695
Variance of VR		0,00014	0,000489	0,001223	0,002708275
Std		0,011823	0,022119	0,034973	0,05204109
Z-stat		-3,994381	-4,197421	-3,809323	-3,66954161
P-value		0,000*	0,000*	0,000*	0,000*
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000146	0,000265	0,0005	0,000914	0,001663522
VR		-0,091657	-0,144499	-0,21768	-0,28826428
Variance of VR		0,00014	0,000489	0,001223	0,002708275
Std		0,011823	0,022119	0,034973	0,05204109
Z-stat		-7,752482	-6,532883	-6,224273	-5,53916673
P-value		0,000*	0,000*	0,000*	0,000*
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000134	0,000244	0,000355	0,000876	0,001715744
VR		-0,088654	-0,335664	-0,180227	-0,1973726
Variance of VR		0,00014	0,000489	0,001223	0,002707518
Std		0,011821	0,022116	0,034968	0,052033818
Z-stat		-7,499559	-15,17771	-5,154068	-3,79316019
P-value		0,000*	0,000*	0,000*	0,000*
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000129	0,000252	0,000462	0,000844	0,001591577
VR		-0,022667	-0,104331	-0,181577	-0,22853897
Variance of VR		0,000139	0,000487	0,001217	0,002695465
Std		0,011795	0,022066	0,03489	0,051917865
Z-stat		-1,921783	-4,728057	-5,204278	-4,40193323
P-value		0,0273*	0,000*	0,000*	0,000*
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000204	0,000397	0,000771	0,001459	0,002850652
VR		-0,025287	-0,053976	-0,104559	-0,12552174
Variance of VR		0,00014	0,000489	0,001221	0,002704495
Std		0,011815	0,022103	0,034948	0,052004756
Z-stat		-2,140293	-2,442001	-2,99182	-2,41365891
P-value		0,0161*	0,0073*	0,0013*	0,0078*
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,0004	0,000796	0,001543	0,0028	0,005683565
VR		-0,005142	-0,035315	-0,124878	-0,11184088
Variance of VR		0,000139	0,000487	0,001217	0,002695465
Std		0,011795	0,022066	0,03489	0,051917865
Z-stat		-0,435922	-1,600386	-3,5792	-2,15418882
P-value		0,331447	0,054756	0,0001*	0,0156*
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,935464	44,98975	50062,15	15220661	3,2678E+11
VR		23,04675	13377,96	2033837	21832707769
Variance of VR		0,000153	0,000536	0,001341	0,002968894
Std		0,012379	0,023159	0,036617	0,054487555
Z-stat		1861,801	577669,4	55543799	4,00692E+11
P-value		0,000*	0,000*	0,000*	0,000*
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000216	0,000452	0,000905	0,001805	0,003777549
VR		0,048677	0,049986	0,046388	0,095193605
Variance of VR		0,000146	0,00051	0,001274	0,002821465
Std		0,012067	0,022576	0,035696	0,053117464
Z-stat		4,033708	2,214096	1,299528	1,792133852
P-value		0,000*	0,0134*	0,0968	0,0365*
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00022	0,00045	0,000899	0,001865	0,003931216
VR		0,022605	0,020768	0,059065	0,115938527
Variance of VR		0,000155	0,000542	0,001354	0,002999226
Std		0,012442	0,023277	0,036803	0,05476519
Z-stat		1,816859	0,892251	1,604886	2,117011324
P-value		0,0346*	0,1861	0,0542	0,0171*
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000148	0,000306	0,000624	0,001182	0,002343389
VR		0,034588	0,056078	0,00039	-0,00818946
Variance of VR		0,000143	0,000499	0,001248	0,00276312
Std		0,011942	0,022342	0,035325	0,052565391
Z-stat		2,896354	2,51002	0,011032	-0,1557956
P-value		0,0018*	0,0060*	0,4955	0,4389

Sub period 1: 1995-01-16 - 1999-12-31					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000176	0,000371	0,000766	0,001515	0,003136
VR		0,051903	0,08617	0,074703	0,112238
Variance of VR		0,000797	0,002791	0,006978	0,015451
Std		0,028239	0,052831	0,083532	0,1243
Z-stat		1,837969	1,631056	0,894305	0,902961
P-value		0,0330*	0,0514	0,1855	0,1832
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000101	0,000202	0,000388	0,000684	0,001267
VR		-0,001903	-0,041108	-0,154739	-0,21682
Variance of VR		0,000797	0,002791	0,006978	0,015451
Std		0,028239	0,052831	0,083532	0,1243
Z-stat		-0,067401	-0,778118	-1,852436	-1,744322
P-value		0,4731	0,218	0,0319*	0,0405*
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	9,77E-05	0,000199	0,000377	0,000695	0,001368
VR		0,016129	-0,036494	-0,111108	-0,124746
Variance of VR		0,000797	0,002791	0,006978	0,015451
Std		0,028239	0,052831	0,083532	0,1243
Z-stat		0,571143	-0,690774	-1,330115	-1,003584
P-value		0,2840	0,2449	0,0917	0,1578
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	9,86E-05	0,000214	0,000402	0,000674	0,00127
VR		0,084499	0,019635	-0,145522	-0,194973
Variance of VR		0,000772	0,002703	0,006757	0,014961
Std		0,027789	0,051988	0,082199	0,122317
Z-stat		3,040791	0,377692	-1,770348	-1,594002
P-value		0,0011*	0,3528	0,0383*	0,0554
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000194	0,000372	0,000693	0,001272	0,002631
VR		-0,04262	-0,109308	-0,182045	-0,154179
Variance of VR		0,000773	0,002705	0,006762	0,014973
Std		0,027799	0,052008	0,082231	0,122364
Z-stat		-1,533135	-2,101764	-2,213822	-1,259999
P-value		0,0626	0,0177*	0,0134*	0,103835
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000827	0,001705	0,003335	0,005702	0,011771
VR		0,031214	0,008258	-0,138099	-0,110356
Variance of VR		0,000772	0,002703	0,006757	0,014961
Std		0,027789	0,051988	0,082199	0,122317
Z-stat		1,123286	0,158843	-1,680049	-0,902218
P-value		0,1306	0,4368	0,0464*	0,1834
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,002537	0,005912	0,009476	0,02311	0,046585
VR		0,165323	-0,066108	0,138768	0,147791
Variance of VR		0,001757	0,006151	0,015378	0,034051
Std		0,041922	0,078429	0,124007	0,184529
Z-stat		3,943573	-0,842902	1,119029	0,80091
P-value		0,000*	0,1996	0,1315	0,2115
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000297	0,000611	0,001253	0,002639	0,005405
VR		0,028803	0,055271	0,110941	0,137647
Variance of VR		0,000964	0,003375	0,008438	0,018684
Std		0,031054	0,058096	0,091858	0,136688
Z-stat		0,927525	0,951385	1,207753	1,007012
P-value		0,1768	0,1707	0,1135	0,1569
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00024	0,000484	0,000925	0,00203	0,004379
VR		0,006281	-0,037812	0,055426	0,138545
Variance of VR		0,001534	0,005368	0,01342	0,029716
Std		0,039163	0,073267	0,115846	0,172384
Z-stat		0,16038	-0,516077	0,478446	0,8037
P-value		0,4362	0,3029	0,3161	0,2107
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000147	0,000331	0,000745	0,001534	0,003543
VR		0,126922	0,270307	0,307424	0,509255
Variance of VR		0,000875	0,003062	0,007655	0,016951
Std		0,029579	0,055336	0,087495	0,130196
Z-stat		4,291022	4,884794	3,513642	3,91145
P-value		0,000*	0,000*	0,000*	0,000*

Sub period 2: 2000-01-03 - 2005-12-31					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00042	0,000834	0,001537	0,002957	0,005747
VR		-0,007763	-0,085714	-0,120594	-0,145369
Variance of VR		0,000663	0,000489	0,001223	0,002708
Std		0,025751	0,022119	0,034973	0,052041
Z-stat		-0,301478	-3,875178	-3,448233	-2,793355
P-value		0,3815	0,000*	0,0002*	0,0026*
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000142	0,000277	0,000516	0,000959	0,001812
VR		-0,026904	-0,091839	-0,156956	-0,203351
Variance of VR		0,000663	0,002321	0,005802	0,012848
Std		0,025751	0,048176	0,076173	0,11335
Z-stat		-1,044749	-1,906312	-2,060515	-1,794017
P-value		0,148	0,0283*	0,0196*	0,0364*
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000134	0,000262	0,000502	0,000973	0,001847
VR		-0,025718	-0,065681	-0,094684	-0,140561
Variance of VR		0,000663	0,002321	0,005802	0,012848
Std		0,025751	0,048176	0,076173	0,11335
Z-stat		-0,998714	-1,36334	-1,243008	-1,240067
P-value		0,1589	0,0863	0,1069	0,1074
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000134	0,000254	0,000448	0,000793	0,001513
VR		-0,055497	-0,167204	-0,262724	-0,296371
Variance of VR		0,000644	0,002252	0,005631	0,012468
Std		0,025367	0,047458	0,075038	0,111659
Z-stat		-2,187729	-3,5232	-3,501237	-2,654239
P-value		0,0143*	0,0002*	0,0002*	0,003*
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000184	0,000374	0,000733	0,001451	0,002745
VR		0,01587	-0,004327	-0,01407	-0,067385
Variance of VR		0,000639	0,002235	0,005587	0,012372
Std		0,02527	0,047276	0,074749	0,111231
Z-stat		0,628038	-0,091518	-0,188234	-0,605813
P-value		0,2649	0,4635	0,4253	0,2723
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00033	0,000687	0,001348	0,002588	0,005147
VR		0,040624	0,020604	-0,019993	-0,025394
Variance of VR		0,000644	0,002252	0,005631	0,012468
Std		0,025367	0,047458	0,075038	0,111659
Z-stat		1,601433	0,434146	-0,266443	-0,227425
P-value		0,0546	0,33209	0,3949	0,41004
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00754	0,02698	0,06625	0,147369	0,282516
VR		0,789213	1,196698	1,443205	1,341899
Variance of VR		0,000668	0,00234	0,005849	0,012951
Std		0,025854	0,048369	0,076478	0,113803
Z-stat		30,52532	24,74096	18,87078	11,79139
P-value		0,000*	0,000*	0,000*	0,000*
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000224	0,000493	0,000965	0,00201	0,004271
VR		0,100331	0,075632	0,120868	0,190448
Variance of VR		0,000663	0,002321	0,005802	0,012848
Std		0,025751	0,048176	0,076173	0,11335
Z-stat		3,896152	1,569898	1,586747	1,68018
P-value		0,000*	0,0582	0,0562	0,0464*
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000164	0,00034	0,000683	0,001315	0,002667
VR		0,03816	0,043811	0,005247	0,019195
Variance of VR		0,000639	0,002236	0,005591	0,01238
Std		0,025278	0,047291	0,074773	0,111266
Z-stat		1,509613	0,926407	0,070175	0,172514
P-value		0,0655	0,1771	0,47202	0,4315
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000129	0,000283	0,0006	0,001162	0,002351
VR		0,096053	0,159842	0,123903	0,136361
Variance of VR		0,000664	0,002322	0,005806	0,012857
Std		0,02576	0,048192	0,076199	0,113387
Z-stat		3,72878	3,316753	1,626053	1,202615
P-value		0,000*	0,0004*	0,0519	0,1145

Sub period 3: 2006-01-02 - 2010-03-31					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000286	0,000511	0,000904	0,001685	0,003407
VR		-0,107074	-0,210822	-0,264687	-0,256479
Variance of VR		0,000936	0,003277	0,008193	0,018141
Std		0,0306	0,057246	0,090515	0,13469
Z-stat		-3,499209	-3,682717	-2,924246	-1,904214
P-value		0,0002*	0,0001*	0,0017*	0,0284*
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000266	0,000461	0,000782	0,001421	0,002638
VR		-0,133745	-0,264411	-0,331715	-0,379943
Variance of VR		0,000936	0,003277	0,008193	0,018141
Std		0,0306	0,057246	0,090515	0,13469
Z-stat		-4,370826	-4,618814	-3,664765	-2,820871
P-value		0,000*	0,000*	0,0001*	0,0023*
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000222	0,000384	0,000661	0,00121	0,002404
VR		-0,134475	-0,25501	-0,318439	-0,322873
Variance of VR		0,000936	0,003277	0,008193	0,018141
Std		0,0306	0,057246	0,090515	0,13469
Z-stat		-4,394692	-4,454602	-3,518092	-2,397159
P-value		0,000*	0,000*	0,0002*	0,0082*
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000241	0,000443	0,00075	0,001392	0,002738
VR		-0,082467	-0,222785	-0,278729	-0,290682
Variance of VR		0,000943	0,003302	0,008255	0,018278
Std		0,030715	0,057462	0,090855	0,135197
Z-stat		-2,684916	-3,87708	-3,067826	-2,150061
P-value		0,0036*	0,000*	0,0010*	0,0157*
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000347	0,000658	0,001215	0,002209	0,004354
VR		-0,051336	-0,124734	-0,203906	-0,215543
Variance of VR		0,000951	0,003327	0,008317	0,018417
Std		0,030831	0,05768	0,0912	0,13571
Z-stat		-1,665045	-2,162512	-2,235806	-1,588256
P-value		0,0479*	0,0152*	0,0126*	0,0561
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000477	0,000934	0,00167	0,002885	0,00532
VR		-0,021673	-0,125164	-0,244075	-0,303108
Variance of VR		0,000943	0,003302	0,008255	0,018278
Std		0,030715	0,057462	0,090855	0,135197
Z-stat		-0,705611	-2,178201	-2,686406	-2,241966
P-value		0,2402	0,0147*	0,0036*	0,0124*
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,235829	1,603025	4,379585	42,96152	542,2854
VR		2,398706	3,64276	21,77157	142,718
Variance of VR		0,000951	0,00333	0,008325	0,018435
Std		0,030846	0,057708	0,091244	0,135775
Z-stat		77,76398	63,12449	238,6091	1051,137
P-value		0,000*	0,000*	0,000*	0,000*
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000426	0,000894	0,001785	0,003289	0,007203
VR		0,049884	0,047596	-0,034718	0,056943
Variance of VR		0,000954	0,00334	0,008349	0,018488
Std		0,03089	0,05779	0,091374	0,135969
Z-stat		1,614899	0,8236	-0,37995	0,418792
P-value		0,0531	0,2051	0,3519	0,3376
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000455	0,000917	0,001834	0,003953	0,008615
VR		0,007288	0,007821	0,085958	0,183233
Variance of VR		0,000968	0,003388	0,00847	0,018756
Std		0,031114	0,058208	0,092035	0,136953
Z-stat		0,234252	0,13437	0,933968	1,337927
P-value		0,4073	0,4465	0,1751	0,0904
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000264	0,000545	0,001057	0,001816	0,0033
VR		0,032843	0,002595	-0,138749	-0,217568
Variance of VR		0,000943	0,003299	0,008247	0,018261
Std		0,0307	0,057435	0,090813	0,135134
Z-stat		1,069792	0,045179	-1,527862	-1,610022
P-value		0,1423	0,4819	0,0632	0,0536

Sub period 4: 2010-04-01 - 2019-10-31					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000118	0,000229	0,000443	0,000803	0,00144176
VR		-0,028099	-0,059778	-0,148399	-0,2353758
Variance of VR		0,000414	0,00145	0,003625	0,0080261
Std		0,020353	0,038077	0,060205	0,08958849
Z-stat		-1,380585	-1,56991	-2,464872	-2,6273
P-value		0,0837	0,058218	0,0068*	0,0043*
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	8,81E-05	0,000168	0,000324	0,000576	0,00103208
VR		-0,049101	-0,080878	-0,182442	-0,2681428
Variance of VR		0,000414	0,00145	0,003625	0,0080261
Std		0,020353	0,038077	0,060205	0,08958849
Z-stat		-2,412429	-2,124055	-3,030318	-2,9930493
P-value		0,0079*	0,0168*	0,0012*	0,0013*
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	7,99E-05	0,000153	0,000299	0,00054	0,00100322
VR		-0,044393	-0,065576	-0,154993	-0,2156428
Variance of VR		0,000414	0,00145	0,003625	0,0080261
Std		0,020353	0,038077	0,060205	0,08958849
Z-stat		-2,181152	-1,722181	-2,574397	-2,4070368
P-value		0,0145*	0,0425*	0,005*	0,0080*
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	8,26E-05	0,000169	0,000402	0,000595	0,00101902
VR		0,025521	0,217942	-0,098884	-0,2289726
Variance of VR		0,00042	0,001469	0,003673	0,00813392
Std		0,020489	0,038332	0,060608	0,09018825
Z-stat		1,245568	5,685609	-1,631518	-2,5388291
P-value		0,1064	0,000*	0,0513	0,00556*
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000171	0,000329	0,000654	0,001241	0,00239158
VR		-0,038974	-0,045244	-0,093237	-0,1265184
Variance of VR		0,000422	0,001478	0,003695	0,00818201
Std		0,02055	0,038445	0,060787	0,09045446
Z-stat		-1,89654	-1,176839	-1,533827	-1,3986975
P-value		0,0289*	0,1196	0,0625	0,0809
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,0002	0,000442	0,000883	0,001727	0,00363899
VR		0,105062	0,103892	0,079184	0,13730577
Variance of VR		0,00042	0,001469	0,003673	0,00813392
Std		0,020489	0,038332	0,060608	0,09018825
Z-stat		5,127648	2,710298	1,306488	1,52243522
P-value		0,000*	0,0033*	0,0956	0,0639
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	2,403797	120,2145	135569,1	41249360	5296734611
VR		24,00512	14098,48	2145010	137717931
Variance of VR		0,000415	0,001451	0,003628	0,00803275
Std		0,020362	0,038093	0,06023	0,08962563
Z-stat		1178,942	370106,6	35613439	1536591004
P-value		0,000*	0,000*	0,000*	0,000*
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	9,33E-05	0,000199	0,000403	0,00077	0,0014916
VR		0,066105	0,079776	0,032419	-0,0006715
Variance of VR		0,000414	0,00145	0,003625	0,0080261
Std		0,020353	0,038077	0,060205	0,08958849
Z-stat		3,247882	2,095104	0,538465	-0,0074951
P-value		0,0005*	0,0180*	0,2951	0,4971
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000189	0,000391	0,00078	0,001617	0,00346442
VR		0,03616	0,033297	0,070783	0,14694902
Variance of VR		0,000429	0,001503	0,003757	0,00831902
Std		0,020721	0,038766	0,061294	0,09120867
Z-stat		1,74509	0,858913	1,154804	1,61112995
P-value		0,0404*	0,1951	0,1241	0,0535
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	9,13E-05	0,00018	0,000341	0,000624	0,00109653
VR		-0,016528	-0,066477	-0,145736	-0,2494414
Variance of VR		0,000418	0,001461	0,003653	0,00808977
Std		0,020434	0,038228	0,060444	0,08994315
Z-stat		-0,808865	-1,738973	-2,411106	-2,7733228
P-value		0,2092	0,0410*	0,0079*	0,0027*

Sub period 5: 2019-11-01 - 2021-12-30					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000296	0,000417	0,0009	0,001758	0,003747
VR		-0,295991	-0,241266	-0,258793	-0,209969
Variance of VR		0,001832	0,00641	0,016026	0,035485
Std		0,042796	0,080064	0,126592	0,188376
Z-stat		-6,916314	-3,013408	-2,044302	-1,114632
P-value		0,000*	0,001*	0,020*	0,1325
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000253	0,00035	0,00078	0,001493	0,003239
VR		-0,30877	-0,230167	-0,263432	-0,201077
Variance of VR		0,001832	0,00641	0,016026	0,035485
Std		0,042796	0,080064	0,126592	0,188376
Z-stat		-7,214908	-2,874781	-2,080948	-1,067427
P-value		0,000*	0,0020*	0,0187*	0,1428
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000282	0,000408	0,000924	0,001762	0,00365
VR		-0,274951	-0,179169	-0,217428	-0,18953
Variance of VR		0,001832	0,00641	0,016026	0,035485
Std		0,042796	0,080064	0,126592	0,188376
Z-stat		-6,424671	-2,237817	-1,717543	-1,006126
P-value		0,000*	0,0126*	0,0429*	0,1571
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000197	0,000382	0,000758	0,001574	0,003112
VR		-0,02866	-0,037363	-0,000119	-0,011614
Variance of VR		0,001876	0,006567	0,016417	0,036351
Std		0,043315	0,081035	0,128127	0,190659
Z-stat		-0,661678	-0,461076	-0,00093	-0,060913
P-value		0,2541	0,3223	0,4996	0,4757
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000189	0,000393	0,000857	0,001676	0,003392
VR		0,036676	0,131417	0,106778	0,119782
Variance of VR		0,001894	0,006629	0,016572	0,036695
Std		0,043519	0,081417	0,128732	0,19156
Z-stat		0,842742	1,614111	0,829457	0,625298
P-value		0,1996	0,0532	0,2034	0,26588
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000466	0,000704	0,001485	0,003111	0,007371
VR		-0,245292	-0,20399	-0,166178	-0,012175
Variance of VR		0,001876	0,006567	0,016417	0,036351
Std		0,043315	0,081035	0,128127	0,190659
Z-stat		-5,663014	-2,517325	-1,296978	-0,06386
P-value		0,000*	0,0059*	0,0973	0,4745
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000177	0,000349	0,000745	0,00171	0,003572
VR		-0,015606	0,05262	0,207588	0,261204
Variance of VR		0,001835	0,006422	0,016055	0,03555
Std		0,042835	0,080137	0,126709	0,188548
Z-stat		-0,364337	0,656616	1,63831	1,385341
P-value		0,3578	0,2557	0,0506	0,0829
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000249	0,000457	0,000905	0,002015	0,004471
VR		-0,081533	-0,09176	0,011595	0,12234
Variance of VR		0,002004	0,007014	0,017535	0,038828
Std		0,044766	0,08375	0,13242	0,197047
Z-stat		-1,821308	-1,095649	0,087559	0,620865
P-value		0,0342*	0,1366	0,4651	0,2673
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000119	0,000244	0,000518	0,000955	0,001552
VR		0,029095	0,091427	0,006302	-0,182604
Variance of VR		0,00189	0,006616	0,016541	0,036626
Std		0,043478	0,08134	0,12861	0,191378
Z-stat		0,669196	1,124	0,049	-0,954149
P-value		0,251685	0,130507	0,480459	0,170004
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000222	0,000398	0,00089	0,001906	0,003862
VR		-0,104017	0,001177	0,071282	0,085569
Variance of VR		0,001845	0,006458	0,016144	0,035747
Std		0,042954	0,080359	0,127059	0,189069
Z-stat		-2,4216	0,014648	0,561016	0,452582
P-value		0,0077*	0,4941	0,2873	0,3254

Sub period 6: 2022-01-03 - 2023-06-16					
US (NASQ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000327	0,000653	0,001197	0,002177	0,004348
VR		-0,002772	-0,085612	-0,168932	-0,169957
Variance of VR		0,002747	0,009615	0,024038	0,053228
Std		0,052414	0,098058	0,155043	0,230712
Z-stat		-0,052889	-0,873075	-1,089579	-0,736664
P-value		0,4789	0,1913	0,1379	0,2306
US (S&P)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000187	0,000378	0,0007	0,001288	0,002438
VR		0,008399	-0,06584	-0,140046	-0,186224
Variance of VR		0,002747	0,009615	0,024038	0,053228
Std		0,052414	0,098058	0,155043	0,230712
Z-stat		0,16024	-0,671441	-0,90327	-0,807171
P-value		0,4363	0,2509	0,1831	0,2097
US (DJ)					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000128	0,00026	0,000495	0,000972	0,001956
VR		0,013983	-0,032976	-0,05044	-0,045117
Variance of VR		0,002732	0,009563	0,023907	0,052937
Std		0,052271	0,09779	0,154619	0,230081
Z-stat		0,267502	-0,337211	-0,326221	-0,196093
P-value		0,3945	0,3679	0,3721	0,4222
UK					
k	**1**	**2**	**4**	**8**	**16**
Variance	8,99E-05	0,00017	0,000291	0,000535	0,001012
VR		-0,053097	-0,191592	-0,256476	-0,296573
Variance of VR		0,002747	0,009615	0,024038	0,053228
Std		0,052414	0,098058	0,155043	0,230712
Z-stat		-1,013028	-1,953861	-1,65422	-1,285468
P-value		0,1555	0,0253*	0,0490*	0,0993
Japan					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00014	0,000283	0,000579	0,001115	0,001906
VR		0,01168	0,034306	-0,004391	-0,149085
Variance of VR		0,002809	0,009831	0,024579	0,054424
Std		0,053	0,099154	0,156776	0,23329
Z-stat		0,220381	0,345984	-0,028005	-0,639055
P-value		0,412787	0,364677	0,488829	0,261394
Brazil					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000168	0,000369	0,000736	0,001459	0,003065
VR		0,096485	0,095096	0,085016	0,139462
Variance of VR		0,002747	0,009615	0,024038	0,053228
Std		0,052414	0,098058	0,155043	0,230712
Z-stat		1,84082	0,969792	0,548337	0,604485
P-value		0,0328*	0,166	0,2917	0,2727
Russia					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000736	0,001356	0,00253	0,005163	0,009355
VR		-0,078447	-0,140404	-0,122754	-0,20524
Variance of VR		0,002208	0,007726	0,019316	0,04277
Std		0,046984	0,087899	0,138981	0,20681
Z-stat		-1,669657	-1,597334	-0,883246	-0,992408
P-value		0,0474*	0,0551	0,1885	0,1604
India					
k	**1**	**2**	**4**	**8**	**16**
Variance	9,42E-05	0,000191	0,000382	0,000781	0,001572
VR		0,013193	0,014528	0,036644	0,042822
Variance of VR		0,00277	0,009695	0,024238	0,05367
Std		0,052632	0,098465	0,155686	0,231669
Z-stat		0,250664	0,147548	0,235372	0,184842
P-value		0,4011	0,4413	0,4069	0,4266
China					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,000104	0,000208	0,000402	0,000706	0,001359
VR		-0,000877	-0,035367	-0,154087	-0,185469
Variance of VR		0,002841	0,009943	0,024858	0,055043
Std		0,0533	0,099716	0,157664	0,234612
Z-stat		-0,016459	-0,354676	-0,977313	-0,790535
P-value		0,4934	0,3614	0,1642	0,2141
South Africa					
k	**1**	**2**	**4**	**8**	**16**
Variance	0,00015	0,000318	0,000566	0,000962	0,001851
VR		0,061558	-0,055525	-0,19794	-0,228077
Variance of VR		0,002747	0,009615	0,024038	0,053228
Std		0,052414	0,098058	0,155043	0,230712
Z-stat		1,17445	-0,566248	-1,276672	-0,988577
P-value		0,1201	0,2856	0,1008	0,1614

* significant at 5%

4.5 Results of Runs test

The Runs test is used to analyse the presence of trends and is used to assess the independence between successive price changes. Table 6 shows the results for every period; if the Z-statistic is significant, the null hypothesis is rejected and concludes the presence of a positive correlation, which implies violation of random walk. In sub-period one, the null hypothesis is rejected for most of Russia, India, China, South Africa, and one US market. In contrast, Brazil, Japan, the UK, and two US markets show insignificant Z-statistics. In sub-period two, the BRICS markets continue to show significant negative Z-statistics, and Japan shows similar values as well. The UK and US markets present significant and positive Z-statistics. In sub-period three, only Russia and the US reject the null hypothesis, which coincides with the serial correlation, whilst the other markets accept the null hypothesis. There are no significant Z-statistics in sub-period four. In sub-period five, only Brazil, UK and US have significant Z-statistics, and all markets (except India) have experienced an improvement. In sub-period six, only Brazil and India reject the null hypothesis, meaning the other markets are following a random path. However, the AC for Brazil and India suggest they also follow a random walk. This suggests the markets are weak-form efficient.

A study by Ahmad, Ashraf and Ahmed (2006) used a random walk test to determine if four Indian stock markets (1999-2004) were weak-form efficient, and two of the markets were found to follow a random walk whilst the other two did not. This contradicts our results for Indian NSEI shows a random walk is evident in sub period 1,2,4,5, and 6. In addition a study by Ryaly, Kumar and Urlankula (2014) used the Runs test for five Asian marks and India was one of them and found that India market follows a random which support this study's findings.

The Runs test for these markets predominantly suggests that the successive changes in the prices of each period are not random, meaning they are following a strong EMH, and if yesterday's stock price decreased, it was dependent on the previous price. This result contradicts the variance ratio test and suggests the BRICS markets are market inefficient. What is interesting to see that the runs for most periods are close to each other, meaning there was not significant continuous growth or decline of prices. But we know stock prices fluctuate and are usually not too predictable but generally do not change drastically from day to

day.

Table 6: Results of Runs test

Market	Total case	Cases<Mean	Actual Runs	Z-Statistic
Full period: 1995-01-16 - 2023-06-16				
BRICS				
Brazil	7186	3573	3572	-0.5191
Russia	6524	3262	3233	-0.7429**
India	6866	3433	3190	-5.8898***
China	6458	3229	3155	-1.8667*
South Africa	7010	3505	3378	-3.0578***
Benchmark				
Japan	7162	3581	3606	0.5672
UK	7186	3593	3624	0.7078
US (NASQ)	7152	3576	3595	0.4257
US (S&P)	7152	3576	3753	4.1625**
US (DJ)	7154	3577	3717	3.2870**
Sub period 1: 1995-01-16 - 1999-12-31				
BRICS				
Brazil	1294	647	614	-1.8911**
Russia	568	284	234	-4.2836***
India	1036	518	448	-4.4139***
China	650	325	293	-2.5907***
South Africa	1142	571	508	-3.7894***
Benchmark				
Japan	1292	646	662	0.8349
UK	1294	647	632	-0.8899
US (NASQ)	1252	626	581	-2.6011**
US (S&P)	1252	626	633	0.3392
US (DJ)	1252	626	618	-0.5089
Sub period 2: 2000-01-03 - 2005-12-31				
BRICS				
Brazil	1552	776	768	-0.4570
Russia	1494	747	694	-2.7951*
India	1506	753	687	-3.4541***
China	1564	782	724	-2.9847***
South Africa	1506	753	697	-2.9386***
Benchmark				

Japan	1564	782	743	-2.0235**
UK	1552	776	804	1.3712
US (NASQ)	1506	753	755	0.0516
US (S&P)	1506	753	821	3.4541**
US (DJ)	1506	753	805	2.6293**
Sub period 3: 2006-01-02 - 2010-03-31				
BRICS				
Brazil	1058	529	519	-0.6767
Russia	1050	525	585	3.6433***
India	1046	523	512	-0.7424
China	1032	516	512	-0.3114
South Africa	1060	530	530	-0.0614
Benchmark				
Japan	1050	525	548	1.3585
UK	1058	529	556	1.5994
US (NASQ)	1066	533	554	1.2257
US (S&P)	1066	533	600	4.0448**
US (DJ)	1066	533	578	2.6965**
Sub period 4: 2010-04-01 - 2019-10-31				
BRICS				
Brazil	2380	1190	1202	0.4510
Russia	2410	1205	1244	1.5484
India	2412	1206	1160	-1.9144*
China	2328	1164	1154	-0.4560
South Africa	2394	1197	1197	-0.0409
Benchmark				
Japan	2366	1183	1213	1.1926
UK	2380	1190	1163	-1.1481
US (NASQ)	2412	1206	1242	1.4256
US (S&P)	2412	1206	1244	1.5071
US (DJ)	2412	1206	1237	1.2219
Sub period 5: 2019-11-01 - 2021-12-30				
BRICS				
Brazil	532	266	309	3.6450***
Russia	544	272	273	0.1000
India	498	249	229	-1.884*
China	528	264	283	1.5680
South Africa	540	270	284	1.1200
Benchmark				

Japan	526	263	278	1.2220
UK	532	266	298	2.6910**
US (NASQ)	544	272	296	1.9740**
US (S&P)	544	272	292	1.6310
US (DJ)	544	272	300	2.3170**
Sub period 6: 2022-01-03 - 2023-06-16				
BRICS				
Brazil	362	181	157	-2.6316**
Russia	452	226	212	-1.4126
India	360	180	153	-2.9556***
China	350	175	178	0.21412
South Africa	362	181	182	0.2000
Benchmark				
Japan	354	177	170	-0.8516
UK	362	181	184	0.2105
US (NASQ)	362	181	180	-0.2105
US (S&P)	362	181	179	-0.3158
US (DJ)	364	182	180	-0.3150

* significant at 10%, ** significant at 5%, *** significant at 1%

4.6 Results of Cox-Stuart test

Another test for detecting trends in ordered data is the Cox-Stuart test. Table 7 shows the one-tail and two-tail tests on all the periods and markets. Almost all the markets and periods suggest the data has a positive monotonic trend. If the right side (RS) or left side (LS) have significant values, it indicates a negative monotonic trend (such as India, South Africa and the UK) in sub-period two. If the TS have significant values, it indicates the null hypothesis is rejected, and the market is weak-form inefficient; this is not seen much in the results, which indicates the markets are weak-form efficient in other words there is randomness within the BRICS markets. This test is better non-parametric method and matches with the variance test proving the BRICS markets follow a weak EMH and are market efficient.

Table 7: Results of Cox-Stuart test

	RS		**TS**		**LS**	
Market	**Z-Statistic**	**P-value**	**Z-Statistic**	**P-value**	**Z-Statistic**	**P-value**
			Full period: 1995-01-16 - 2023-06-16			
BRICS						

Brazil	1751	0.9376	1751	0.1332*	1751	0.0666
Russia	1555	0.9963	1555	0.0081***	1555	0.0040***
India	1725	0.3924	1725	0.7848	1725	0.6207
China	1604	0.6507	1604	0.7249	1604	0.3624
South Africa	1729	0.7912	1729	0.4372	1729	0.2186
Benchmark						
Japan	1818	0.1834	1818	0.3669	1818	0.8253
UK	1797	0.5	1797	1	1797	0.5133
US (NASQ)	1827	0.0989	1827	0.1979	1827	0.9068
US (S&P)	1838	0.0489**	1838	0.0978	1838	0.9544
US (DJ)	1832	0.0752	1832	0.1504	1832	0.9294
Sub period 1: 1995-01-16 - 1999-12-31						
BRICS						
Brazil	327	0.4068	327	0.8135	327	0.6234
Russia	163	0.0074***	163	0.0148**	163	0.9947
India	285	0.0124**	285	0.0249**	285	0.9901
China	154	0.841	154	0.3748	154	0.1874
South Africa	287	0.4667	287	0.9333	287	0.5665
Benchmark						
Japan	329	0.3326	329	0.6652	329	0.6955
UK	318	0.6814	318	0.6942	318	0.3471
US (NASQ)	334	0.0506	334	0.1012	334	0.9572
US (S&P)	308	0.6699	308	0.7191	308	0.3595
US (DJ)	301	0.8412	301	0.3580	301	0.1790
Sub period 2: 2000-01-03 - 2005-12-31						
BRICS						
Brazil	407	0.0920*	407	0.1841	407	0.9193
Russia	377	0.4131	377	0.8263	377	0.6151
India	407	0.0143**	407	0.0287**	407	0.9881
China	360	0.9879	360	0.0290**	360	0.0145**
South Africa	410	0.0080***	410	0.0161**	410	0.9934
Benchmark						
Japan	329	0.3326	329	0.6652	329	0.6955
UK	419	0.0142**	419	0.0284**	419	0.9882
US (NASQ)	391	0.1538	391	0.3075	391	0.8629
US (S&P)	398	0.0629	398	0.1258	398	0.9456
US (DJ)	390	0.1717	390	0.3434	390	0.8462
Sub period 3: 2006-01-02 - 2010-03-31						
BRICS						
Brazil	256	0.7831	256	0.4867	256	0.2433

Russia	263	0.5**	263	1	263	0.5348*
India	249	0.8722	249	0.294	249	0.147
China	220	0.9997	220	0.000***	220	0.000***
South Africa	271	0.3164	271	0.6328	271	0.7138
Benchmark						
Japan	278	0.0951	278	0.1904	278	0.9188
UK	269	0.364	269	0.728	269	0.6681
US (NASQ)	259	0.7558	259	0.5443	259	0.2721
US (S&P)	254	0.87	254	0.2985	254	0.1493
US (DJ)	259	0.7558	259	0.5443	259	0.2721
Sub period 4: 2010-04-01 - 2019-10-31						
BRICS						
Brazil	619	0.0865*	619	0.173	619	0.9223
Russia	598	0.6133	598	0.8177	598	0.4089
India	592	0.7461	592	0.5454	592	0.2727
China	602	0.1265	602	0.253	602	0.8853
South Africa	588	0.7376	588	0.5632	588	0.2816
Benchmark						
Japan	578	0.7922	578	0.4497	578	0.2249
UK	588	0.6576	588	0.7278	588	0.3639
US (NASQ)	623	0.1307	623	0.2614	623	0.8811
US (S&P)	616	0.2358	616	0.4716	616	0.7816
US (DJ)	627	0.0879	627	0.1759	627	0.9209
Sub period 5: 2019-11-01 - 2021-12-30						
BRICS						
Brazil	129	0.7094	129	0.6679	129	0.3339
Russia	138	0.4279	138	0.8557	138	0.6191
India	118	0.8125	118	0.447	118	0.2235
China	129	0.6667	129	0.7584	129	0.3792
South Africa	148	0.064*	148	0.128	148	0.9499
Benchmark						
Japan	122	0.8913	122	0.267	122	0.1335
UK	133	0.5244	133	1.049	133	0.5244
US (NASQ)	131	0.7476	131	0.5853	131	0.2927
US (S&P)	130	0.7847	130	0.5049	130	0.2524
US (DJ)	129	0.8184	129	0.4306	129	0.2153
Sub period 6: 2022-01-03 - 2023-06-16						
BRICS						
Brazil	97	0.1862	97	0.3725	97	0.851

Russia	124	0.0811*	124	0.1623	124	0.9371
India	95	0.2512	95	0.5024	95	0.7938
China	86	0.6188	86	0.8799	86	0.4399
South Africa	90	0.5591	90	1	90	0.5
Benchmark						
Japan	93	0.2739	93	0.5478	93	0.7738
UK	86	0.7713	86	0.5522	86	0.2761
US (NASQ)	96	0.2287	96	0.4574	96	0.8138
US (S&P)	94	0.3279	94	0.6557	94	0.7239
US (DJ)	102	0.0596	102	0.1193	102	0.9560

* significant at 10%, ** significant at 5%, *** significant at 1%

4.7 Results of Bartels test

The Bartels test is used to analyse the correlation between the data values and their respective time indices, measuring the strength and direction of any linear trend present in the series. Table 8 shows the results of the Bartels test, which examines the LS and RS, and most markets indicate the LS to have significant Z-statistic, which means the null hypothesis is accepted and the market is weak-form efficient.

Table 8: Results of Bartels Test

	LS		**RS**	
Market	**Z-Statistic**	**P-value**	**Z-Statistic**	**P-value**
Full period: 1995-01-16 - 2023-06-16				
BRICS				
Brazil	-1.4513	0.073*	-1.4513	0.9267
Russia	-0.3798	0.352	-0.3798	0.648
India	-7.292	0.00***	-7.292	1
China	-2.1686	0.015**	-2.1686	0.9849
South Africa	-4.5323	0.000***	-4.5323	1
Benchmark				
Japan	1.2087	0.8866	1.2087	0.1134
UK	1.1284	0.8704	1.1284	0.1296
US (NASQ)	0.3345	0.631	0.3345	0.369
US (S&P)	3.5243	0.9998	3.5243	0.000***
US (DJ)	3.01	0.9987	3.01	0.001***
Sub period 1: 1995-01-16 - 1999-12-31				
BRICS				

Brazil	-3.1513	0.0008***	-3.1513	0.9992
Russia	-5.1034	0.000****	-5.1034	1
India	-3.4893	0.0002**	-3.4893	0.9998
China	-1.0551	0.1457	-1.0551	0.8543
South Africa	-5.9862	0.000**	-5.9862	1
Benchmark				
Japan	1.2487	0.8941	1.2487	0.1059
UK	-2.7254	0.0032**	-2.7254	0.9968
US (NASQ)	-3.3837	0.0004**	-3.3837	0.9996
US (S&P)	-1.3386	0.0903	-1.3386	0.9097
US (DJ)	-1.8823	0.0299**	-1.8823	0.9701
Sub period 2: 2000-01-03 - 2005-12-31				
BRICS				
Brazil	-1.1804	0.1189	-1.1804	0.8811
Russia	-3.688	0.000***	-3.688	0.9999
India	-4.421	0.000***	-4.421	1
China	-1.5985	0.05496	-1.5985	0.945
South Africa	-4.7052	0.000***	-4.7052	1
Benchmark				
Japan	-1.5423	0.062	-1.5422	0.9385
UK	1.9002	0.971	1.9002	0.0287**
US (NASQ)	-0.2945	0.384	-0.2939	0.6156
US (S&P)	1.778	0.962	1.778	0.038**
US (DJ)	2.0511	0.980	2.0511	0.020**
Sub period 3: 2006-01-02 - 2010-03-31				
BRICS				
Brazil	0.0499	0.5199	0.04989	0.4801
Russia	2.9789	0.9986	2.9789	0.0014***
India	-1.3768	0.08429*	-1.3768	0.9157
China	-0.7973	0.2126	-0.7973	0.7874
South Africa	-0.7036	0.2408	-0.70364	0.7592
Benchmark				
Japan	1.685	0.954	1.685	0.0459**
UK	2.0732	0.9809	2.0732	0.0191**
US (NASQ)	1.6238	0.9478	1.6238	0.0522
US (S&P)	3.5751	0.9998	3.5751	0.0002**
US (DJ)	3.3087	0.9995	3.3087	0.0005**
Sub period 4: 2010-04-01 - 2019-10-31				
BRICS	0.4179	0.662	0.4179	0.338

Brazil	0.4179	0.662	0.4179	0.338
Russia	4.818	1	4.818	0.000***
India	-3.6131	0.0015***	-3.6131	0.9998
China	-0.6352	0.2627	-0.6352	0.7373
South Africa	0.4755	0.6828	0.4755	0.3172
Benchmark				
Japan	1.1555	0.876	1.1555	0.124
UK	-0.5276	0.2989	-0.5276	0.7011
US (NASQ)	1.0144	0.8448	1.0144	0.1552
US (S&P)	1.9249	0.9729	1.9249	0.027**
US (DJ)	1.5973	0.9449	1.5973	0.0551
Sub period 5: 2019-11-01 - 2021-12-30				
BRICS				
Brazil	3.9885	1	3.9885	0.000***
Russia	0.5060	0.6936	0.5060	0.3064
India	-1.8512	0.0320**	-1.8512	0.9679
China	0.8119	0.7916	0.8119	0.2084
South Africa	0.5522	0.7096	0.5522	0.2904
Benchmark				
Japan	0.5119	0.6957	0.5119	0.3043
UK	2.0484	0.9797	2.0484	0.0202**
US (NASQ)	3.2757	0.9995	3.2757	0.0005***
US (S&P)	3.0084	0.9987	3.0084	0.0012***
US (DJ)	2.3951	0.9917	2.3952	0.008***
Sub period 6: 2022-01-03 - 2023-06-16				
BRICS				
Brazil	-2.0713	0.0191**	-2.0713	0.9808
Russia	-2.6754	0.0037***	-2.6754	0.9963
India	-1.8612	0.0313**	-1.8612	0.9686
China	0.3799	0.648	0.37998	0.352
South Africa	-1.2044	0.1142	-1.2044	0.8858
Benchmark				
Japan	-0.2846	0.388	-0.2846	0.612
UK	0.3813	0.648	0.3813	0.351
US (NASQ)	-0.3160	0.376	-0.3160	0.624
US (S&P)	-0.4883	0.313	-0.4883	0.687
US (DJ)	-0.6989	0.242	-0.6989	0.757

* significant at 10%, ** significant at 5%, *** significant at 1%

4.8 Results of difference and rank test

The difference test is used to analyse whether the median of a paired sample is significantly different from a hypothesised median. In addition, the Mann-Kendall rank test is used to analyse trends in time series data. Table 9 shows the results of difference and rank test. For the difference test, if the value is significant, the null hypothesis is accepted, which means the market is weak-form efficient, which seems to be the case for quite a few markets in different periods. For the rank test, if the value is significant, the null hypothesis is accepted, which indicate the market has no trend in the series. However, the majority of markets and periods suggest that the alternative hypothesis is accepted suggesting there is a trend in the series.

Table 9: Results of difference and rank test

	Difference		Rank	
Market	**Z-Statistic**	**P-value**	**Z-Statistic**	**P-value**
Full period: 1995-01-16 - 2023-06-16				
BRICS				
Brazil	-5.2510	0.000***	-1.2273	0.2197
Russia	-3.5168	0.000***	-2.132	0.0330**
India	-5.4758	0.000***	0.4613	0.6445
China	-6.8308	0.000***	0.1437	0.8857
South Africa	-2.7508	0.005***	-0.7943	0.4271
Benchmark				
Japan	-6.5274	0.000**	2.0081	0.0446**
UK	-3.9711	0.000**	-0.3133	0.7541
US (NASQ)	4.9758	0.000**	0.0855	0.9318
US (S&P)	5.3444	0.000**	0.3689	0.7122
US (DJ)	-5.7940	0.000**	-0.0755	0.9398
Sub period 1: 1995-01-16 - 1999-12-31				
BRICS				
Brazil	-3.2717	0.001***	0.7983	0.4246
Russia	0.21822	0.8273	1.517	0.1293
India	1.6128	0.1068	1.4481	0.1476
China	-2.9146	0.003***	-1.9302	0.0535*
South Africa	-0.9217	0.3567	0.7387	0.4601
Benchmark				
Japan	-3.8986	0.000**	0.5856	0.5581
UK	-1.9245	0.0542	-0.4186	0.6755

US (NASQ)	-2.3957	0.0165**	2.0267	0.0426**
US (S&P)	0.2444	0.8069	-0.2927	0.7698
US (DJ)	-2.4935	0.0126**	-0.5576	0.5771
Sub period 2: 2000-01-03 - 2005-12-31				
BRICS				
Brazil	-3.6456	0.0002***	2.0221	0.0431**
Russia	-1.2087	0.2268	0.6195	0.5356
India	-3.9683	0.000***	2.8225	0.0047***
China	-4.5521	0.000***	-3.2706	0.0010***
South Africa	1.6949	0.090	1.8459	0.0649
Benchmark				
Japan	-3.8942	0.000**	2.9481	0.0032**
UK	-0.2196	0.8262	1.8679	0.0618
US (NASQ)	-2.1848	0.0289**	1.5185	0.1289
US (S&P)	-3.1657	0.0015**	1.4431	0.1491
US (DJ)	-2.8982	0.0037**	0.5860	0.5579
Sub period 3: 2006-01-02 - 2010-03-31				
BRICS				
Brazil	-1.0103	0.3123	-0.0387	0.9691
Russia	-3.0973	0.002***	-0.7622	0.4459
India	-2.8343	0.005***	-1.0228	0.3064
China	-2.6932	0.007***	-1.8488	0.0644
South Africa	-1.1693	0.2423	0.9884	0.3231
Benchmark				
Japan	-3.3627	0.0007**	0.3344	0.7381
UK	-0.3195	0.7493	0.4196	0.6748
US (NASQ)	-2.0661	0.0388**	0.9944	0.3201
US (S&P)	-3.4434	0.0005**	0.9505	0.3418
US (DJ)	-3.4434	0.0005**	0.3161	0.7519
Sub period 4: 2010-04-01 - 2019-10-31				
BRICS				
Brazil	-1.0999	0.2714	2.0528	0.0400**
Russia	-2.5035	0.0123*	0.1245	0.9009
India	0.5347	0.5928	0.5347	0.5928
China	-3.3012	0.000***	0.8414	0.4001
South Africa	-2.9016	0.003***	-0.9038	0.3661
Benchmark				
Japan	-2.3843	0.0171**	0.2991	0.7649
UK	-3.9915	0.000**	-0.6563	0.5116

US (NASQ)	-3.1368	0.0017**	0.2789	0.7803
US (S&P)	-4.1942	0.000**	0.0830	0.9338
US (DJ)	-2.8907	0.0038**	0.5759	0.5647
Sub period 5: 2019-11-01 - 2021-12-30				
BRICS				
Brazil	-2.6983	0.0069***	-1.0855	0.2777
Russia	-0.7413	0.4585	-0.3575	0.7207
India	-2.1689	0.0300**	-0.3388	0.7347
China	-1.3542	0.1757	-0.3358	0.7370
South Africa	-2.4529	0.0140**	0.3714	0.7103
Benchmark				
Japan	-1.1296	0.2586	0.0532	0.9575
UK	-0.22549	0.8216	0.4116	0.6806
US (NASQ)	-1.1109	0.2666	-1.1750	0.24
US (S&P)	-0.66651	0.5051	-0.4978	0.6186
US (DJ)	-2.8907	0.0038**	0.5759	0.5647
Sub period 6: 2022-01-03 - 2023-06-16				
BRICS				
Brazil	-1.1786	0.2386	0.1008	0.9197
Russia	0.32516	0.7451	1.6319	0.1027
India	-2.0028	0.045**	0.5128	0.6081
China	-0.0922	0.9265	0.3182	0.7503
South Africa	-1.1786	0.2386	0.6099	0.5419
Benchmark				
Japan	0.45835	0.6467	2.0503	0.0403**
UK	-1.9091	0.0562	0.5433	0.5869
US (NASQ)	0.0907	0.9278	1.9017	0.0572
US (S&P)	0.2719	0.7856	1.4878	0.1368
US (DJ)	-0.2712	0.7862	1.0158	0.3097

* significant at 10%, ** significant at 5%, *** significant at 1%

4.9 Summary

This chapter began with an analysis of the source data from the selected markets, featuring graphical representations of stock market returns over the entire period and emphasised descriptive statistics. Subsequently, the chapter delved into the examination of commonly used tests to assess the EMH, followed by additional tests. It is important to note that each test was applied across the full period of each market and then applied to six sub-periods. Throughout this analysis,

various patterns and trends related to the EMH, as well as factors pertaining to developed and emerging economies and significant economic events, were identified. These findings are crucial as they directly contribute to the comprehensive purpose of this study. The following chapter concludes the research by examining the rationale, outcomes, limitations, opportunities, and contributions and recommendations.

Chapter 5

Conclusion

5.1 Introduction

The final chapter of this mini-thesis examines the study's problem statement, evaluates the study's outcomes concerning the tested hypotheses, and provides a summary of findings. Following this is the limitations for this study will be explained. Finally, the contributions of the study and recommendations will be discussed.

5.2 Rational and Objectives of the Study

This study aimed to determine if the BRICS economies are weak-form efficient according to the EMH. The motivation behind this study was to evaluate the type of EMH and the profitability of the BRICS stock markets, should they be deemed weak-form efficient.

The study aimed to achieve several objectives, yielding intriguing results. Firstly, it investigated the type of EMH prevalent in the selected economies, leading to insightful comparisons. A summary of the findings: The autocorrelation and hypothesis concluded that most of the BRICS markets are weak-form EMH. The variance ratio test showed some interesting patterns such as the developed markets follow a trend and are market inefficient which are strong-form EMH whilst the Brazil, India, China and South Africa countries followed a random walk and are proven market efficient which are weak-form EMH. The Runs test was used to see trend analysis and if autocorrelation was present it is a violation of the random walk this contradicts the other results and suggest BRICS successive price changes are not random and thus are strong-form EMH and evidence that there was not significant continuous growth or decline of share prices. The Cox-Stuart test proved mainly positive monotonic trend which indicates weak-form EMH. The Bartels test also proved BRICS markets are weak-form EMH. Finally, the difference and rank test identified weak-form EMH for a few markets in different periods and the rank test suggested a trend in the series. Overall, from all these tests, it can be concluded that BRICS markets are weak-form EMH based on the investigation.

Secondly, it evaluated the potential impact of EMH on informed decision-making

and the maximisation of investment returns within these economies, shedding light on the efficiency of market mechanisms. Based on the main findings suggesting BRICS are weak-form EMH, current and future investors can use the findings to future invest in these emerging economies and maximise their investment returns. Since the study used developed economies as benchmarks the results suggest they are strong-form EMH meaning past share prices (public knowledge) and other private information cannot be used to predict future positive or negative growth of share prices. Thus, it will be more beneficial with a bit of risk to invest in the emerging economies to improve those countries economic growth.

Lastly, the study assessed whether global crises exerted discernible effects on these economies, offering valuable commentary on their resilience and susceptibility to external economic shocks. The study used a large sample of data that captured a few economic events that varied from financial crises, COVID-19 and the current Ukraine war. The asset share prices for those specific markets did show evidence of shocks to the markets. The results showed that developed economies and more impacted by these economic events and are more negatively impacted compared to the emerging economies. The results for each test and sub-period were discussed and linked to certain economic events.

When comparing the results to existing literature some of it matches the findings of other scholars. For instance, the variance and run test done by Mobarek and Fiorante (2014) have the same conclusion as this study. Emerging economies tend to be weak-form and often get over looked when it comes to portfolio investments because of risk diversification. This study has done eight empirical methodologies all to test linear and non-linear dependencies.

Therefore, all the objectives of this study were researched and suggested favourable results with insightful information on market efficiency.

5.3 Limitations of the Study

This study exhibits two constraints, with the primary constraint being the duration and scope of the observation period. Despite the large size of the data, it would have been advantageous to include a greater number of markets for comparative analysis. The report did not examine any particular industries that are thriving,

which would have provided investors with more valuable insights.

The secondary constraint being the fact that the testing carried out in the EMH literature has primarily concentrated on market efficiency in weak-form scenarios. Markets are subject to the influence of various types of information, and it is imperative for future research to ascertain if certain markets demonstrate other forms of efficiency. "The existing testing methodologies lack the necessary level of sophistication to effectively evaluate strong form efficiency, whereas the assessment of semi-strong efficiency is a very recent development" (Degutis & Novicktye, 2014).

5.4 Contributions and recommendations of the Study

The study aims to contribute to the existing body of literature on market efficiency by addressing the limited attention given to BRICS nations in previous research. While numerous studies have explored market efficiency in developed nations, such as the US, conflicting findings have emerged, necessitating further investigation. This study aimed to mitigate these conflicts and provide a comprehensive understanding of market efficiency within the BRICS context by employing a range of statistical tests and time-varying methodologies. Additionally, the study aimed to capture the impact of contemporary global events, including the COVID-19 pandemic and the ongoing conflict in Ukraine, which have not been adequately addressed in previous literature.

Furthermore, the study's focus on BRICS countries, particularly South Africa, adds a novel dimension to the research landscape. By examining the weak-form efficiency of BRICS markets amidst various global challenges, this study offers valuable insights for investors and policymakers. Investors and policymakers can use various hedge strategies to outperform and if the market is weak-form EMH and should hold more assets in developing or emerging economies rather than developed.

As of 2023, BRICS welcomed new member countries, significantly expanding the coalition's reach and influence. Including these new members underscores BRICS' commitment to fostering collaboration and partnership among emerging economies on the global stage. Future research would be useful to see if these

new member countries are market efficient as well and will they be able to add value to emerging economies some might argue that the countries that joined are not emerging enough and are still developing and might bring down the status of the original BRICS.

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Appendices

Ethical clearance letter

Data Classification - Business General

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28 April 2023

Proposal Approval and Conditional Ethics Clearance for Master International Business

Student name: Joshua Heath Kretzschmar
Student number: [redacted]
Brand and campus: IIEMSA

Dear Joshua,

We are pleased to inform you that the Higher Degrees Committee considered and approved your research proposal titled: **Market efficiency in emerging economies: a case of BRICS countries** with minor revisions.

You are requested to critically reflect on the feedback provided by the Academic Seminar panel members (attached to this letter) and address the recommendations under the guidance and to the satisfaction of your supervisor. We are confident that the feedback will improve the quality of your work and will assist you in navigating the process to successful completion.

This study has been granted conditional ethics clearance. This means that you must submit the revised research proposal (with an expanded research methodology section) together with the data collection instrument, participant consent form and if applicable gatekeepers' letter to the Programme Coordinator by **18 May 2023**. You may only proceed with data collection after the Higher Degrees Committee released an Ethics Clearance letter to you.

If you have any questions, please feel free to contact the programme team or supervisor directly.

All the best with your research studies.

Dr WH Engelbrecht
Chair: Higher Degrees Committee

ADvTECH House: Inanda Greens, 54 Wierda Rd West, Wierda Valley 2196
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Language Editing
28 March 2024

To Whom It May Concern:

This letter is to confirm that this manuscript, ‘A technical analysis of market efficiency of emerging economies: the case of BRICS countries’ by Joshua Heath Kretzchmar, was proofread for proper English language, grammar and quality.

Please use this letter as confirmation that this work is of a good language standard.

This process was conducted by me, Caitlin Heather Brookstein, as an English language specialist. The original research was not altered during the proofing process.

Sincerely,

Caitlin Heather Brookstein

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

At a congregation of the University

held on 18 July 2022

Caitlin Heather Brookstein

having satisfied the requirements

is hereby granted the

Postgraduate Certificate in Education in Senior Phase and Further Education and Training Teaching

Competence in Information Technology for Education Purposes

Language of Learning and Teaching: English

Language of Communicative Competence: South African Sign Language

Dean: Faculty of Humanities

Vice-Chancellor and Principal

Registrar

2022N07366

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

At a congregation of the University

held on 21 July 2021

Caitlin Heather Brookstein

was admitted to the Degree of

Bachelor of Arts

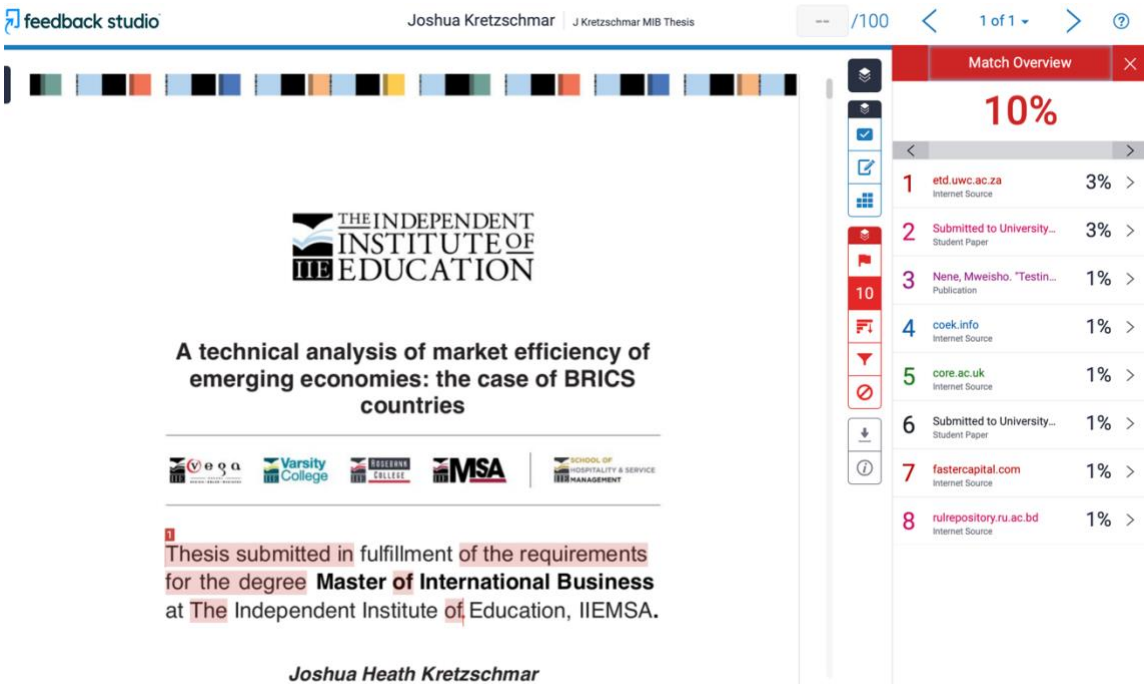
Dean: Faculty of Humanities

Vice-Chancellor

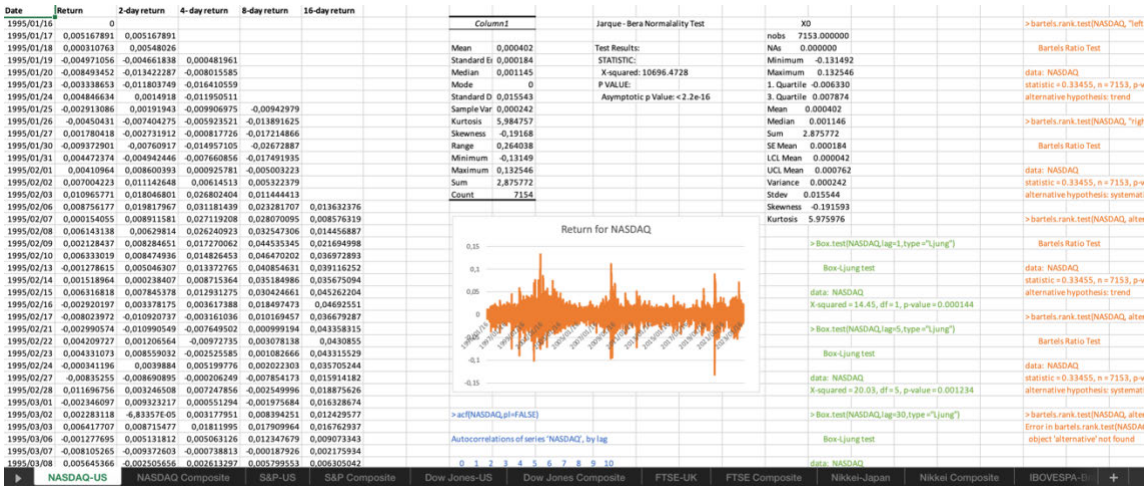
Registrar

2021N00848

Turnitin Score



Sample of my data collected



Date	Return	2-day return	4-day return	8-day return	16-day return
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1995/01/17	0,005167891	0,005167891			
1995/01/18	0,000310763	0,00548026			
1995/01/19	-0,004971056	-0,004661838	0,000481961		
1995/01/20	-0,008493452	-0,013422287	-0,008015585		
1995/01/23	-0,003338653	-0,011803749	-0,016410559		
1995/01/24	0,004846634	0,0014918	-0,011950511		
1995/01/25	-0,002913086	0,00191943	-0,009906975	-0,00942979	
1995/01/26	-0,00450431	-0,007404275	-0,005923521	-0,013891625	
1995/01/27	0,001780418	-0,002731912	-0,000817726	-0,017214866	
1995/01/30	-0,009372901	-0,00760917	-0,014957105	-0,02672887	
1995/01/31	0,004472374	-0,004942446	-0,007660856	-0,017491935	
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1995/02/03	0,010965771	0,018046801	0,026802404	0,011444413	
1995/02/06	0,008756177	0,019817967	0,031181439	0,023281707	0,013632376
1995/02/07	0,000154055	0,008911581	0,027119208	0,028070095	0,008576319
1995/02/08	0,006143138	0,00629814	0,026240923	0,032547306	0,014456687
1995/02/09	0,002128437	0,008284651	0,017270062	0,044535345	0,021694998
1995/02/10	0,006333019	0,008474936	0,014826453	0,046470202	0,036972893
1995/02/13	-0,001278615	0,005046307	0,013372765	0,040854631	0,039116252
1995/02/14	0,001518964	0,000238407	0,008715364	0,035184986	0,035675094
1995/02/15	0,006316818	0,007845378	0,012931275	0,030424661	0,045262204
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1995/02/17	-0,008023972	-0,010920737	-0,003161036	0,010169457	0,036679287
1995/02/21	-0,002990574	-0,010990549	-0,007649502	0,000999194	0,043358315
1995/02/22	0,004209727	0,001206564	-0,00972735	0,003078138	0,0430855
1995/02/23	0,004331073	0,008559032	-0,002525585	0,001082666	0,043315529
1995/02/24	-0,000341196	0,0039884	0,005199776	0,002022303	0,035705244
1995/02/27	-0,00835255	-0,008690895	-0,000206249	-0,007854173	0,015914182
1995/02/28	0,011696756	0,003246508	0,007247856	-0,002549996	0,018875626
1995/03/01	-0,002346097	0,009323217	0,000551294	-0,001975684	0,016328674
1995/03/02	0,002283118	-6,83357E-05	0,003177951	0,008394251	0,012429577
1995/03/03	0,006417707	0,008715477	0,01811995	0,017909964	0,016762937
1995/03/06	-0,001277695	0,005131812	0,005063126	0,012347679	0,009073343
1995/03/07	-0,008105265	-0,009372603	-0,000738813	-0,000187926	0,002175934
1995/03/08	0,005643366	-0,002505656	0,002613297	0,005799553	0,006305042

Column1	
Mean	0,000402
Standard Er	0,000184
Median	0,001145
Mode	0
Standard D	0,015543
Sample Var	0,000242
Kurtosis	5,984757
Skewness	-0,19168
Range	0,264038
Minimum	-0,13149
Maximum	0,132546
Sum	2,875772
Count	7154

Jarque - Bera Normalality Test

Test Results:
STATISTIC:
X-squared: 10696.4728
P VALUE:
Asymptotic p Value: < 2.2e-16

Return for NASDAQ

> acf(NASDAQ,pl=FALSE)

Autocorrelations of series 'NASDAQ', by lag

0 1 2 3 4 5 6 7 8 9 10

X0	
nobs	7153.000000
NAs	0.000000
Minimum	-0.131492
Maximum	0.132546
1. Quartile	-0.006330
3. Quartile	0.007874
Mean	0.000402
Median	0.001146
Sum	2.875772
SE Mean	0.000184
LCL Mean	0.000042
UCL Mean	0.000762
Variance	0.000242
Stdev	0.015544
Skewness	-0.191593
Kurtosis	5.975976

> Box.test(NASDAQ,lag=1,type="Ljung")

Box-Ljung test

data: NASDAQ
X-squared = 14.45, df = 1, p-value = 0.000144

> Box.test(NASDAQ,lag=5,type="Ljung")

Box-Ljung test

data: NASDAQ
X-squared = 20.03, df = 5, p-value = 0.001234

> Box.test(NASDAQ,lag=30,type="Ljung")

Box-Ljung test

data: NASDAQ

> bartels.rank.test(NASDAQ, "left

Bartels Ratio Test

data: NASDAQ
statistic = 0.33455, n = 7153, p-v
alternative hypothesis: trend

> bartels.rank.test(NASDAQ, "righ

Bartels Ratio Test

data: NASDAQ
statistic = 0.33455, n = 7153, p-v
alternative hypothesis: systemat

> bartels.rank.test(NASDAQ, alte

Bartels Ratio Test

data: NASDAQ
statistic = 0.33455, n = 7153, p-v
alternative hypothesis: trend

> bartels.rank.test(NASDAQ, alte

Bartels Ratio Test

data: NASDAQ
statistic = 0.33455, n = 7153, p-v
alternative hypothesis: systemat

> bartels.rank.test(NASDAQ, alte
Error in bartels.rank.test(NASDA
object 'alternative' not found

NASDAQ-US | NASDAQ Composite | S&P-US | S&P Composite | Dow Jones-US | Dow Jones Composite | FTSE-UK | FTSE Composite | Nikkei-Japan | Nikkei Composite | IBOVESPA-B